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**Research Article**

# EtherRights: Securing Intellectual Property Rights with Ethereum-Based Blockchain Solutions

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**ABSTRACT**

Blockchain technology has become a disruptive breakthrough in the digital age, altering how information is maintained and exchanged. However, traditional intellectual property systems face several challenges, such as centralized data repositories, dependability issues, performance bottlenecks, and opaque processes. These problems necessitate a novel strategy, and blockchain enables safe, open, and unchangeable record-keeping via a connected chain of blocks. A new age of tamper-proof digital collaboration is introduced owing to this distributed structure, which eliminates intermediaries and permits trustless peer-to-peer transactions. Furthermore, conventional approaches to securing intellectual property rights are no longer relevant due to the growing digitization of information. Our system integrates blockchain technology, Non-Fungible Tokens (NFTs), and the Interplanetary File System (IPFS) to revolutionize patent administration. Our work aims to provide a cutting-edge platform for patent registration, trade, and management by utilizing blockchain technology's decentralization, transparency, immutability, the distinctiveness of NFTs, and the strength of IPFS. Our framework modernizes the intellectual property landscape by bolstering rights and encouraging a more creative and collaborative atmosphere. It handles essential issues such as data transparency, ownership identification, secure storage, and transaction efficiency.

**Keywords:** Blockchain, Digital Rights Management, Ethereum, Immutable Records, Tokenization of IP.

## 1. INTRODUCTION

Intellectual property rights (IPR) are the legal privileges accorded to people or organizations for their original works of art or scientific discoveries. These rights enable innovators to regulate how their creative works are utilized, shared, and profitably exploited. Offering people who create novel concepts, creations, and artistic endeavors with legal defense, rights to intellectual property promotes invention and creativity. A particular type of intellectual property right is a patent. A patent is a formal award from the nation's government that gives a creator only the authority to develop, utilize, and trade their creation for a certain amount of time, often 20 years from the application filing date. Patents protect novel, non-obvious, and significant innovations (Chandratre & Pathak, 2019). Patents provide benefits to their owners, society, and the world as a whole. They first offer their creators full rights, allowing them to utilize, trade, produce, or license their innovations for a predetermined time. Patents assist in propagating knowledge and advancing technology. After creators describe their creations in their patent applications, those inventions eventually pass into the general public's sphere immediately following the patent expiry. This release of information aids in expanding current knowledge and generating fresh concepts by additional researchers and innovators. By encouraging invention, which develops new markets, goods, and solutions, patents contribute to worldwide economic prosperity. This invention may lead to more employment possibilities and boost the economy. Patents are anchors of development, shielding creative ideas and technical breakthroughs. Intellectual property faces challenges such as centralized data storage, a lack of transparency, and difficulties with patent transfers. Even while patent offices offer information; it can be difficult to determine genuine ownership, which hinders authenticity. Intellectual property (IP) asset transfers are complex with paper-based procedures while monitoring and evidence retention are complicated with the fast data dispersion of the internet. These challenges continue to exist throughout all intellectual property ecosystem stages, exacerbating issues with widespread infringement. We can overcome these difficulties in

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the area of intellectual property by utilizing blockchain technology (Reshi & Sholla, 2024a). It offers a decentralized, impenetrable archive for ownership and patent records, increasing openness and confidence. Patent transfers might be automated via smart contracts, improving efficiency and lowering administrative burden (Clark &Burstall, 2019). Additionally, because of the immutability of blockchain, infringement concerns are reduced by providing a safe and unchangeable record of ownership. Blockchain can completely change how intellectual property rights are safeguarded and handled. Our research is inspired by the urgent need to modernize and secure the intellectual property landscape. We intend to solve the issues and revolutionize patent administration to promote innovation and economic progress by leveraging the power of blockchain technology. Our commitment to developing a disruptive solution is driven by the possibility of producing safe, open, and impenetrable records that can additionally streamline operations and promote cooperation. We aim to improve intellectual property accessibility, dependability, and overall efficacy through the combination of blockchain, NFTs, and IPFS.Section 2 of this paper explains the conventional IP ecosystem's concepts. Section 3 discusses the application of blockchain technology in the IP ecosystem. Section 4 sheds light on existing literature. Section 5 contains the methodology and includes the proposed system. Finally, Section 6 presents results followed by the conclusions in Section 7.

## 2. CONVENTIONAL IP ECOSYSTEM

### 2.1 The Framework and Operating Principles of Intellectual Property Management

#### 2.1.1 Patent Application Process

A patent is an exclusive right that an inventor can obtain through a formal procedure called thepatent application process, as depicted in Figure 1. An invention's patentability is assessed byemploying a method conducted at a national PO (patent office).A patent assessor will approve or deny the patent application as a consequence of this assessment.An examiner reviews the description of creation to see if the patent requirements are satisfied before taking office action on an application submitted to a patent office like the USPTO (UpCounsel).Consider, for instance, the scenario where the claimed creation is not a patentable idea or fails to satisfy any patent criterion, such as originality. In that situation, the assessor will give the filer written notice of the rejected claims and the grounds for the decision. After being issued, a patent must be maintained by regular payments of maintenance fees or annuities. The patent might lose its validity if this isn't done.

In answer to this official response, the person applying could ask for reassessment by stating anyerrors they believe the office action may have made. The filer's response to the final office action is examined, after which the Examiner renders a final judgment (Doe, 2018). When an application satisfies all conditions for a patent, and the filer clears the requisite fee, a patent is awarded and made public in the authorized document.

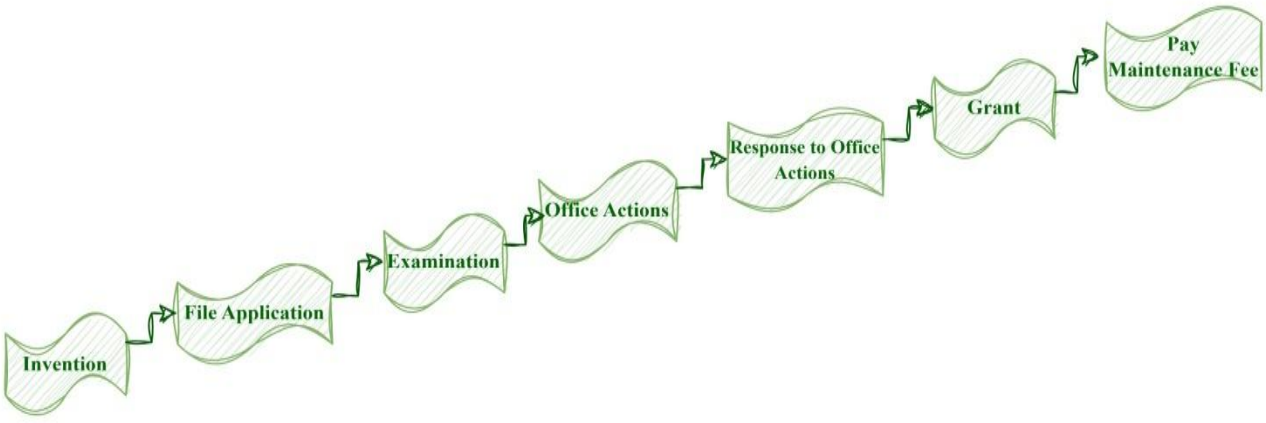


**Figure 1.** Patent application process.

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### 2.1.2 Patent Trade

The purchasing, selling, or licensing of patent rights among individuals, groups, or other entities is referred to as "patent trade", sometimes known as "patent trading" or "patent transactions". It is essential in the intellectual property (IP) landscape because it allows patent owners to profit from their ideas while allowing others to use and access protected technology. It's crucial to ascertain a patent's worth before purchasing or selling it (Mondaq). This can be achieved by performing market research, evaluating the patent's probability of commercial success, and speaking with subject-matter experts, as shown in Figure 2. Once the patent's value has been determined, the patent is advertised to prospective buyers or licensees. The next step is determining the people or organizations genuinely interested in acquiring the patent and negotiating the licensing or buying agreement details after identifying a possible buyer or licensee (Patent Attorney Worldwide). At this point, the patent can be transmitted to the new owner if negotiations are successful. Thus, the purchasing party is grantedthe rights regarding the patent. Notably, the seller and the buyer must file a transaction report with the USPTO or concerned patent office if the patent gets transferred via an assignment. Thus, the patent records get updated to reflect the ownership change.

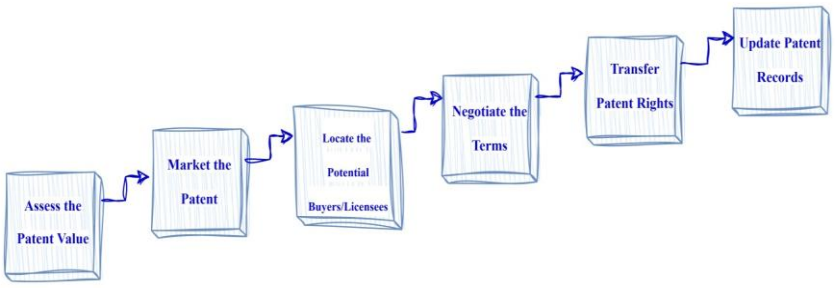


**Figure 2.** Patent trade process.

### 2.2 Problems in the existing IP ecosystem

In the sphere of intellectual property, many complex obstacles encircle conventional space. The centralized archives of information structure lack indispensable protection and dependability, and difficulties with performance and reliance on centralized servers introduce further hindrances (Yang et al., 2019). Information asymmetry, soaring prices, dependency on intermediaries, tiresome procedures, lack of clarity, and time delays only escalate the complexity. Patent offices play a pivotal role by maintaining records and databases that facilitate patent access for concerned parties. However, their part is mainly to offer crucial patent information, and they aren't anticipated to explicitly intervene amongst holders of patents (possible sellers) and other individuals (potential "buyers"). Though functional, these systems have limitations, they are centralized at regional or nationalstages, and precise updates depend on patent holders. In the area of patent transfers, two fundamental conditions are critical: awareness of marketable subject matter and authorization to use the patented innovation from the appropriate individual. As patents are registered rights, subject matter monitoring is quite simple. However, determining the owners can be difficultbecause assignments and licenses are only sometimes represented in patent records. Access to bothsubject matter and patentee details is critical for efficient patent interchange. Unfortunately, not all parties comply with the requirement of registering for an update like selling or licensing, thus harming and shrinking transparency in the system. Further, Transferring IP asset is a laborious process because the information is entirely centred around paper, and finding the paperwork might take quite a while. Even when files become electronic and housed in a centralized information system, there is only one breakdown point and the likelihood of information alteration increases. Additionally, the advancement of the internet has expedited the distribution of information. Due to the fast distribution and hidden characteristic of network violation, data is nowadays hard to track down and quick to amend, rendering it infeasible to relive the incident once it's taken place (Song et al., 2021), as shown in Figure 3.

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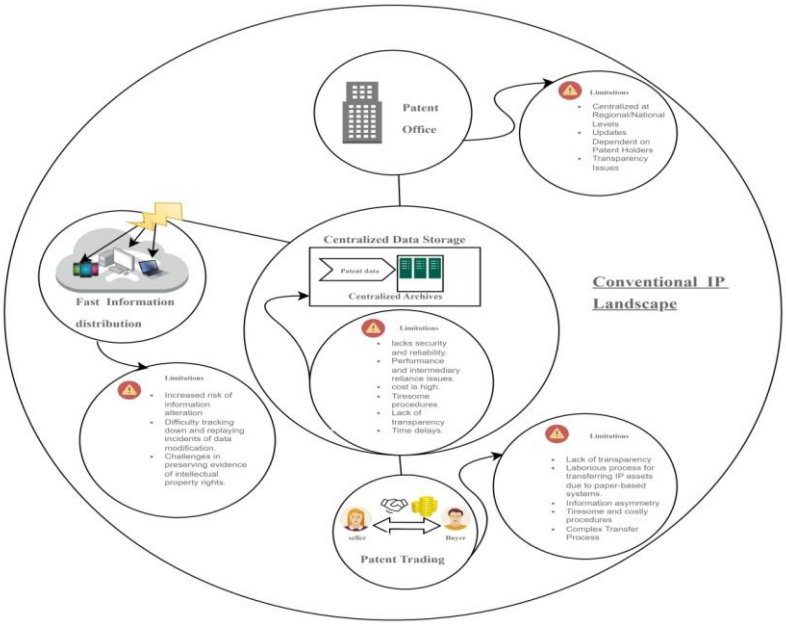
Consequently, safeguarding evidence beforehand has become a successful means in the context of safeguarding intellectual property rights and protecting rights once infringement occurs. Thus, encroaching actsare common at all phases of the intellectual property system.

## 3. APPLICATION OF BLOCKCHAIN TECHNOLOGY IN IP ECOSYSTEM

The term "Blockchain" comprises two terms: block and chain. Thus, it is comprehensibly the chain of blocks. A block is a data structure where the number of transactions is stored. A Cryptographic hash of a preceding block is tied to a succeeding block, forming a chain of blocks (Singhal, Dhameja, & Panda, 2018). So, blockchain is a shared, peer-to-peer, unalterable, moreover generally public, encrypted digital ledger system. Blockchain network members care for the peer-to-peer decentralized database and do not need tobe maintained by a central authority or a trusted




third party (Reshi & Sholla, 2024b). The technology ensures reliability by making tampering data stored in the block visible (Singh & Tripathi, 2019). In simple words, architecturally, blockchain can be considered as the distributed database spread among the members of the decentralized network, including timestamped blocks of transactions linked together in a train of blocks by pointing to the block before them. Operatively, they record independently available data transparently and tamper-proof while still providing transactional service (Gorbatyuk& Gils, 2022). Figure 4 shows the structure of a block in a blockchain. Each block entity is made up of a header for a block and the body of the block. A block's header, in particular, consists of the following different elements:

- Parent Block Hash is a 256-bit hash that connects with the preceding block. There couldbe no relationship or timeline across the block on the distributed ledger lacking thiselement. On the opposite side, the block body involves each transaction acknowledged andauthenticated inside the block.
- Block version is the number that determines the protocol for consensus that is employed.
- A Nonce is a random number used once in a cryptographic transmission. This four-bytefield typically commences with "0s" and expands with each hash calculation.
- The timestamp is presented in seconds from the first of January 1970. It monitors the block's construction and modification times to ensure block consistency.
- The Merkle Tree Root Hash confirms the hash value for recognizing every block transfer. It can be described as a binary tree comprising hash values (Torky& Hassanein, 2020).

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Mathematically, the set $B_i$ consists of the elements $T_1$, $T_2$, ..., $T_n$, $H_{i-1}$, N, *Merkle_Root*.Where: - $T_1$, $T_2$, ..., $T_n$denote the transactions included in the block. The hash $H_{i-1}$ represents the cryptographic output of the preceding block $B_{i-1}$, serving as a means to establish a connection between the blocks. N represents the nonce, which is a randomly generated number utilised to introduce variability in the hash output. The *Merkle_Root* refers to the hash of all transactions in the block, known as the Merkle root.

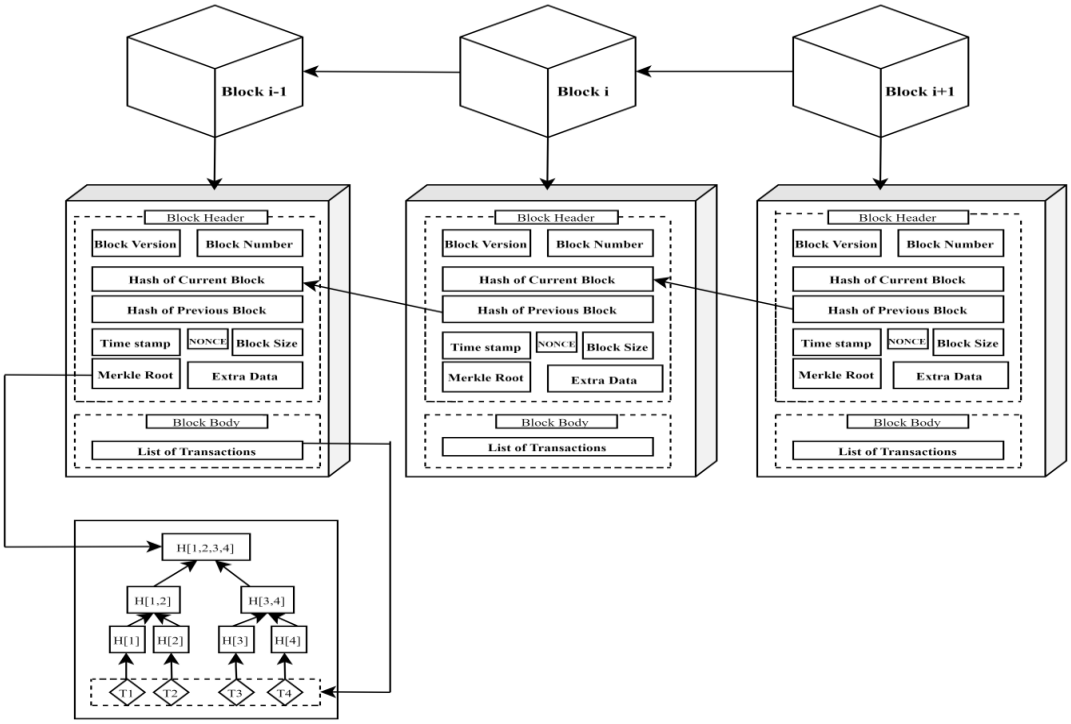


**Figure 4.** Block structure.

The interconnection between the blocks can be depicted as:

$$H_i = H(B_i) = H(T_1, T_2, ..., T_n, H_{i-1}, N)$$

Where $H_i$ is the cryptographic hash of block $B_i$, computed using a function H(x), such as SHA-256. The cryptographic hash function guarantees the unchangeability of the blockchain by making any modification in $B_i$ easily observable, as even a minor update would produce a completely distinct hash. Blockchain is a decentralised system where a set $\mathcal{L}$of blocks is used to form a distributed ledger.
The set $\mathcal{L}$ consists of *n* elements, denoted as $B_1$, $B_2$, ..., $B_n$.

This ledger guarantees that the likelihood of tampering with any block is minimised. The integrity and immutability of each block $B_i$ depend on cryptographic principles such as the unidirectional nature of hash functions and the computational challenge of reversing them.

### 3.1 Block Structure and Cryptographic Hashes

Every block within the blockchain comprises the subsequent fundamental elements: The parent block hash refers to the hash value of the previous block, which is represented as $H_{i-1}$. The integrity of the blockchain is protected through the use of measures that guarantee:

$$H_i = H(T_1, T_2, ..., T_n, H_{i-1}, \mathbf{N})$$

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Nonce: A nonce is a random or unique number that is used just once in a cryptographic communication to prevent replay attacks. The value Nis a randomly generated variable employed in the PoW algorithm to guarantee that:

$$H(B_i) < target\_threshold$$

The equation represents the criterion for mining, whereby the hash value of a block must be less than a predetermined goal threshold in order to be deemed valid.
The Merkle root serves as a concise summary of all the transactions contained within a block. The Merkle root can be calculated using the given transactions $T_1, T_2, \ldots, T_n$.

$$Merkle\_Root = H(H(T_1) \,||\, H(T_2) \,||\, \ldots \,||\, H(T_n))$$

Where || denotes the operation of concatenation.

### 3.2 Smart Contracts

Szabo defines a smart contract as a digitized transactional mechanism that accomplishes the conditions of an agreement. Smart contracts are elements of code that may include obligatedstipulations. They get executed themselves. Smart contracts are required to initiate automaticexchanges among the distributed ledger addresses. The conditions of real-life agreements aremerely enclosed and duplicated in smart contracts, which are pieces of code. A contract is anenforceable agreement among any number of parties, with each side obligated to uphold the endof the deal (Taherdoost, 2023). Additionally, they enable business dealings between unreliable individualswithout requiring face-to-face meetings, the use of mediators, or the payment of broker commissions (Reshi & Sholla, 2024c). As smart contracts are frequently stored on and secured via the distributed ledger, they have advantages over traditional agreements in terms of lowering transactional threats, decreasing management and operating expenses, and improving the efficacy of company operations. A smart contract, denoted as $\mathcal{C}$, is a collection of executable instructions that automatically execute when predetermined conditions are fulfilled. A conventional smart contract can be formulated as:

$$\mathcal{C} = \{P_1, P_2, \ldots, P_m\}$$

Where $P_1, P_2, \ldots, P_m$ represent propositions or circumstances that initiate the implementation of the contract. The operational mechanism of the intelligent agreement might be depicted as:

$$\mathcal{C}(x_1, x_2, \ldots, x_k) = \begin{cases} \text{Execute actions} & \text{if } P1 \wedge P2 \wedge \ldots \wedge Pm \\ \text{Abort} & \text{otherwise} \end{cases}$$

The contract will only execute if the requirements $P_1, P_2, \ldots, P_m$ are satisfied. The contract will only be executed if all conditions are true.

### 3.3 Blockchain in the IP ecosystem

In the realm of intellectual property (IP), implementing blockchain technology pledges to solveseveral persistent problems. As a distributed ledger, blockchain excellently maintains records of dealings, recognizes when anaction occurred, and assures that there is only one possessor of every object and that no doubleexploitation occurs (Thakur, Doja, Dwivedi, Ahmad, &Khadanga, 2020). When distributed ledger technology is applied to the IP landscape, itstreamlines tracing and identifying patent infringements by storing data and event logs in anunchangeable manner. Distributed ledger pledges of verifiable testimony to proof of existence, proof of ownership, and chain of evidence (Wüst & Gervais, 2018). Implementing novel blockchain technology in theIP space fosters true digital confidence amongst every party engaged, enabling them to makespeedy choices as they all know comprehensive data simultaneously without any reliance on anyintermediary. One of the significant advantages of blockchain is its ability to pace up the processesof IP space, and crucially, patent assets can be liquidated using the platform (Khan, Ansari, Jain, & Sachdeva, 2020). Furthermore, blockchain in the IP landscape streamlines the entire process of paying royalties tothe creators. Unlike traditional IP databases, systems based on blockchain technology go beyondjust displaying issued rights. They represent a shift from static registries to flexible, dynamicsystems that enable efficient administration and commerce. This multipurpose strategy unlocks new opportunities for value development and innovation. Blockchain-powered markets canpotentially disrupt the intellectual property (IP) field, ready to change the trading of assets throughincreased visibility, traceability, efficacy, and accessibility of IP. This transformation

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elongates topatent systems, providing third parties access to up-to-date, trustworthy, and complete patent data. Blockchain's core value in the IP space is overcoming previous ownership accountabilitydifficulties. Patent disputes regarding ownership might result in transactional complexity. However, blockchain's abilities, such as non-fungible token (Wang, Li, Wang, & Chen, 2021) based tokenization and smartcontracts; establish explicit, irreversible ownership recordings, simplifying patent transactionswhile improving the safety and accessibility of licensing and assignment. Combining the potentialof non-fungible tokens, also known as NFTs, and the Interplanetary File System (Kang, Yang, & Zheng, 2022) (IPFS)promises authentication, i.e., metadata is closely linked to the appropriate data. Hence, blockchain technology holds the transformative potential to significantly propel the realms ofintellectual property in dimensions of trading and security (Sharma, Chandra, Makkar, & Semwal, 2021).

### 3.4 The Role of Blockchain in the Intellectual Property Ecosystem

Within the realm of IP, blockchain technology offers a decentralised ledger, denoted as $\mathcal{L}$, which effectively oversees and establishes unambiguous ownership of documents. Each record corresponds to a block $B_i$, in which the ownership of an IP asset Ais determined by the following relation:

$$\text{Owner (A)} = H(\text{IP\_Details} \,||\, \text{Owner\_ID}\})$$

The cryptographic hash function establishes a connection between the asset data and the owner's identity, rendering any alteration of ownership impossible without modifying the hash.
Blockchain streamlines the process of managing patents and distributing royalties. Every transaction associated with royalty payment can be encoded within the block $B_i$ as:

$$T = \text{Royalty\_Payment}(A, O, V)$$

Where: - A represents the asset. O is the proprietor. V represents the monetary amount of the royalty payment.
Non-fungible tokens (NFTs) enable the process of converting intellectual property assets into tokens. A NFT representing an IP asset A can be expressed as:

$$\text{NFT}(A) = H(A \,||\, \text{Metadata}(A))$$

Where *Metadata* refers to further information about the item.

### 3.5 Blockchain Consensus Mechanism

Consensus mechanisms are relied on by blockchain to ensure a uniform state is maintained across all nodes in a decentralised system. A commonly used approach is Proof of Work (PoW), in which every member solves a cryptographic puzzle to add a block. The complexity of the puzzle can be represented as:

$$\text{Difficulty} = \frac{T_{max}}{T_{actual}}$$

Where $T_{max}$ represents the desired time for block creation, and $T_{actual}$ represents the actual time it takes to mine the block. The PoW algorithm maintains a consistent average block discovery time, irrespective of the processing capacity of the network (Saif, Migliorini, & Spoto, 2024).

## 4. Related Work

Zhu et al. (Zhu, Hu, Li, & Zhu, 2023) provide blockchain service architecture in their work, to enhance the traceability and security of IP, including copyrights and patents. They provide a blockchain-based traceability system that has been verified by simulations and offers a comparison study that highlights the benefits of the system over current approaches. Furthermore, the writers point out possible wider uses for blockchain technology in other fields. They do, however, recognize that their study, which mainly focuses on intellectual property, has limits and that further research is necessary for wider application. In putting their suggested approach into practice, the authors also highlight difficulties with legislative concerns, technical complexity, and stakeholder adoption.
Song et al. (Song, Ran, & Yang, 2024), offer a framework for enhancing technology transfer and patent analysis. They draw attention to the shortcomings of the present frameworks for facilitating technology transfer and cooperative R&D. The suggested method combines machine learning (ML) and natural language processing (NLP) to build models for research team identification, transferability assessment, and patent suggestion. According to the authors, by assisting businesses in locating pertinent patents and research partners, this strategy improves the effectiveness

of patent transactions and R&D collaborations. They also stress how important NLP and ML are to enhancing patent analysis.

Kale et al. (Kale, 2024) look at how patent law and the metaverse—a cutting-edge technology that combines virtual and augmented realities intersect. They draw attention to the necessity of changing patent law to handle issues with jurisdictional interoperability and inventorship in this brand-new digital environment. The study highlights the inadequacy of the present patent systems for the metaverse and urges the use of multi-jurisdictional strategies to guarantee effective legal protection. It calls for more conversation on modifying patent rules to encourage creativity in the metaverse in its conclusion.

Yang et al. (Yang, Zhao, Leng, & Shi, 2024) investigate how open innovation communities (OICs) might improve security using blockchain technology. They stress that the distributed ledger of blockchain technology successfully tackles threats related to IP, including copyright and privacy violations, as well as information security issues. The study emphasizes how crucial it is to have outside scrutiny, like the media and charitable institutions, to improve blockchain oversight. The study also describes a consensus process that uses hash values and Merkle roots to further enhance transaction security and ensure data integrity. This paper offers insightful information about integrating blockchain technology to secure knowledge transfers in open innovation communities.

Sibahee et al. (Sibahee et al., 2024) examine how blockchain technology might improve security and privacy in smart environments such as smart homes, smart cities, smart grids, smart transportation, and smart housing by enabling authentication. The research shows that most blockchain solutions are still in the conceptual stage and have a lot of untapped potential after employing the PRISMA approach to evaluate 39 publications. The results indicate that while blockchain can adjust to different security issues, it has to be integrated with other technologies to function more effectively. The direction this evaluation offers for further research on blockchain applications in smart environments is really helpful.

Gürkaynak et al. (Gürkaynak, Yılmaz, Yeşilaltay, & Bengi, 2018) investigate the use of blockchain technology in IP law. The authors offer a thorough review of the existing issues affecting the registration and management of IP and suggest blockchain-based solutions to address theseissues. The possible effects of blockchain technology on the creation, administration, and safeguarding of rights to intellectual property are thoroughly examined in this article. The authors suggest using decentralized databases and smart contracts in addition to other blockchain-based strategies to increase the effectiveness of IP rights management. The study emphasizes the potential advantages of applying blockchain technology to IP law, including improved robotics, safety, and openness. There is no empirical investigation or data analysis in this conceptual work. In addition to highlighting operational and execution issues that need to be resolved, Ito and O'Dair (Ito &O'Dair, 2019) offer a critical analysis of the promise of the distributed ledger to handle IP, such as authenticity, provenance, and seamless royalty payment. The authors provide solutions to these problems, such as using incentive structures based on tokens and tying digital currencies to fiat money. However, the application of distributed ledger technology for protecting IP must be fully discussed in the article regarding judicial and regulatory implications. Hugendubel (Hugendubel, 2021) thoroughly introduces the effects of distributed ledger technology on the IP ecosystem. It addresses some efforts and projects in both the public and commercial sectors, emphasizing the possible use of the distributed ledger for the administration of IP assets and the creation of unified blockchain registries for all IP rights that have been registered. The constraints and difficulties of integrating blockchain technology into the IP ecosystem are also covered in the report. However, the usage of the technology known as blockchain in the IP industry is not thoroughly examined in the report in terms of foreseeable regulatory and legislative difficulties. The article does not cover the possible impacts on society and the economy of integrating blockchain technology into the IP ecosystem. Bamakan et al. (Bamakan et al., 2021) put out a multi-layered structure on a conceptual basis for inventions to be represented as tokens that are not fungible (NFTs) on distributed ledger networks. The researchers thoroughly cover every single component of the framework—storage, decentralized authentication, decentralized validation, the distributed ledger, and the application layer. The study has certain shortcomings, such as the majority of the study is conceptual, and there isn't any data to back up the suggested framework's usefulness in practical situations. Its focus on patents and other IP assets could restrict its application to additional asset classes or business sectors. Furthermore, the writers might have elaborated more on the restrictions and difficulties of employing NFTs for inventions and IP assets. Paul et al. (2018-20224) suggest various studies that will help to understand classification concepts.

Gorbatyuk and Gils (Gorbatyuk & Gils, 2022) investigate the possible application of blockchain technology in administering IPR and expediting patent trade talks. It thoroughly reviews the intricate workings of the distributed ledger system. It discusses how it may be applied to overcome some problems with traditional patent registries. The study also examines the conceivable advantages of adopting blockchain technology to streamline patent dealings, including raising the visibility and traceability of IP assets, lowering related expenses, and offering a safer and open method of managing and exchanging IP assets. However, it does not substantiate the alleged advantages of employing the distributed ledger to facilitate patent deals with actual evidence or case research. In Barakat et al. (Barakat, Yaghi, & Al-Zagheer, 2022) study, a novel patent protection strategy based on NFTs, and the technology known as blockchain is proposed. A basic architecture for an NFT witha Blockchain technology patent safeguarding system is presented in the article. It describes creating NFTs associated with every patent and putting them on the Ethereumdistributed ledger. Before it can be used, the suggested system needs more study and developmentbecause it remains in its conceptual phase. Denter et al. (Denter, Seeger, & Moehrle, 2023) offer a thorough and organized overview of the available research on applyingblockchain, or distributed ledger technology, in patent administration. The origination, reinforcement, and utilization of patents are three of the primary emphases of DLT technology inpatent administration, according to the contributors, who categorize the works chosen using the 7D Patent Administration Maturity Model (MM). By rearranging or eliminating stakeholders, thearticle addresses how blockchain can reduce ecological and behavioral ambiguity regarding patentmanagement and inspire novel legislative forms and commercial models. The research does havea few drawbacks, such as the fact that it solely examines the application of blockchain systems formanaging patents and does not consider other possible uses for managing IP. Furthermore, the article must thoroughly investigate the regulatory and legal ramifications ofapplying blockchain innovation to patent administration. Nam et al. (Nam, Lee, Park, & Lee, 2023) suggest IP dLedger, a decentralized database for managing IP. The researchers contend that IP dLedger can considerably lower IP management expensesand enhance IP utilization. The centralized IP management mechanism could be more effectiveregarding execution rapidity, safety, and cost. According to the research, IP dLedger can linkcentralized databases and blockchain networks by employing IP codes incorporating time stampsand hash data. Nevertheless, the study has certain areas for improvement in actual execution, legalevaluation, contrasting it with current methods, scaling issues, and talks of security and privacy ofdata. The requested IP dLedger solution has yet to be used or tested in the real world; it is vital toremember that. Therefore, it is still being determined how well the framework will handle thedifficulties with present IP management platforms' expenses, safety, and productivity.

## 5. PROPOSED DECENTRALIZED IP SYSTEM

The proposed system aims to address the limitations of traditional IP systems byleveraging blockchain technology, NFTs, and the Inter Planetary File System (IPFS) to establish a secure, transparent, and efficient platform for patent management andtrading. The methodology of our proposed system involves a systematic approach. We adhere to a detailedprocedure that includes many essential stages. We begin the proposed method with a detailed requirement analysis, identifying flaws in the present patent space and defining preciserequirements for the new blockchain-based patent administration platform. Then, proceeding tothe next step, we design the blockchain-based platform's architecture, considering the integrationof the Ethereum (Buterin, 2016) blockchain, NFTs, and the Inter Planetary FileSystem (IPFS) as shown in Figure 5. We also defined the structure of smart contracts for serviceslike patent registration, patent commercialization, and patent management. Proceeding to the nextstep, we create smart contracts for patent registration, the creation of NFTs to uniquely representpatents, the transfer of ownership, patent management, and the integration of IPFS for safe anddecentralized file storage employing Remix IDE v0.35.1 (Readthedocs.io, 2023). We implement functions thatguarantee patent-related transactions are secure, transparent, and immutable and establishmechanisms to provide secure user authentication and authorization. Our proposed systemprioritizes simplicity and user-friendliness. We concentrate on forging a pleasant and efficient userexperience for creators, investors, and administrators. This interface will enable smooth patentregistration, management, trade, and licensing interactions. The system is rigorously tested toverify its operation, security, and performance. The unified system is then deployed using Ganachev2.7.1 (Blockchain Council, 2023), and its efficacy in a live environment is validated by real-world testing. We monitorthe system's effectiveness, safety, and efficiency so that functionality remains at its peak, providinga solid answer to the issues of the traditional patent domain.

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**Research Article**

A scientifically sound and technologically advanced patent management system is essential in the dynamic IP landscape. This proposal presents a multidimensional approach tomanaging, commercializing, and authenticating patents, all supported by the safe framework ofblockchain technology. This suggested IP management system consists offour dimensions as shown in Figure 6 and various facets within these dimensions, each of whichis distinguished by different features.

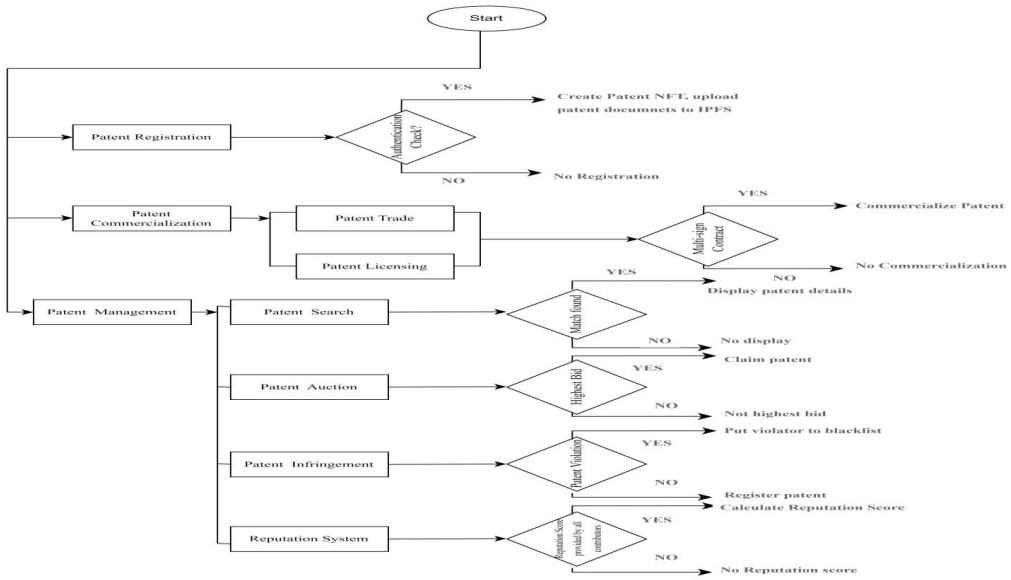


**Figure 5.** System flow diagram.

### 5.1 Dimension 1: Patent Registration

After a patent is successfully granted, we begin a careful procedure that includes gathering all necessary patent information. After thorough authentication tests, we tokenize the patent into apatent-specific NFT. We simultaneously store documents and metadataabout patents on the IPFS.

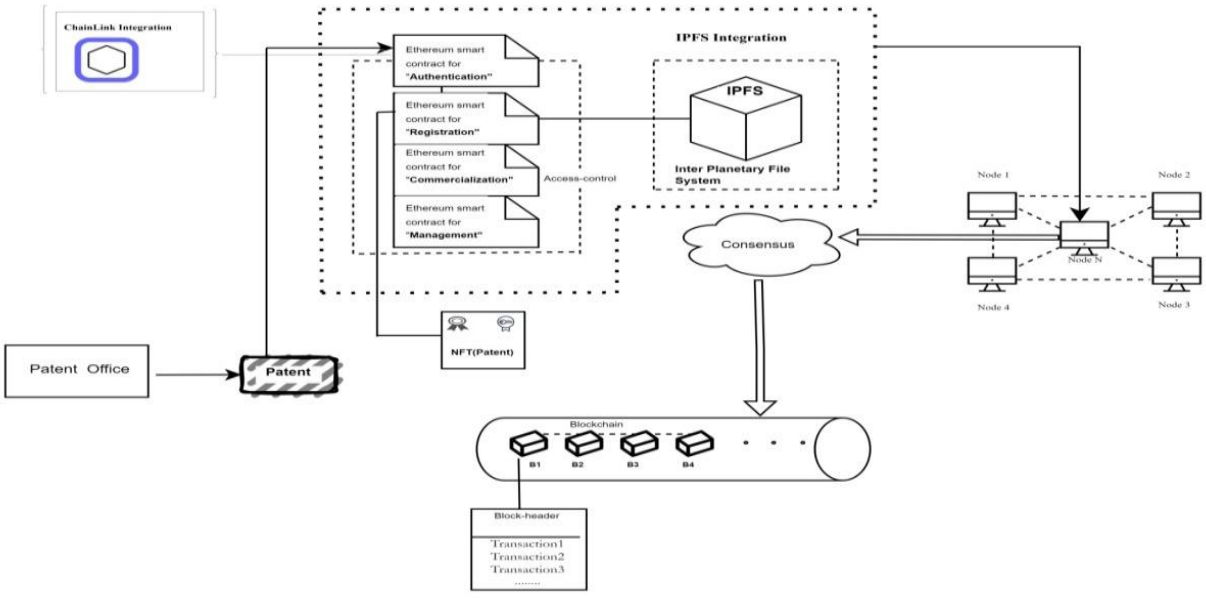


**Figure 6.** Proposed system.

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This transaction, recorded on theblockchain's decentralized and distributed ledger, provides unquestionable evidence of ownershipand existence and solidly establishes the relationship between the patent and its rightful owner.

Patent_Registration() smart contract function is briefly summarized in Algorithm 1. Algorithm 1 concentrates on the registration of patents, streamlining the entire process and assuring a complete analysis of patent eligibility.

**Algorithm 1** IP_Registration()

```
Start
Input patent details: patentNumber, inventionTitle, inventorName
ConcatenatedString ← Concatenate(patentNumber, msg.Sender)
HashValue ← Hash(ConcatenatedString)
if isRegistered(HashValue) then
    Display "This patent has already been registered."
else
    CreatePatentNFT(patentNumber, inventionTitle, inventorName)
    IpfsHash ← uploadPatentDocumentsToIPFS(MetadataFile, documents)
    Create Patent Ownership transaction
end if
End
```

### 5.2 Dimension 2: Authentication

Our system dedicates a separate dimension to critical authentication, prioritizing security andaccuracy. The first step in authentication methods is thoroughly verifying the integrity of theinformation supplied during the patent registration process. Our system's patent can only beregistered after getting the approval signal from the authentication dimension.

### 5.3 Dimension 3: Patent commercialization

In the area of patent commercialization, we place a strong emphasis on safe transactions andaccountability. The implementation of multi-signature access control techniques is required for thestart of patent commercialization.

**Algorithm 2:**IP_Licensing()

```
Start
Input patent details: patentNumber, licenseFees, expiryDate
ConcatenatedString ← Concatenate(patentNumber, msg.Sender)
HashValue ← Hash(ConcatenatedString)
if !isRegistered(HashValue) then
    Display "This patent is not registered."
else
    if approvalFromPatentOwner and approvalFromContractOwner == true then
        Display "Patent is made available for licensing."
    else
        Display "Approvals from both patent owner and contract owner are needed."
    end if
end if
End
```

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**Algorithm 3:** IP_Auction()

```
1: Start
2: Input patent details: patentNumber, auctionStart, auctionEnd
3: ConcatenatedString ← Concatenate(patentNumber, msg.Sender)
4: HashValue ← Hash(ConcatenatedString)
5: if !isRegistered(HashValue) then
6:     Display "This patent is not registered."
7: else
8:     Start auction
9:     if msg.value ≥ highestBidthen
10:      Display "You are the highest bidder."
11:    else
12:      Display "Oops, this is not the highest bid."
13:    end if
14:    if auctionEnded and msg.sender == highestBidder then
15:        Transfer ownership to the highest bidder.
16:    end if
17: end if
18: End
```

This feature ensures that only parties with the properauthorization transfer ownership or particular rights. Then, safe transactions are documented onthe blockchain. License_Patent() smart contract function is briefly summarized in Algorithm 2. Algorithm 2 revolves around patent licensing, which makes it easier to handle licenses, royalties, and negotiations among patent owners and licensees.

### 5.4 Dimension 4: Patent Management

The management dimension includes several elements, such as reputation systems, patentauctions, patent search and discovery, and patent infringement detection. The blockchainrigorously records transactions related to these aspects, making them transparent and available toall network users. IP_Auction() smart contract function is briefly summarized in Algorithm 3. Lastly, Algorithm 3 automates the whole auction process, including the listing of patents forbidding and the transfer of ownership. The aforementioned algorithms work together to provide amore structured and accessible environment for businesses dealing with intellectual property, patent holders, and inventors.
We incorporate Chainlinks (Breidenbach et al., 2021) Oracle services, which improve the accuracy and reliability ofdata and real-world retrieval of information within the system, solving a vital issue with blockchainsystems, i.e., the inability to access data outside (e.g., patent databases) of the blockchain's safeenvironment. Chainlink services can even be used to send OTP to the actual patent holder beforeregistering the patent to our platform to add an extra layer of security by not letting any illegitimateperson anybody else's rightful patent.

## 6. RESULTS

This section demonstrates the empirical findings derived from our comprehensive study, highlighting the clear connection between solidity patent functions and the associated gas fees (gauged in wei). To provide a thorough overview of this pivotal component of blockchaintechnology, we employed a visual depiction in a bar chart and a data table. We have developed a bar chart (Figure 7) based on in-depth data research to better understand thevariances

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in Gas fees(wei) across various solidity patent Functions. This graphic depiction makesit simple to see how multiple functions affect Gas prices (wei) on the Ethereum network. Figure 7displays solidity patent functions on the x-axis while quantifying the gas fee(wei) related to eachfunction on the y-axis. The heights of the bars reflect the considerable differences in gas fees(wei)generated by various functions, with greater fees matching transactions that were more complex.We noticed an interesting trend where certain transactions were routinely charged more for gasfees.Along with the visual depiction, we have also assembled a data table (Figure 8) that thoroughlyexplains the gas fees (wei) related to specific solidity patent functions.Figure 9 demonstrates how our system interacts with IPFS and uses this system for storing andretrieving data. This interface is the gateway for managing, retrieving, and uploading files and data stored on the decentralized IPFS network. It is an essential part of our project that enables safe andimpenetrable data retrieval and storage in line with the fundamentals of blockchain technology.

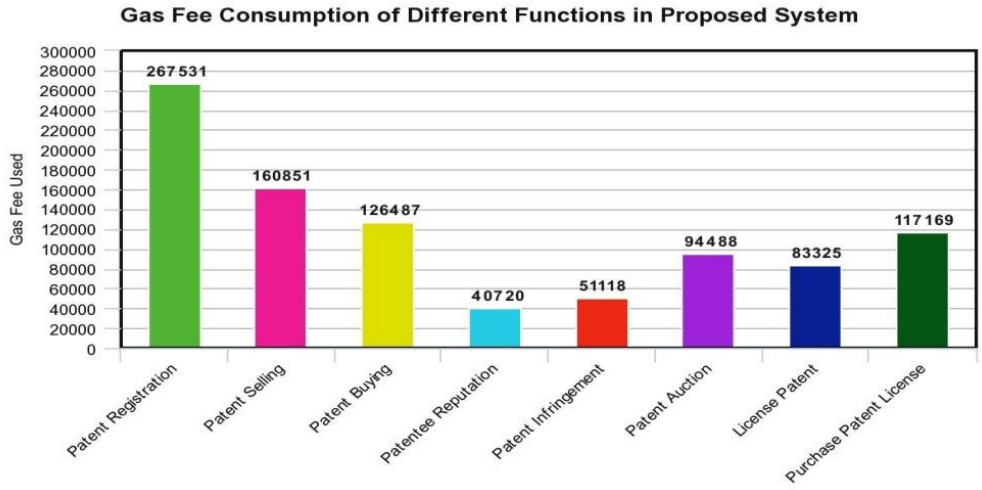


**Figure 7.** Gas fee consumption graph.

The Remix IDE is a vital tool for developing, testing and deploying smart contracts on theEthereum blockchain, showing their capacity to safely conduct transactions, store patent data, andenact ownership rights. Notably, we witnessed these functions performed effectively andconsistently, underscoring the potential of real-world application. Figure 10 illustrates the specificSolidity patent functions crucial to our research.

| Function | Gas -Fee Used(Wei) |
|---|---|
| Patent Registration | 267531 |
| Patent Selling | 160851 |
| Patent Buying | 126487 |
| Patentee Reputation | 40720 |
| Patent Infringement | 51118 |
| Patent Auction | 94488 |
| License Patent | 83325 |
| Purchase Patent License | 117169 |

**Figure 8.** Gas fee consumption against solidity patent functions table.

These results support the primary claim of our paper, highlighting the applicability and viabilityof blockchain technology in modernizing patent systems and safeguarding intellectual propertyrights. Blockchain's innovative capabilities are showcased through its role in enhancingtransparency, audibility, security, and decentralization. Thus,

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our system is much more transparent, fault-tolerant, economical, secure as well as speedy as opposed to conventional IP ecosystem.

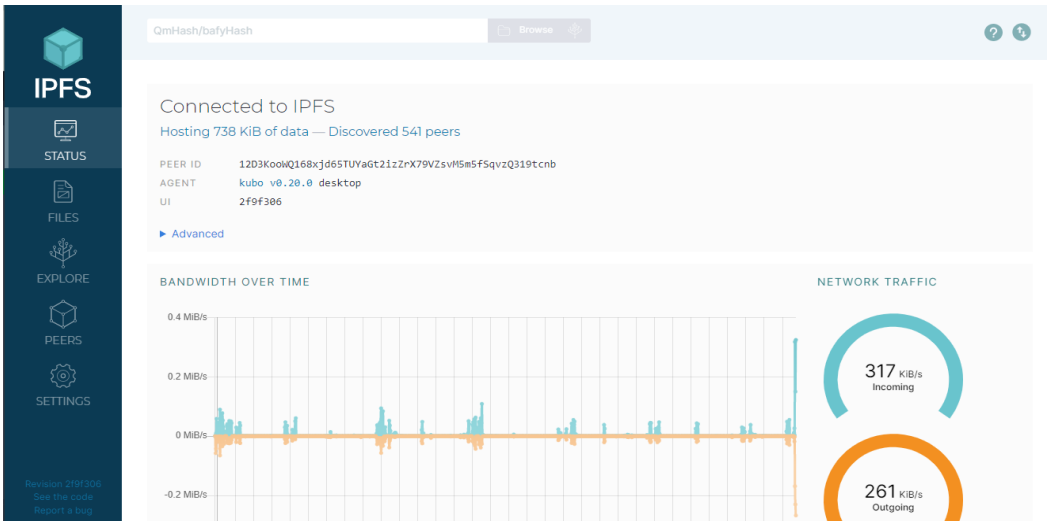


**Figure 9.** IPFS.

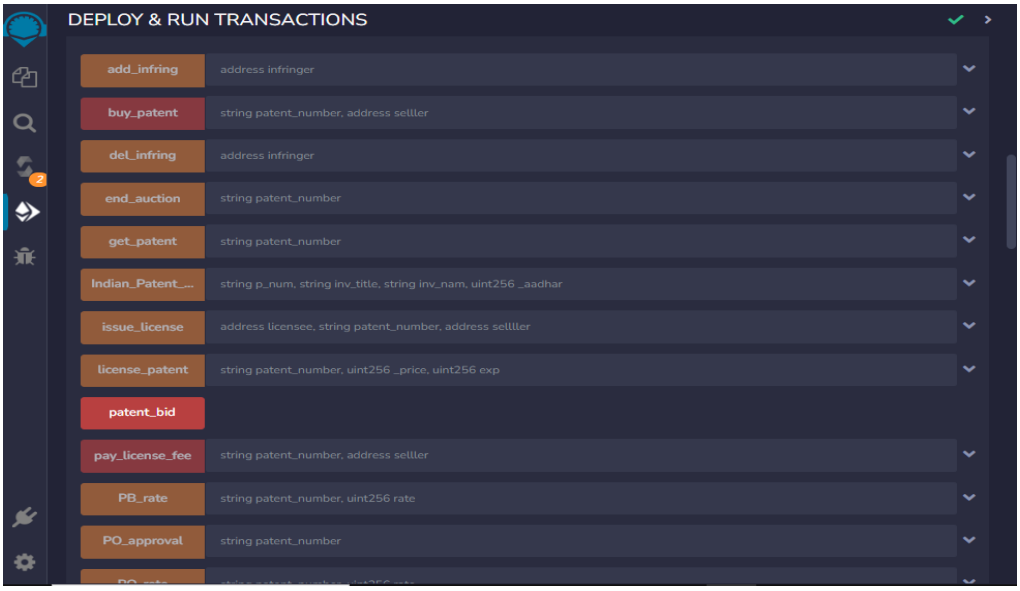


**Figure 10.** Remix IDE.

### 6.1 Assessment and Analysis of Experiments:

We offer in-depth explanations of the Experimental Assessing and Analysis carried out on theproposed solution in this part. We used the Remix Integrated Development Environment (IDE) asan in-browser development and testing environment to conduct our experiments. Theimplementation of this strategic approach was to enable a comprehensive investigation of theinterconnections between the smart contracts. We initiated testing to validate and verify three pivotal scenarios in the proposed model:

1) Patent Registration by Patent Authority.
2) Patent Selling and Buying by an authorized party.
3) Patent search and Patent infringement.

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*Patent Registration by Patent Authority*: Following authorization from the patent office, the patentofficer can register or not register the patent on the Blockchain. Patent registration is carried outusing the "patent_registration()" smart contract function, while when a patent does not qualify themulti-level verification patent will not get registered on to the blockchain. If any participant, apartfrom the patent officer who deployed the smart contract, attempts to invoke the"patent_registration()" function, it results in execution failure. Additionally, if a registered patent isregistered again by a malicious person it leads to patent infringement and the person responsible for it will be put onthe blacklist. Figure 15 displays the decoded output of the triggered"Patent_Infringement()" function. Figure 11 illustrates the successful Patent registration.
*Patent Selling and Buying by authorized party*: An authorized patentee can put his/her patent on saleusing the "patent_selling()" smart contract function, while an authorized buyer can buy any desired patentwhich is put on sale using the "patent_buying()" smart contract function. In the patent_selling() functionmulti multi-signature scheme is implemented for multiple-level checking before putting the patent on sale.Figures 12 and 13 illustrate the successful selling and buying of patents respectively.
*Patent search and patent infringement*: Participants can search the patent by calling the"patent_search()" smart contract function with appropriate parameters. Participants can even rate apatentee who either sold or licensed his/her patent by calling the "patentee_reputation()" function. Thisfunction is a multi-signature scheme where multiple signatures are requiredbefore rating any patenteeto avoid fabrication of information. Thus, every participant in the blockchain network receivescorrect information as shown in Figure 14. Having successfully validated and verified various functionalities within the proposed model, weproceeded to analyze the feasibility of the solution, considering factors such as cost, and security.

### 6.2 Cost Analysis

On the Ethereum Blockchain, every transaction results in a given quantity of Gas, which is the unitof cost for a particular activity. As the cryptocurrency fuel for executing apps on the Blockchainnetwork, Ethereum allows users to pay for gas in terms of ether. On the blockchain network, thereare transaction and execution gas fees associated with every operation. The execution cost includesall of the charges connected to any alteration of the Blockchain state and internal storage in smartcontracts. The execution cost as well as other fees, including contract setup and data transmissionto the Blockchain network, is included in transaction costs. The gas expenses related to the suggested model's smart contract features are shown in Table 1. In the suggested paradigm, participants carry out these smart contract operations. The"Patent_search()" function is the least expensive because it doesn't need any Blockchain statemodifications. On the other hand, because it modifies the state of the variables recorded on the Blockchain to a great extent, the "Patent_registration()" method is the most expensive. The"constructor()" method is unique in that it is only run once during the proposed model's life cycleand is related to the smart contract's deployment.

### 6.3 Security evaluation

This section presents a brief security analysis that explains how our suggested solution meets therequirements for integrity, non-repudiation, availability, authorization, and accountability, amongother important security goals.
1) Integrity: Integrity is maintained in the suggested paradigm by storing traceable provenance data in anunchangeable Blockchain infrastructure. By using cryptographic hash functions, theimmutability is accomplished.
2) Non-Repudiation: In the suggested paradigm, every activity is precisely documented in irreversible logs. Sinceeverything is safely stored in tamper-proof logs, participants cannot deny taking any role inthe action because each action is connected and cryptographically signed by the initiator.
3) Authorization: Solidity modifiers are incorporated into the proposed model to impose role limits. This guarantees that all smart contract functions are executed only after thorough authorizationchecks.
4) Availability: When a patent is deployed on the Blockchain, verifiers may easily access it. Because it is distributed and decentralized; data saved on the Blockchain is not susceptible to a single point of failure, guaranteeing continuous availability.
5) Accountability: Since every action on the blockchain network is visible to every singleparticipant of the network, thus everybody is accountable for their respective actions on theblockchain.

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```
status               true Transaction mined and execution succeed
transaction hash     0x657706ebde83d053c658fd9c0a4199198b17105528a899df398036c49f8fd040
block hash           0x16657d4591bdd4833d570af9c72b42ff3745e88a674ede6a4d72f3e87090847e
block number         3
from                 0x8f3B37734bec9890D47D6bb0A37AD7664F093167
to                   0xB033c2dD47450DcF5a7A76A850905aDB6B82a6EF
gas                  267531 gas
transaction cost     267531 gas
```

**Figure 11.** The results of successful registration of a patent on the blockchain network.

```
status               true Transaction mined and execution succeed
transaction hash     Oxe2c046442de4133a4968517e69cbd6d74576f7d1611ea8c17907605b2ca39bad
block hash           0xc1829dc1174f0c4f14ca4c6b2580e5db0e2ade643326075470ca0b72eda5bca3
block number         7
from                 DxBf3B37734bec9890D47D6bb0A37Ab7664F093167
to                   0xB033c2dD47450DcF5871761850905aDB6BB2a6EF
gas                  160851 gas
transaction cost     160851 gas
```

**Figure 12.** The result of successful selling of a patent on the blockchain network.

```
status               true Transaction mined and execution succeed
transaction hash     Oxab6da424035465958c7826cele3cc10f34d3d8865619398409969 5fd556f48c3
block hash           0x72bb231dce9deefe0d564865acc72a6aa7183407776034537b69a714bdf397fe
block number         9
from                 0x197f07d40EE37e2cc6fE4B9261a158C5ef6db442
to                   0xB033c2dD47450DcF5a7A76A850905aDB6B82a6EF
gas                  131287 gas
transaction cost     126487 gas
```

**Figure 13.** The result of successful buying of a patent on the blockchain network.

```
status               true Transaction mined and execution succeed
transaction hash     0x72bd4c874cc43a5288e7019871884ee6f998204dda0c41c336d7867d35fa3a90
block hash           0x20b5af778a0cb147a1e68faf8d6cefleb8b0306f58f5dc2d0e2dd526dcd98c1b
block number         12
from                 0x50c8C2724d16520b42CaEece4beac3717£8033B1
to                   0xB033c2dD47450DcF5a7A76A850905aDB6B8286EF
gas                  40720 gas
transaction cost     40720 gas
```

**Figure 14.** The reputation of the patentee is set and distributed among all members of the blockchain network.

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**Figure 15.** The result of patent infringement is distributed among all members of the blockchain network.

## 7. CONCLUSION AND FUTURE WORK

IPRs are the cornerstone for protecting creators' IP and supporting innovation. Patents are essential among these rights because they offer inventorsexclusive rights to create, trade, and use their original ideas. However, in a digital era marked byfast information distribution, the IP sector confronts issues ranging fromcentralization to data integrity, limiting its usefulness. Because of its decentralized and tamper-resistant ledger structure, blockchain technology provides robust time stamping capabilities, assuring the correctness and immutability of recorded data. Thus, complementing the flaws in theIP space, blockchain technology bestows the boon that the IP space has been yearning for a longtime. The fundamental advantage of deploying blockchain in the field of IP is the elimination of reliance on mediators for legitimacy. This transition allows more people to storeinformation on the distributed blockchain, producing an irreversible repository where data resistschange. The use of the technology of blockchain in the IP environment promises to improveownership clarity and reduce fraudulent transactions. We propose a revolutionary solution thatuses blockchain, NFTs, and IPFS to transform patent administration and IPlandscapes. This revolutionary solution uses blockchain's decentralization, NFT's singularity, andIPFS robustness to build a revolutionary patent registration, exchange, and administration system.Our proposed system demonstrates blockchain's adaptability in dealing with complex situationswithin the field by including patent auctions, reputation systems, and other processes.While our proposed solution has established a solid framework for blockchain-based patentadministration, there are various opportunities for further development. Integrating machine learning and artificial intelligence algorithms for patent search and infringement detection may improve the system's accuracy, intelligent decision-making, and efficiency. Our proposed system'sdevelopment on the Ethereum blockchain illustrates a key issue given by Ethereum's intrinsicscalability restrictions. To remedy this, overcoming the Ethereum blockchain's scalability limits iscritical. These constraints may impair the system's effectiveness when it expands to meet risingdemand. In the future, combining blockchain technology and AI (Artificial Intelligence) will becritical for promoting a safe, fast, translucent, and responsive IP management environment.

**Conflicts of Interest:** The authors assert that they have no conflicts of interest.

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