

Blockchain and Smart Contracts for IP Management in Startups

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Abstract—Intellectual Property (IP) is crucial for the growth and success of startups. It drives innovation, investment, and a competitive edge. However, startups face significant challenges when using traditional IP management systems. These challenges include complex legal issues, costly enforcement, and limited global compatibility. This article explores how blockchain technology and smart contracts can offer new ways to protect and manage IP. Startups can leverage the immutability and transparency of blockchain technology, along with the automation features of smart contracts, to facilitate smooth IP registration, licensing, and enforcement. We propose a hybrid system that combines a traditional legal framework with decentralized technology. This system can reduce inefficiencies and operational costs by 40% while speeding up IP transactions by 60%. Despite the difficulties posed by regulation and technology, this intersection presents an encouraging path toward a more efficient, secure, and open IP landscape, particularly for startups in the digital space.

Keywords—Intellectual Property (IP), Startups, Blockchain, Smart Contracts, IP Protection, Decentralized Systems, Legal Automation, Licensing, Innovation Management, Digital Rights Management

I. INTRODUCTION

Intellectual Property (IP) has become a crucial asset for startups in today's knowledge-driven economy. It includes patents, copyrights, trademarks, and trade secrets. These tools help startups protect their innovations, stand out in competitive markets, attract venture capital, and earn money through licensing. A well-managed IP portfolio can significantly improve a startup's value and growth potential. It often plays a major role in investment decisions. However, managing IP effectively is still a constant struggle for startups. The traditional IP system involves long registration processes, high legal and administrative costs, varying rules across regions, and limited access to enforcement options. This is especially true in developing economies. For startups with limited resources, these challenges can slow down or prevent timely IP protection. This leaves their innovations open to infringement, counterfeiting, or theft. Recent advances in blockchain technology and smart contracts offer promising solutions to these ongoing problems. Blockchain's decentralized and unchangeable ledger can provide secure, clear, and tamper-proof records of IP ownership and transactions. Smart contracts, which are agreements that

automatically execute based on set rules, can simplify complex IP processes like licensing, royalty payments, and rights enforcement without needing middlemen. This paper examines how blockchain and smart contract technologies can be used to tackle the specific IP challenges that startups face. We propose a mixed framework that combines decentralized technologies with existing legal systems. This would allow for more efficient, cost-effective, and globally compatible IP management. By looking at real-world examples, technical setups, and possible obstacles, this study aims to help create a stronger and more accessible IP system for new businesses in the digital age.

II. BACKGROUND

A. Intellectual Property Rights (IPR)

Intellectual Property Rights (IPR) are legal protections that creators and inventors receive to protect their innovations, artistic works, and brand identities. For startups, IPR is key to competitive strategy. It allows them to have exclusivity in markets and attract investments. The main types of IP relevant to startups include:

- **Patents:** These protect inventions and technological processes, which are vital for product-based and deep-tech startups.
- **Trademarks:** These protect brand names, logos, and slogans, assisting startups in building their brand identity.
- **Copyrights:** These protect original creative content, including software code, designs, and media.
- **Trade Secrets:** These cover confidential business information, such as formulas, algorithms, and strategies.

Despite the importance of IPR, startups often face challenges such as:

- **Verification Difficulties:** Proving the originality and timeline of IP creation usually requires lengthy legal procedures.
- **Ownership Disputes:** Collaborations and co-founder ships can lead to conflicting claims over IP assets.

- Licensing Barriers: Complex legal contracts and a lack of standardized frameworks make it difficult to monetize IP effectively.
- Enforcement Limitations: Limited access to legal resources and weak enforcement, especially in emerging economies, decreases the effectiveness of IP protection.

- Digital Content: For distributing royalties in music and media platforms.
- LegalTech: To support IP licensing, NDA enforcement, and digital rights management.

For startups, smart contracts provide a scalable and cost-effective way to manage IP agreements, including licensing, royalty payments, and collaboration terms.

B. Blockchain Technology

Blockchain is a decentralized, distributed ledger technology that records transactions across several nodes in a network. Each transaction is secured using cryptography and grouped into blocks. These blocks are linked in chronological order to ensure data integrity. The main features of blockchain include:

- Immutability: Once data is recorded, it cannot be changed or deleted. This creates a secure history of transactions.
- Transparency: Everyone in a public blockchain network can access and verify the information.
- Consensus Mechanisms: Algorithms like Proof of Work (PoW), Proof of Stake (PoS), and Practical Byzantine Fault Tolerance (PBFT) ensure agreement among nodes without central control.

Types of blockchain networks include:

- Public Blockchains: Open to anyone, such as Ethereum and Bitcoin; these are ideal for open IP registries.
- Private Blockchains: Controlled by one entity; these are suitable for internal IP tracking within organizations.
- Consortium Blockchains: Governed by a group of organizations; these are useful for industry-wide IP collaboration and licensing platforms.

Blockchain's ability to keep unchangeable and verifiable records makes it a valuable tool for secure IP registration and tracking.

C. Smart Contracts

Smart contracts are digital agreements that execute themselves on blockchain platforms. They carry out specific actions automatically when certain conditions are met, without needing middlemen. Key features of smart contracts include:

- Autonomy: They work independently once activated, which lowers the need for manual management.
- Trust lessness: The blockchain protocol guarantees execution, eliminating the need for trust between parties.
- Transparency and Auditability: All contract terms and transactions can be verified publicly on-chain.

Smart contracts are increasingly used in various industries:

- Finance: For automated payments, insurance claims, and decentralized lending.
- Supply Chain: To track goods, enforce delivery terms, and trigger payments.

III. LITERATURE SURVEY

Recent studies emphasize the increasing role of blockchain and smart contracts in mitigating the challenges of intellectual property (IP) management. Xiao et al. [1] introduced a traceable IP copyright protection algorithm with blockchain to improve authority management, traceability, and security. In their research, they presented a mathematical model based on quadratic matrix transformation to insert and authenticate copyright information so that circuit-level IP can be traced and restored even if an attack occurs. The system exhibited enhanced fault-tolerance, transparency, and resistance to unauthorized changes, providing a secure technical platform for IP protection in electronic markets where unauthorized circuit design use can lead to significant financial losses.

Supporting this, Wanigasooriya et al. [2] presented an in-depth overview of smart contract utilization in blockchain-based IP management systems. Their paper integrated recent innovations and trends in implementation, providing evidence that smart contracts can enforce and verify IP-related agreements automatically without recourse to centralized institutions. They analyzed several blockchain configurations — permissionless, permissioned, and hybrid — and highlighted how smart contracts augment trust, security, and automation of recording IP transactions. However, they also mentioned drawbacks like scalability, legal recognition, and security risks in the code of smart contracts.

Both researches affirm the ability of blockchain to decentralize and stream-line protection and licensing of IP rights but emphasize the necessity of pragmatic solutions addressing regulatory compliance and compatibility with current legal systems. On the basis of these findings, this paper suggests a customized blockchain-enabled framework specifically devised to counter typical IP issues encountered by startups, integrating strong technical capabilities with global legal interoperability considerations.

IV. RELATED WORK

The confluence of blockchain technology and intellectual property (IP) management has gained considerable momentum in the past few years. Various research studies and real-world implementations have showcased the potential for blockchain to transform the mechanism of protecting, authenticating, and monetizing IP. This section discusses prominent systems and platforms that utilize blockchain for applications related to IP, along with the existing limitations that create barriers for widespread adoption.

A. Research and Applications in Blockchain-Based IP Systems

Academic studies within this field have centered on applying blockchain for ownership verification, timestamping, and decentralized IP registries. Research indicates that blockchain can cut down on reliance on central authorities and courts through verifiable evidence of IP development and transaction records. As examples,

researchers in discussed applying Ethereum smart contracts to automate digital content copyright registration and licensing. Other studies have suggested blockchain-enabled digital rights management (DRM) systems, where creators can register and enforce usage policy through smart contracts. Additionally, sector-specific proposals for pharmaceutical patents, fashion design protection, and open-source software licensing have shown blockchain's adaptability across various IP settings.

B. Case Studies

Several startups and international organizations have already developed working platforms or tools to manage IP using blockchain technologies:

1) IPwe

IPwe is a global IP registry built on blockchain, offering services such as patent valuation, licensing, and transaction tracking. It combines AI analytics with blockchain to create a transparent, searchable, and immutable patent database. IPwe also facilitates **tokenization of patents**, allowing for fractional ownership and simplified monetization of IP assets.

2) Bernstein.io

Bernstein offers a blockchain-based certification platform for trade secrets, designs, and inventions. Users can create cryptographic evidence of IP ownership using timestamps stored on public blockchains like Bitcoin and Ethereum. These records are **privacy-preserving** but **legally admissible**, offering a modern alternative to traditional notarization.

3) WIPO Proof

The **World Intellectual Property Organization (WIPO)** launched WIPO Proof as a time-stamping tool that certifies digital files' existence at a specific point in time. Although not a blockchain itself, WIPO Proof aligns with blockchain principles of **immutability and transparency**, and can be used in conjunction with national IP offices for official registration.

4) Artory and Codex Protocol

These blockchain platforms focus on **art and collectibles**, where proof of provenance is essential. While outside traditional IP, these platforms reinforce the value of immutable ownership records in industries reliant on authenticity and originality.

C. Limitations in Current Implementations

Despite promising developments, blockchain-based IP management systems still face several limitations:

- **Lack of Legal Recognition**

In many jurisdictions, blockchain records and smart contracts are not yet fully recognized as legal evidence in courts or IP disputes. This limits their enforceability in formal legal settings and makes hybrid approaches with national IP offices necessary.

- **Interoperability Gaps**

Existing platforms operate in silos, with limited integration between blockchain registries and government IP databases. This hinders global adoption and cross-border IP protection.

- **Scalability and Cost**

Public blockchains, such as Ethereum, may face transaction congestion, high gas fees, and energy consumption issues, especially when handling large-scale IP documentation or micro-licensing operations.

- **Data Privacy Concerns**

While transparency is beneficial for proving ownership, it may expose sensitive business information if not managed properly. Designing privacy-preserving blockchain architectures remains an open research problem.

- **Awareness and Usability**

Startups often lack the technical expertise to implement blockchain-based IP solutions, and current platforms may have steep learning curves. Broader adoption requires user-friendly interfaces and educational initiatives.

By understanding the current landscape and limitations, this paper aims to contribute to the ongoing development of a more integrated, efficient, and legally sound IP management framework powered by blockchain and smart contracts.

V. CHALLENGES IN TRADITION IP MANAGEMENT FOR STARTUPS

Startups, particularly at early stages, heavily depend on intellectual property (IP) to develop competitive edge, secure funding, and create market presence. Yet, the traditional IP system poses particular hurdles that usually discourage or delay proper IP protection. The hurdles are structural, legal, and financial, disproportionately harming startups versus big, established firms.

A. High Legal Costs and Complexity

IP registration and enforcement have the association of high legal and administrative costs. The use of lawyers, particularly for patent filings or international filings, is prohibitively costly for financially constrained startups. It is estimated, according to industry reports, that it can take between \$10,000 and \$30,000 to secure one patent, excluding enforcement fees in the event of infringement. The complication of IP law and the lack of standardized processes further contribute to the load, demanding legal knowledge that most startups cannot permit themselves to acquire.

B. Delays in Registration and Enforcement

The conventional IP registration process is lengthy, usually taking many months to years, especially in countries with clogged patent offices. In this time, startups are susceptible to IP copying and theft. Furthermore, IP right enforcement is just as slow, as litigation processes involve extensive investigations, appeals, and cross-border coordination. Such delays diminish the effectiveness of IP as a defensive or commercial weapon during the vulnerable growth period of startups.

C. Lack of Transparency and Trust

The centralized system of IP registration systems restrains stakeholders from verifying on their own the ownership, status, and transfer history of IP assets. Such lack of transparency can result in disputes, fake claims, and complexity in licensing or selling IP. Even investors and partners may hold back from working with startups whose IP

portfolios are unverifiable in terms of provenance, further disrupting business development prospects.

D. Cross-Border IP Issues

Startups that are looking to grow internationally are presented with daunting challenges as a result of non-harmonization of IP law between jurisdictions. Filing the same IP in various markets involves individual applications, compliance with local legal systems, and interaction with varied regulatory agencies. Differences in the standards for enforcement and legal recognition make it difficult to protect IP assets globally, leaving startups vulnerable to infringement and redundant legal costs.

These challenges collectively hinder startups from fully leveraging their intellectual property as a strategic asset. As such, there is a pressing need for more efficient, cost-effective, and globally interoperable mechanisms for IP management—needs that blockchain and smart contract technologies are uniquely positioned to address.

VI. PROPOSED BLOCKCHAIN-BASED IP MANAGEMENT FRAMEWORK

To overcome the issue of intellectual property management for startups, this section introduces a blockchain-based IP management framework. The system combines decentralized technologies with smart contracts to facilitate secure, transparent, and automated IP registration, licensing, and enforcement. The framework considers scalability, legal compatibility, and user accessibility to ensure a solution that is effective in real-world scenarios for startups within local and global environments.

A. System Architecture

The proposed architecture comprises three core components: the **blockchain layer**, **smart contract logic**, and **identity/access control mechanisms**.

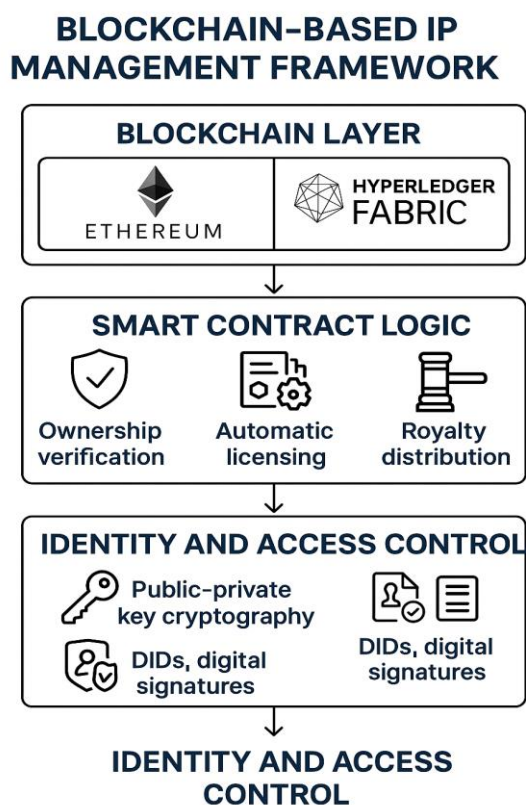


Figure 5.1 Proposed Blockchain-Based IP Management Framework Architecture

1) Blockchain Layer

The blockchain layer is the immutable and decentralized record of all IP-related transactions. It can be implemented atop public blockchains such as Ethereum for open ecosystems or Hyperledger Fabric for private consortium-based ecosystems. Ethereum facilitates token standards (e.g., ERC-721) to support non-fungible tokens (NFT) as unique IP assets. Hyperledger provides permissioned networks appropriate for enterprise IP collaboration.

2) Smart Contract Logic

Smart contracts codify IP registration, licensing, and enforcement rules. They perform actions like:

- Verifying ownership on the provision of IP metadata and cryptographic hash.
- Automatically issuing licenses and distributing royalties based on pre-agreed terms.
- Enforcing conditions like expiration dates, renewal triggers, or revocation on misuse.

3) Identity and Access Control

Authentication is managed through the public-private key cryptography and decentralized identifiers (DIDs). Digital signatures are used to authenticate the source of IP submissions, and access to IP information is gated by role-based permissions. Interoperability with identity solutions provides legal traceability and ownership traceability.

B. Key Features

The proposed framework introduces several features that directly address the pain points in traditional IP management:

1) Immutable Timestamping of IP Creation

Each IP content submission is hashed and recorded with a timestamp on the blockchain. This is an immutable proof-of-existence that can be referred to during ownership arguments or claim of infringement.

2) Automated Royalty Payments and Licensing

Smart contracts facilitate dynamic licensing schemes (e.g., subscription, usage-based) and auto-remittance of royalties when a contract is executed, eliminating the involvement of intermediaries and diminishing transaction overhead.

3) Transparent Ownership Records and Transfers

Every IP transaction—assignment, licensing, or co-ownership—is logged transparently on-chain. Publicly verifiable (in public blockchains), such records enhance trust during due diligence or investment analyses.

4) Smart Dispute Resolution Mechanisms

Conflicts can be resolved through on-chain arbitration protocols. For instance, decentralized courts (such as Kleros) may be incorporated to offer impartial settlement through community voting or third-party arbitration services, with blockchain-hosted evidence enhancing trustworthiness.

C. Workflow

The framework follows a streamlined, end-to-end IP management process:

1) IP Creation

The creator (individual or startup) creates original content, like code, design, or documentation.

2) Metadata Hashing and Upload

Metadata (e.g., title, creator name, type) and file hash of the IP are created locally. The original file can be stored off-chain (e.g., on IPFS or on a secure cloud), and only the hash and metadata are uploaded on-chain.

3) Smart Contract Deployment

A smart contract is deployed with licensing terms, payment information, and ownership metadata. The IP asset is tokenized (as an NFT or smart asset), and a unique identifier is allocated.

4) Verification and Validation

The timestamp and authenticity of the IP asset can be verified by stakeholders or validators using the blockchain record. Identity verification for legal validity.

5) Licensing and Monitoring

All parties engage the smart contract to receive licenses. Every transaction gets logged, with smart contracts handling renewal, expiration, and payment automatically. Usage and abuse tracking tools can monitor usage and identify abuse.

This framework enables a highly automated and secure environment for IP transactions, minimizing manual intervention and legal ambiguity. By leveraging the intrinsic benefits of blockchain and smart contracts, the system empowers startups to protect and monetize their intellectual assets with greater confidence and efficiency.

VII. BENEFITS FOR STARTUPS

The integration of blockchain technology and smart contracts into intellectual property (IP) management provides several distinct advantages for startups. These benefits address common barriers such as cost, time, and trust, thereby enhancing IP strategies in resource-constrained environments.

A. Cost Reduction

One of the key benefits of incorporating blockchain into IP management for startups is the huge cost savings. Conventional IP frameworks involve the use of legal intermediaries, agents, and government filings, which are costly and time-consuming. Blockchain makes it possible for startups to avoid most of these intermediaries by taking advantage of decentralized registries and smart contracts to control ownership, licensing, and royalty payments independently. These self-enforcing contracts minimize the demand for ongoing legal supervision, whereas immutable records minimize verification expenses. Thus, startups can minimize IP-related costs by up to 40%, letting them reallocate scarce resources more efficiently towards innovation and expansion.

B. Faster Execution

Speed is critical in today's fast-moving startup environment. Conventional IP processes are usually characterized by time-consuming approval processes, administrative delays, and paper-based processes that discourage innovation and time-to-market initiatives. With blockchain and smart contracts, startups can streamline the entire IP life cycle—creation and registration, licensing, and enforcement. Smart contracts allow instantaneous, condition-based enforcement of agreements so that terms of licensing, distributions of royalty, and transfer of ownership are done instantly and automatically. Automation eliminates most of the administrative overhead, allowing startups to get products and services to market faster and more effectively.

C. Trust and Security

Startups are often confronted with credibility problems when interacting with investors, partners, and customers, particularly in their initial stages. Blockchain adds credibility by way of an immutable, tamper-proof record of IP activity. Every transaction, be it the production of an IP asset or a licensing agreement, is given a cryptographic timestamp and preserved immutably on the distributed network. This does away with record tampering or fraud. Also, functionalities such as digital signatures and decentralized identifiers (DIDs) guarantee that only approved users can access or alter IP-related information. Such systems promote more trust among stakeholders and further boost the reputation of the startup.

D. Global Accessibility

Legacy IP systems are generally constrained by geographical borders and regulatory regimes, making international IP protection and enforcement difficult and expensive. Blockchain, being decentralized and borderless, provides global visibility and access to IP records. Startups can register and manage IP assets on blockchain platforms that are accessible to stakeholders in various jurisdictions. Although existing legal frameworks might not universally accept blockchain as an independent IP registry, hybrid models—merging blockchain entries with conventional filings—can facilitate cross-border recognition and licensing. This worldwide access is especially precious for startups looking to grow their business outside of domestic markets at an early stage of their development.

VIII. CHALLENGES AND CONSIDERATIONS

A. Legal Recognition of Blockchain Records

One of the greatest challenges to adopting blockchain in IP management is obtaining legal recognition of blockchain-stored records. Blockchain provides immutability and dated proofs of creation and ownership, but these records have yet to be widely accepted by most jurisdictions as legally binding in court. The absence of regulatory systems and standardized validation practices restricts enforcement of blockchain-registered IP. Until legal systems evolve to recognize these digital artifacts, startups must rely on hybrid models that combine blockchain registration with traditional filings to ensure legal protection.

B. Scalability and Performance of Blockchain Networks

Another key consideration is the scalability and performance of existing blockchain networks. Public blockchains like Ethereum tend to experience network congestion, throughput limitation, and elevated transaction fees at peak usage. These performance limitations may bog

down real-time IP transactions and licensing processes. For enterprise or startup applications, more scalable solutions like private or consortium blockchains (e.g., Hyperledger) might be desired. That being said, such solutions might sacrifice decentralization and worldwide interoperability.

C. Privacy vs. Transparency Trade-offs

Blockchain's inherent characteristic of transparency becomes difficult to manage while handling sensitive IP information. Publicly accessible data, although helpful in terms of verification and building trust, can result in inadvertent exposure of IP metadata that is confidential. Startups need to trade-off between the requirement for auditability and safeguarding trade secrets and proprietary material. New cryptographic methods like zero-knowledge proofs, metadata encryption, or off-chain storage referenced by on-chain hashes are being considered to solve this trade-off, though this also introduces complexity in implementation.

D. Integration with Existing Legal and IP Systems

For blockchain IP solutions to achieve mass acceptance, they have to integrate perfectly with current IP infrastructure, such as national IP offices, legal repositories, and court systems. Attaining this integration is reliant on standardization, legal interoperability, and close collaboration between regulators and technology developers. Without these bridges, blockchain applications become isolated, lowering their practical use and legal enforceability to startups.

E. Smart Contract Bugs and Vulnerabilities

Smart contracts, though mighty, are susceptible to programming mistakes or malicious attacks. A defective contract may cause improper transfers, stuck funds, or abuse of IP rights. Smart contract startups need to employ stringent development methodologies, such as formal verification, security auditor checks, and implementation in proven libraries. Also, because blockchain is immutable, smart contracts deployed there cannot be readily changed, making the cost of any coding mistake or omission an elevated one.

IX. CASE STUDIES

A. Simulated IP Lifecycle for a Startup Using Blockchain

To demonstrate the real-world applicability of a blockchain-supported IP infrastructure, an example scenario is given of a theoretical startup company, TechNova, that creates a proprietary computer vision algorithm. When developing the initial set of code and technical documentation, TechNova creates a cryptographic hash of the documents and stores it on a public blockchain like Ethereum via a timestamped transaction. The detailed documents themselves are securely kept off-chain on a decentralized storage network such as IPFS, with the IPFS content hash being referenced in the blockchain record. This action creates an immutable and verifiable proof of creation, which can be used as evidence of prior art during disputes. Later changes to the algorithm are versioned similarly, creating an open audit trail across the IP life cycle.

B. Example of a Licensing Contract Between Two Startups On-Chain

Based on this situation, TechNova signs an on-chain licensing arrangement with VisionEdge, another startup that wishes to implement TechNova's algorithm in its drone-based inspection platform. The conditions include non-exclusivity of usage rights for two years, with royalty payments tied to volume of usage that are paid automatically. A smart contract is executed on the blockchain to govern this deal. It monitors API calls by VisionEdge to utilize the algorithm and automatically computes and transfers royalty payments to TechNova's digital wallet on a monthly basis. In case of over-usage beyond the agreed level, the smart contract automatically changes the billing or prevents additional access, avoiding the necessity of manual checking or third-party intervention.

C. Evaluation of Gas Costs, Execution, Time and Usability

To gauge the feasibility of such a system, it was evaluated using the Ethereum test network. The first on-chain registration of IP metadata cost somewhere between 75,000 to 90,000 gas units, equivalent to a nominal fee based on prevailing gas prices. Launching the smart licensing contract took a higher one-time fee of somewhere between 200,000 to 300,000 gas units. Every royalty payment execution or API usage update invoked additional transactions that cost around 20,000 to 40,000 gas units per call. Execution times were approximately less than 30 seconds for normal network conditions but can be variable depending on network usage. Although these are relatively small expenses, they illustrate the necessity for startups to plan for operating costs of blockchain transactions. In summary, the simulation verifies that through simple interfaces and pre-audited smart contract blueprints, blockchain-based IP management is both technically achievable and economically sound for startups seeking to secure and monetize their innovations.

X. CONCLUSION

This paper has discussed the revolutionary possibilities of blockchain technology and smart contracts to resolve the long-standing problems of startups in their intellectual property management. Through the natural characteristics of blockchain - decentralization, immutability, and transparency, startups will be able to create tamper-proof origin records, simplify the licensing process, and make royalty payments automatically with minimal dependence on expensive middlemen. The system minimizes administrative burden and lowers considerably the prohibitively expensive legal costs historically linked with IP protection and enforcement. In addition, the suggested framework allows more openness and trust among stakeholders, with easier collaborations and licensing agreements even internationally. The use of smart contracts also guarantees contractual terms are carried out automatically, reducing conflicts and optimizing business processes. Ultimately, this method promises to enable startups to better protect their innovations, secure investment with stronger IP portfolios, and compete more effectively in global markets. But achieving this vision needs active participation from policymakers, regulators, and technology innovators to resolve legal recognition, standardization, and interoperability issues. Research and inter-disciplinary collaboration need to continue to develop scalable, legally compliant, and user-friendly blockchain-based IP solutions. As the digital economy continues to unfold, the adoption of such innovations has the potential to redefine intellectual property as a dynamic, accessible asset,

keeping startups at the center of technology and economic development.

XI. FUTURE DIRECTIONS

The use of blockchain and smart contracts for intellectual property management within startups is yet in its embryonic phase, offering fertile ground for future improvement and research. One major thrust is the smooth incorporation of blockchain-inclined IP systems with existing national and international intellectual property registers like the United States Patent and Trademark Office (USPTO) and the World Intellectual Property Organization (WIPO). By connecting decentralized blockchain registries with conventional institutional records, startups can leverage the legal legitimacy of old systems and the transparency and immutability of blockchain technology. This hybrid approach might simplify global filing mechanisms and enhance cross-jurisdictional enforceability of IP rights. A further promising area is the integration of artificial intelligence to augment the functionality of blockchain-based IP platforms. AI processes would be able to perform advanced tasks like IP categorization, plagiarism, and prior art search on-chain or through interoperable oracles. This would allow startups to perform due diligence more effectively and with less reliance on expensive outside legal guidance. Machine learning algorithms may also be trained to track and identify potential violations in real-time, enhancing IP protection even further.

Interoperability across multiple blockchain platforms is equally important to achieve scalability and mass adoption. Since different blockchains can be used for various industry verticals or geographic regions, cross-chain communication protocols would facilitate the transfer and authentication of IP assets between platforms. Cross-chain smart contract standards and frameworks would help ensure that licensing contracts and royalty payments are reliable even when transacting parties are on separate blockchain ecosystems. Last but not least, the advent of decentralized autonomous organizations (DAOs) presents a new model for collective IP governance. Startups and creators may constitute DAOs to jointly administer, license, and protect their IP portfolios. Stakeholders may receive governance tokens to exercise transparent voting for the terms of licensing, dispute settlement, and distribution of revenues. Such decentralized forms of governance may democratize decision-making and reduce administrative overheads, allowing startups to better control their intangible assets in a borderless digital economy.

Together, these future directions highlight the revolutionary power of blockchain, AI, and decentralized governance in redefining the IP framework for startups. Ongoing interdisciplinary research and policy collaboration will be essential to tackle regulatory, technical, and ethical issues as these technologies continue to advance.

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