

# Blockchain and Intellectual Property Governance in the Digital Economy: Innovation, Smart Licensing, and Structural Challenges

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## Abstract:

The notion of intellectual property (IP) in the digital era has transformed significantly due to advancements in blockchain technology. It has changed how rights can be asserted, verified and enforced in the digital assets and how IP is recorded, transferred, and monetized in the digital economy. While the advent of decentralized technologies like Non-Fungible Tokens (NFTs), smart contracts and the InterPlanetary File System (IPFS) offer exciting possibilities, their usage is limited due to their non-recognition in most of the statutory regimes. In the light of these advancements, the basic IP concepts of authorship, ownership, and licensing need reformulation. This paper explores how blockchain-based IP licensing systems can support smarter, more transparent licensing of IP rights and contribute to digital economy. It critically examines the key doctrinal misalignments and regulatory ambiguities, prevailing in India, the EU, and the US, that need to be plugged-in for efficient blockchain-IP integration.. Further, a normative framework based on statutory modernization and procedural enablement led by institutions like WIPO and coordinated with regulatory bodies has been proposed. The findings are relevant for legal reformers, IP policymakers, digital market economists, and platform designers seeking a more coherent system of innovation governance in the age of decentralization.

**Keywords:** Blockchain, Digital Economy, Smart Contracts, Intellectual Property (IP), Legal Reform, Decentralized Governance, Digital Assets

## 1 Introduction

The advancements in blockchain technology have changed how digital assets are created, owned and exchanged globally (Miroshnichenko and Birch, 2024). The blockchain features such as immutability, transparency, decentralized record-keeping, and automated contracts have made it a potential game changer in digital asset management (Ferro et al., 2023). These are driving force towards a new IP paradigm where ownership and licensing are smart contracts that are codified, tokenized and enforced on chain. The creators can use non-fungible tokens (NFTs) and intelligent contracts to mint their work. They can establish their own rights on it using the same while also getting paid automatic royalties if sold (Sheldon, 2022). These developments promise to reduce transactional friction, bypass intermediaries, and democratize access to monetization tools for artists, developers, and inventors alike. Nonetheless, the laws haven't kept up with the new tech (Zou, 2020). Most IP laws continue to favour pre-digital conception of authorship, licensing, and evidence resulting in doctrinal uncertainty and enforcement difficulties in tokenized contexts. Despite studies investigating NFTs and copyright, the topic of tokenization, smart licensing and intellectual property law has remained unexplored in terms of impactful analysis and policy suggestions (Bamakan et al., 2022). There is little discussion on how the ownership of a token either fits with or disrupts traditional copyright and licensing. Most legal discussions are confined to specific jurisdictions and do not provide a comparative or interoperable perspective on digital

intellectual property licensing in decentralized environments. This paper aims to fill this void by offering a detailed, comparative legal examination of blockchain-enabled licensing methods within the framework of intellectual property rights.

The paper aims to rigorously analyze the transformative effects of blockchain technologies, specifically tokenization and smart contracts on the conceptual and regulatory paradigms governing intellectual property licensing, while also advocating for doctrinal and policy-oriented strategies that facilitate the integration of these advancements.

The objectives of the paper are:

- To investigate the effect of blockchain on ownership, licensing and enforcement of IP.
- To identify legal and infrastructural challenges arising from token-based licensing.
- To study the doctrinal gaps and regulatory approaches in blockchain-enabled IP systems.
- To propose legal and policy reforms to integrate decentralized licensing mechanisms into formal IP governance so as to protect digital assets.

This study aims to identify the impact of blockchain technologies on the governance of intellectual property right and offers suggestions on reforms to make the framework more adaptable and enforceable for IP protection of digital assets.

## 2 Blockchain and NFTs in IP Governance

The term “tokenization” refers to converting intellectual property (IP) assets into a unique digital token on a blockchain (Xiao, 2022). These tokens termed as Non-Fungible Tokens (NFTs) are immutable and can be verified publicly so as to serve as proofs of ownership or access rights. Creators can link their unique digital assets like artwork, music, and patents to a blockchain record using NFTs which help in verifying ownership, automate royalty, and rights. Thus, NFTs can be powerful tools to settle disputes regarding originality or infringement as well as chain of title. NFTs have various applications for the IP holders (Hasan et al., 2024; Razi et al., 2024):

*Provenance verification:* Some of the NFT elements such as owner’s address, metadata link, transaction history etc. are recorded on the blockchain which can ensure the authenticity of the origin, ownership history, and legitimacy of an asset.

*Fractional ownership:* The IP artwork can be divided into fractional digital tokens. Each fraction represents the ownership share of a contributor, thus facilitating fractional ownership. Moreover, tokenization facilitates micro-licensing by utilizing smart contract automation that enforces terms involving usage length, territory, and royalties.

*Direct monetization:* Tokenization increases transparency by enabling creators to sell/license their IP directly to consumers, collectors or licensees without requiring traditional intermediaries such as publishers, labels or galleries.

Platforms like OpenSea (“OpenSea, the largest NFT marketplace,” n.d.), Zora (“Zora,” n.d.), Async Art (“Async Classic Art Editor,” n.d.), Audius (“Audius,” n.d.) and Foundation (“Foundation,” n.d.) have emerged as marketplaces for tokenized IP. Some of these platforms enable programmable NFTs with dynamic, layered rights.

Blockchain technology and NFTs, together have led to the transformation of online intellectual property recording, licensing and enforcement procedures. While these technologies offer transparency and control, they also pose legal and regulatory challenges. Most IP laws were not designed for decentralized systems which leads to uncertainties relating to the recognition and

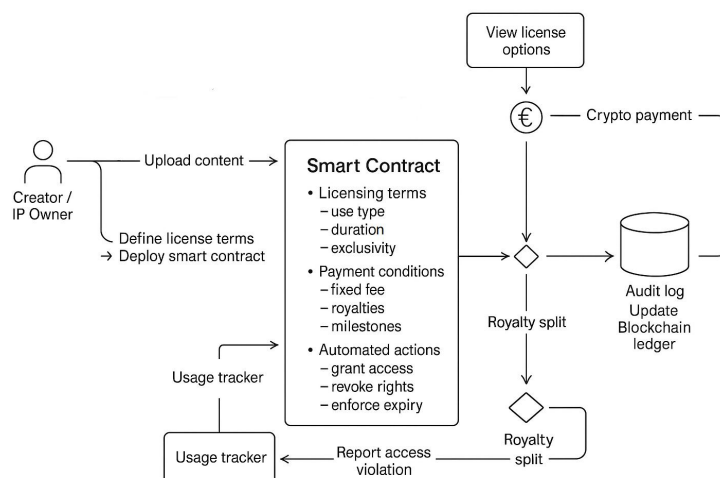
enforcement of tokenized rights (Ciriello et al., 2023). This section focuses on the scope and the existing gaps in how blockchain and NFTs are used to govern intellectual property.

## 2.1 Smart Contracts, Licensing Automation and Monetization Mechanisms

NFTs are increasingly being integrated with smart contracts which are self-executing digital contracts with embedded terms and conditions on blockchain. IP licensing makes it possible to use smart contracts to automate and streamline important processes that would normally require third parties to mediate (Albert et al., 2020). Automated disbursement of royalties to creators whenever a digital asset is resold is one of their most significant features. It ensures that the artists will continue to earn money through a secondary market transaction. Further, smart contracts can manage access to digital content, enabling payment per view, timed access, subscription-based access, and more, thereby broadening the possibilities of monetizing IP assets in a more flexible manner (Ferro et al., 2023; Moreaux and Mitrea, 2023).

Smart contracts can also enable cross-platform licensing, as they keep track of how assets are being used in different digital environments, reducing administration and allowing for a more efficient collection of royalties. This automation reduces the artist's dependence on agents, collecting societies, and digital distributors, thus returning part of the control and revenue to the creators. Smart contracts ensure a more transparent, efficient, and fair licensing environment where transaction records cannot be changed, and terms are executed without dispute (Bodó et al., 2018). Figure 1 shows the smart contract based licensing and monetization flow. Nonetheless, such systems will have a broad applicability only if laws evolve to recognize IP in a more dynamic manner and standards are created to ensure enforceability and interoperability with various IP regimes and national regulatory frameworks.

The ability to program royalties into smart contracts tackles a long-standing issue in IP law, namely ensuring that creators receive a share of the downstream commercial success of their works. Most copyright systems don't guarantee royalty on secondary sale, especially in the case of artwork, music, and such (Tunc et al., 2024). Countries use coded rules to enhance law enforcement. Similarly, royalties can be coded into the asset using blockchain.



**Figure 1: Smart Contract based Licensing and Monetization flow**

## **2.2 Legal and Doctrinal Risks in NFT Ecosystems**

Despite these developments, the intersection of NFTs and IP law continues to raise many doctrinal uncertainties and enforcement risks.

Usually, NFTs do not store the actual asset on the blockchain as it would require significant storage capacity and could lead to inefficiencies in data management. It makes the system expensive and less practical for widespread adoption. Instead, blockchain stores a reference to the asset stored off-chain, ensuring that ownership and authenticity can be verified without the need for the asset itself to be on-chain (Jia and Yao, 2024). The metadata associated with the NFT contains crucial identifying information such as the title of the work, the creator's name, a description, and licensing terms and is either stored off-chain or, less commonly, on-chain.

This metadata travels with the NFT as it changes hands, creating a publicly accessible and auditable trail of all transactions, transfers, and ownership changes. The entire transaction history of the NFT is recorded, allowing anyone to trace the provenance of the digital asset from its creation to its most recent transfer. However, the metadata, particularly when stored off-chain, is easily manipulable, giving rise to significant legal and technical challenges. It can be edited or forged to include unauthorized copyrighted or trademarked content, misrepresent authorship, or inaccurately claim usage rights. Metadata stored on-chain is immutable but misrepresentation can still occur at the time of creation. The reason being that blockchains do not verify if the data being stored into them is correct or false. Subsequently, false or infringing claims may be permanently embedded into the blockchain. The concerns raise complicated legal questions, for example, whether the misuse of metadata constitutes an IP infringement by itself or whether it merely constitutes evidence of some other infringement (Haynes, 2017). NFT creators, consumers and markets are still facing uncertainty on legal standards, with no court or regulator achieving clarity on the issues so far.

## **3 Blockchain-Based IP Registers: Towards Decentralized Rights Management**

The development of blockchain-based IP registers is a transition from centralized repositories, traditionally held by national IP offices, to distributed, tamper-proof right systems. With ownership, licensing, and authorship data directly on a blockchain, the registers provide transparency, immutability, and accessibility across borders. Decentralized systems can help to easily verify rights, reduce transaction costs, and offer real-time updates on transfers or licensing terms.

Blockchain-based IP registers may be a promising solution to various IP related issues, however, they also raise the following legal challenges (Amelin, 2019; Ilegieuno, 2021):

- Blockchain records, being nothing but an entry in a global database, may sometimes be insufficient to demonstrate ownership over a specific asset or IP right. They hardly receive their prima facie validity in courts in most of the jurisdictions such as India, USA, European Union, and others.
- The blockchain-based IP ledgers are not synchronized with the government registry which results in issues like double registrations and ownership disputes. It also leads to uncertainty about the legal validity of tokenized rights.
- Smart contracts are used to automate licensing and rights management, however, it is challenging to enforce smart contracts across borders due to lack of consent or dispute resolution clauses while drafting.

### **3.1 Legal Recognition and Interoperability of Blockchain-Based IP Registers**

IP registers are significant in allowing blockchain technology to provide solutions to licensing, authorship disputes and cross-border enforcement in digital age. The combination of immutable timestamping and programmable licensing can be used to enhance traditional IP regimes. Therefore, legal systems should go beyond technological tokenism to develop coherent frameworks for the recognition, interoperability and enforceability of blockchain-registered rights.

#### ***3.1.1 Harmonizing Legal Standards Across Jurisdictions***

The law regarding tokenized intellectual property rights must be coordinated across boundaries. At present, the lack of concise definitions, enforcement practices, and admissibility standards results in divergent outcomes in cross-border disputes. For the blockchain-based registers to work, there must be international agreement on a set of core legal principles such as - what does a valid tokenized IP asset consist of? How will metadata be treated? How will smart contracts be interpreted? etc. Organizations such as World Intellectual Property Organization (WIPO) (“WIPO - World Intellectual Property Organization,” n.d.) and United Nations Commission On International Trade Law (UNCITRAL) can be instrumental in creating model law/treaty that promotes consistency and interoperability.

#### ***3.1.2 Developing API Bridges Between IP Offices and Blockchain Systems***

Building secure API-based interfaces between national IP registries and trusted blockchain networks is yet another vital step. The synchronization of the systems would allow real-time updates, verification of registrations, and automated licensing records. Integration of ownership and rights history into one system would lead to lower redundancy and more transparency (Pasdar et al., 2023). This would also make IP offices more responsive to decentralized ecosystems and would enable hybrid models in which official registries would interact with decentralized databases in a secure and auditable way.

#### ***3.1.3 Understanding the Legal Validity of Smart Contracts in IP Licensing***

As discussed in previous sections, despite being capable of automating intellectual property transactions, smart contracts are not legally enforceable in most jurisdictions. The efficient integration of smart contracts with IP licensing demands for clarifications from the legislatures and courts of law. It should be clearly formulated upto what extent and under which conditions smart contracts are valid and binding licenses for certainty (Di Angelo et al., 2019; Inshakova, 2020). As of now, certain jurisdictions are applying the civil law to smart contracts, but creative industries and patent portfolios which call for sector-specific regulation stress upon the detailed deliberations for IP licensing in digital era.

## **4 Decentralized Storage and Tokenized Asset Infrastructure**

Recent technologies have allowed the content to exist in increasingly platform-less and borderless ways. Consequently, the traditional IP enforcement mechanisms that relied primarily on server location, identifiable host, and intermediaries are bound to fail. The emergence of decentralized technologies such as InterPlanetary File System (IPFS) and NFTs has transferred the control from intermediaries to creators, leading to new models for copyright preservation, authorship provenance and content tracing (Prakash et al., 2023). However, there are serious legal and doctrinal challenges in imposing their rights on enforceability, jurisdiction and evidentiary values.

#### **4.1 IPFS and Copyright Preservation**

The InterPlanetary File System (IPFS) is a peer-to-peer hypermedia protocol designed to create a content-addressed web. Instead of using location-based addressing like conventional URLs, IPFS identifies content by its cryptographic hash, ensuring integrity and immutability (Prakash et al., 2023).

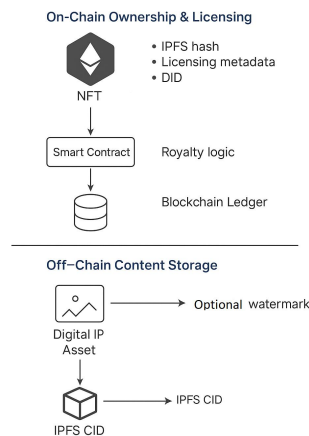
Using IPFS for copyright preservation ensures immutability of the content. IPFS generates a unique cryptographic hash based on the file's content when a file is uploaded to IPFS. The hash can help anyone verify whether the file or document is the same as the original file by using the hash. A change in one byte results in a completely different hash, allowing for a very strong version control and very strong tampering prevention (Ko et al., 2023). IPFS provides persistence along with immutability by virtue of a process called "pinning", i.e., persons or institutions pinning certain content means that it will live forever across multiple nodes. In other words, it ensures permanent access (even if no hosting server is available) and protects the content from deletion or unavailability due to server shutdown or domain suspension (Kulüke et al., 2023). As IPFS is decentralized and Internet based, it can't be censored and no content can be deleted or blocked unilaterally. IPFS's features can ensure that any copyright content can be easily verified, tracked, accessed and referenced. However, the same resilience creates challenges for enforcement against unauthorized distribution of infringing or pirated content across nodes.

#### **4.2 Layered Architectures: IPFS Content and On-Chain Ownership**

The content is stored on IPFS and identified by a tamper-proof hash called Content Identifier (CID). Even if the content is changed, this hash does not change. This characteristic is used to create a strong two-layer architecture based on IPFS and non-fungible tokens (NFTs) for controlling digital intellectual property (IP) and enables content storage and transparent rights management (Ko et al., 2023; Pandey et al., 2024).

NFTs representing the transaction history and ownership and licensing terms of the content are deployed at the second layer of a blockchain network. The tokens hold information and IPFS CID. They also store creator identity and smart contract logic on a blockchain. This division of content and ownership improves asset traceability and decentralization. The layered architecture is shown in Figure 2.

As evident from above, the NFTs and IPFS integration leads to a technologically robust framework for digital IP control, tamper-proof content storage and transparent ownership records. However, it still faces significant challenges in terms of legal interoperability with existing intellectual property systems and enforcement mechanisms. Blockchain and decentralized storage are irreversible, which is one of the main limitations. Once records of NFT metadata on a blockchain or content on IPFS are created, they are immutable and decentralized, and so, unlike centralized platforms, the orders issued by courts to delete or change that content or metadata cannot be enforced (WIPO, 2022).



**Figure 2: Layered Architecture of IPFS-Based Content Storage and On-Chain Ownership in Blockchain-Enabled IP Systems**

Furthermore, national IP offices currently do not recognize token-based records, such as timestamps on a blockchain or NFT ownership proof. Due to this disconnect, blockchain records can't be automatically recognized as proof of ownership, authorship or license under local or international IP laws and regulations. Consequently, creators who depend on NFTs alone for establishing their IP rights may find their claims lack legal basis when formally challenged (Jia and Yao, 2024; Napitupulu et al., 2023).

It is also highly complex to enforce rights against infringing NFT issuers. Because many players act pseudonymously and across jurisdictions, legal action requires a coordinated effort on the part of NFT marketplaces or the decentralized platforms themselves that may not comply with takedown requests. For the most part, creators must engage in civil litigation to seek and identify the offender, often across borders which causes significant costs, delays and uncertainty to the enforcement process.

NFTs and IPFS are powerful tools to protect digital IP in the cyberspace. However, due to limitations of the prevailing formal legal systems and subsequent enforcement, these tools cannot be used effectively. Therefore, there is a need to evolve regulatory and institutional frameworks that can ensure legal protection and access to justice for rights holders.

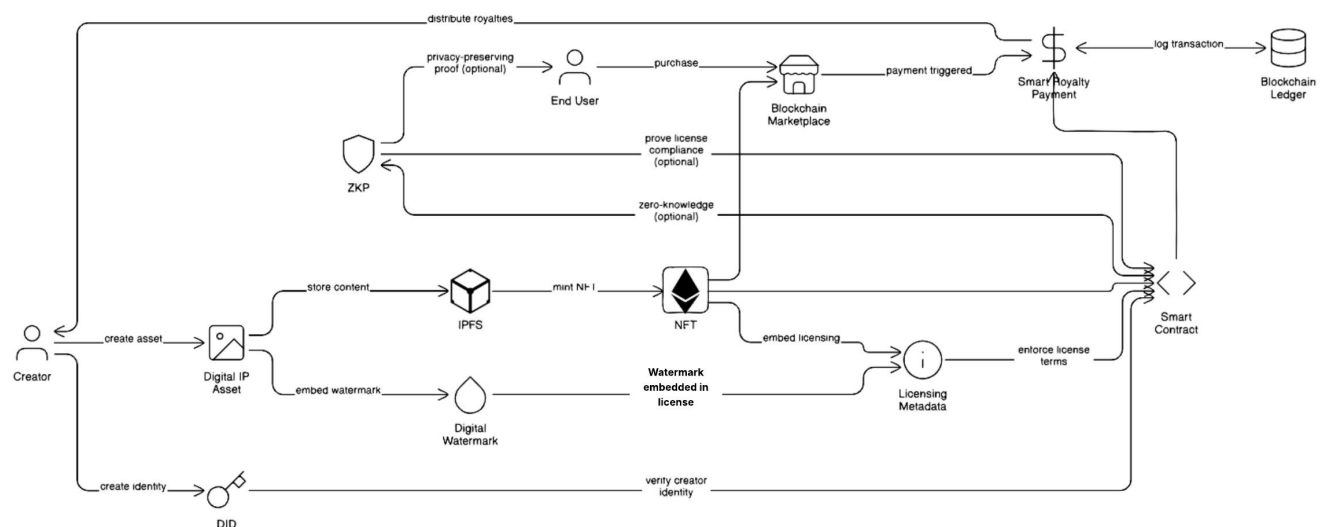
## 5 Architecture of Blockchain-Based IP Licensing System

This section introduces the architecture of block-based IP licensing system integrated with newly emerging privacy-aware technologies for the management of Intellectual Property rights in cyberspace. The privacy-aware tools such as digital watermarking, the technique of embedding imperceptible information within digital content (Zhang, 2009); zero-knowledge proofs (ZKPs), cryptographic proofs that let one party (the prover) convince another party (the verifier) that a claim is true, without revealing any additional information other than the claim being true (Yang and Li, 2020); and decentralized identifiers (DIDs), self-sovereign digital identity protocols that allow users to assert control over their identity without the need for centralized registries or certification authorities (Mazzocca et al., 2025) transform how authorship, licensing and access control are asserted in algorithmic and distributed environment.

This technology triad allows a bottom-up enforcement model. It is less reliant on traditional centralized platforms, and more in tune with the decentralized logic of cyberspace (Mazzocca et

al., 2025; Wang et al., 2024). Still, legal and regulatory norms are required to formally accept these technologies as legitimate proxies for authorship, identity and consent.

A simplified framework for blockchain-based IP licensing system has been depicted in Figure 3. A creator creates a Decentralized Identifier (DID) and a digital IP asset with a watermark which is stored on IPFS, linked to a minted NFT with licensing metadata and the creator's verified identity. A smart contract makes sure that the licensing terms must be followed, manages royalty payments and uses the blockchain ledger for transparency. The end-user can purchase NFT on a blockchain marketplace and optionally leverage Zero-Knowledge Proofs (ZKPs) to privately prove the compliance of the license. The system manages digital rights in a secure, automatic and traceable way.



**Figure 3: Architecture of Blockchain-Based IP Licensing System**

The forthcoming section of the paper outlines normative recommendations that would ensure that these decentralized tools are brought in line with existing IP law doctrines, and that enforcement in the digital ecosystem is effective, fair and fit for purpose.

## 6 Empirical and Policy Gaps in the Blockchain-IP Interface

Though legal and technical developments that allow for effective enforcement of intellectual property (IP) rights in digital environments are becoming available, governance remains reliant on clear data, reliable procedures and more international cooperation. In the absence of these elements, enforcement efforts tend to be sporadic, complex to implement, and largely out of step with fast-moving technologies.

One of the foundational impediments to effective legal and policy development in the domain of blockchain-based intellectual property governance is the absence of structured, empirical data. Regulatory bodies, courts, researchers, and digital platforms currently operate in a landscape where infringements related to blockchain technologies, such as NFTs and smart contracts, are largely undocumented, underreported, or dispersed across platforms without standardization.

The priority domains where there is a lack of empirical evidence but is nonetheless critical for decision-making are given below:



- *Unauthorized NFT Minting of Protected Content:* There is no central mechanism or database that allows one to measure how often copyrighted images, songs, and texts are used without a rightsholder's consent to mint an NFT. The absence of such tracking allows infringers to act with impunity and creates enforcement hurdles, especially across platforms and borders.
- *Metadata Misrepresentation:* Tokenized works come with on-chain or off-chain metadata that asserts authorship, ownership or licensing. Unfortunately, there is a problem when it comes to claiming things like a Creative Commons license for something that is actually commercial. However, how often this happens, whether it goes to court, and what different jurisdictions do about it remains unknown.
- *Royalty Evasion in Decentralized Markets:* The automated nature of smart contracts enables them to process royalty payments and enforce licensing. However, many NFT creators bypass this logic through wrapping, using forks that don't automatically enforce contracts, and using marketplaces that ignore royalty logic. Without a dataset observing how often these evasions happen, we do not know which platforms do not comply or whether attempts to enforce have worked.
- *Platform-Specific Trends and Non-Compliance:* NFT marketplaces like OpenSea, Blur and Rarible follow different takedown policies and moderation standards than those of YouTube and other content share. It is impossible for regulators and researchers to assess which platforms are most susceptible to hosting infringing content, and which are actively investing in compliance infrastructure, without comparative data.

## **7 Doctrinal Gaps and Reform Imperatives**

The application of blockchain technology to intellectual property (IP) systems can both help and hinder legal doctrine. Despite the growing practicality of blockchain-based infrastructures like smart contracts, NFTs and decentralized storage, effective legal frameworks for IP rights have not kept pace with this rapid progression. This disconnect causes critical doctrinal, procedural, and interpretive gaps hampering the adoption and enforceability of blockchain-enabled IP systems.

This section highlights various aspects where conventional legal doctrine falls short or is outdated in relation to tokenized IP assets. It also illustrates a comparative perspective w.r.t. jurisdictional readiness and reform efforts in three major legal regimes viz. India, the European Union, and the United States, to show the doctrinal gaps in the legal regime and suggests reform pathways.

### **7.1 Statutory Misalignments in National IP Frameworks**

Even though blockchain-based mechanisms for registering, verifying, and licensing intellectual property have been gaining popularity, national regulatory frameworks still largely reflect the analog-era or Web 2.0 models of content creation and distribution. The legal provisions don't always match up to the technology. This is causing blind spots in the whole long-term architecture. This includes tokenization, decentralized storage, smart contracts and algorithmic enforcement. This section is devoted to the statutory misalignment of the IP laws of India, the European Union and the United States and how they can (or cannot) identify and regulate IP activity on Blockchain.

### **7.1.1 India: Outdated Statutory Language and Absence of Technological Adaptation**

The Copyright Act, 1957, and Information Technology Act, 2000 (IT Act) are the primary IP laws of India, however, the regime does not recognize blockchain-based authorship, smart contracts, or tokenized licensing. The provisions on authorship and reproduction rights contained in the Copyright Act do not take into account machine-readable licenses, decentralized authorship or token-based revenue models.

Also, Indian law does not provide any statutory treatment for smart contracts.

As per Section 10A of the Indian Contracts Act, 1872 (“Indian Contract Act, 1872,” 1872), electronic contracts are valid. However, the law does not contemplate self-executing code or programmable royalties. As a result, it is unclear whether smart contracts are enforceable by law without a written contract.

India does not have a notice-and-takedown system for blockchain-based infringement. The takedown power, as defined under section 69A of the IT Act, only pertains to centralized platforms which have to get the governmental authority for takedowns. These provisions will not be appropriate for a decentralized structure such as IPFS or a peer-to-peer NFT exchange.

So far, the Indian statutes assume identity, control, and liability, as relevant in ‘pre-blockchain’ times. There is no statutory infrastructure for accepting on-blockchain evidence or rights assertion in formal IP proceedings.

### **7.1.2 European Union: Incremental Recognition, Fragmented Implementation**

The EU has been more proactive than other jurisdictions in adjusting its IP framework to the digital environment. Blockchain, however, is on the margins of such initiatives. The Copyright in the Digital Single Market and amending Directives 96/9/EC (“Directive - 2019/790 - EN - dsm - EUR-Lex,” n.d.) encourages transparency and reform for licensing of online content. However, it does not define or regulate NFTs, tokenized content or smart contracts.

The Digital Services Act and AI Act establish rules related to accountability and platform content moderation, as well as to algorithmic systems. But it does not deal with the issue of copyright in an explicit manner through blockchain. Since the enforceability of smart contracts is governed by the national law of contract which varies significantly among the member states, it makes resolving disputes concerning the licensing of NFT (non-fungible token) across borders or ownership of such tokens difficult.

Various pilot initiatives, including the EUIPO’s Blockchain for IP initiative, are being undertaken to explore the use of blockchain for evidence and registration. Nonetheless, these actions remain non-binding and experimental with no codified status in EU law. The EU’s IP guidelines show some awareness towards blockchain, but do not have the legal precision or harmonization to allow for ease of enforcement across the decentralized landscape.

### **7.1.3 United States: Litigation-Driven Clarification Without Legislative Reform**

The Copyright Act of 1976 (“Appendix A - Circular 92 | U.S. Copyright Office,” n.d.) and the Lanham Act (“Lanham Act,” n.d.) govern the U.S. IP regime, which are misaligned with blockchain. There is no legal definition or acknowledgment of the NFTs, smart contracts or decentralized authorship. As a substitute, courts have had to interpret existing doctrines in the context of the blockchain dispute. Consequently, case law has developed without statutory guidance.

**Table 1: Comparative Insights and Observations**

| <b>Criteria</b> | <b>India</b> | <b>European Union (EU)</b> | <b>United States (US)</b> |
|-----------------|--------------|----------------------------|---------------------------|
|-----------------|--------------|----------------------------|---------------------------|

|                                                   |                                     |                                                         |                                                         |
|---------------------------------------------------|-------------------------------------|---------------------------------------------------------|---------------------------------------------------------|
| <b>Recognition of Tokenized IP</b>                | Absent                              | Partial (via pilot projects)                            | Case-by-case in courts                                  |
| <b>Smart Contract Enforceability</b>              | Ambiguous                           | Fragmented (depends on Member State laws)               | Unclear (no statutory support)                          |
| <b>Metadata / Blockchain Registry Integration</b> | Nonexistent                         | Limited (non-binding initiatives)                       | No formal integration                                   |
| <b>Key Challenge</b>                              | Legal inertia and absence of reform | Fragmentation and lack of uniform statutory recognition | Absence of legislative initiative, reliance on case law |

In the case of *Hermès International v. Rothschild* (*Hermes Int’l v. Rothschild*, 2023), the Southern District of New York held that NFTs can infringe trademarks by causing consumer confusion, thus applying the Lanham Act to tokenized assets. However, such decisions do not have cross-jurisdictional consistency or statutory reform support.

The Electronic Signatures in Global and National Commerce (E-SIGN) Act (“Electronic Signatures in Global and National Commerce Act (E-Sign Act) | NCUA,” 2021) allows for the enforceability of digital contracts, but does not answer questions of self-executing smart contracts or whether contracts established in one jurisdiction must comply with the laws of other jurisdictions. In addition, there is no legal mechanism similar to notice-and-takedown specific to blockchain or mandatory metadata validation.

Consequently, the U.S. model is litigation-led rather than policy-led, creating uncertainty for creators and platforms relying on tokenized IP tools.

In various jurisdictions, the legal framework is yet to adapt to the functional realities concerning blockchain-enabled IP systems. India is lagging behind the EU and the US in terms of some sort of legislative reform or even institutional recognition as is evident from Table 1. A future-ready IP regime should identify and incorporate token-based rights, standardize the enforceability of smart contracts and facilitate API-level interoperability between formal IP registries and blockchain. Achieving this convergence between doctrinal inertia and technological convergence will require legislative amendments, cross-border harmonization, and multistakeholder consultations.

## 7.2 Lack of Harmonization Between IP and Blockchain Law

Intellectual property law and blockchain technology still lack normative, procedural, and institutional harmonization. While blockchain can provide a new way to register, enforce, and monetize IP rights – through tokenization, smart contracts and decentralized storage – existing IP laws were not necessarily designed with this in mind. This causes systemic friction, interpretive uncertainty, and jurisdictional divergence, which prevent the scalability and legal enforceability of IP ecosystems enabled by blockchains.

### 7.2.1 Fragmented Legal Recognition of Tokenized Assets

A key challenge in the broader acceptance of blockchain-oriented intellectual property (IP) structures lies in the inadequate linkage between decentralized registries and established IP institutions. Although blockchain ledgers possess the capability to immutably document ownership, licensing, and transactional metadata, the majority of national IP institutions do not establish an interface with these decentralized frameworks. This disconnection leads to the

replication of claims, evidentiary uncertainty, and deficiencies in enforcement—especially within transnational contexts.

In India, the Copyright Office and the Controller General of Patents, Designs and Trademarks (CGPDTM) (“IP India - Intellectual Property India | Government of India,” n.d.) do not accept blockchain-based evidence or implement mechanisms for linking tokenized IP records with formal registries. There are currently no guidelines or technical frameworks (such as application programming interfaces or metadata standards) to encourage interoperability. The EU is exploring the use of blockchain through the pilot project ‘IP Register in Blockchain’ by the EUIPO to assess blockchain as an ancillary rights registry (“Document Details,” n.d.). However, the project is only in the pilot stage and is not yet legally part of the EU’s IP registration system. Many institutions in the U.S. like the U.S Patent and Trademark Office (USPTO) and the U.S Copyright Office have started public consultations and discussions concerning the role of blockchain and NFTs in IP governance. Though courts have cited blockchain evidence in some disputes, there is no procedure to submit blockchain-based information—like authorship metadata, ownership history and smart licensing terms—during the formal registration of an IP. Further, administrative systems remain unintegrated preventing interaction between blockchain records and official registers.

In conclusion, the lack of both technical and legal interoperability severely hinders the recognition and enforceability of intellectual property claims generated through blockchain. Coordinated reforms would be needed to overcome this challenge by designing standardized linkages from decentralized metadata to national IP databases.

### **7.2.2 *Smart Contracts and Licensing Ambiguity***

Smart contracts are algorithms that execute themselves. They validate licensing terms, royalties, and resale rights. However, their legal status remains unclear throughout most jurisdictions. The Indian Contract Act of 1872 of India does not recognize or regulate smart contracts as such. Some provisions may apply by analogy, e.g. provisions on offer and acceptance, lawful consideration. However, there is no legislative or judicial consensus on whether the terms executed on a blockchain satisfy the statutory requirements of enforceability.

The EU Digital Services Act as well as the ongoing digital policy reforms indicate a growing enthusiasm in the European Union for the future integration of legal technology. However, the enforceability of smart contracts remains inconsistent among member states. Several countries in the EU have started pilot projects or regulatory sandboxes, but there is currently no common legal framework for the recognition of code-based agreements. In the United States, smart contract jurisprudence is similarly in its infancy. Some courts have recognized them as contracts in certain situations, but there are still open issues on liability, remedies, and dispute settlement. Creators and licensees face significant challenges due to this lack of harmonization of legal regimes. Due to the lack of specific statutory recognition or consistent interpretation by the courts, smart contracts cannot be safely regarded as legally binding. This gap limits their use in cross-border licensing situations and calls for normative reform to include technical automation in existing contract law doctrines.

### **7.2.3 *Disjuncture Between IP Registries and Blockchain Metadata***

The integration of decentralized registries with formal IP offices is a significant challenge faced by blockchain-based IP systems. Even though blockchain ledgers can create an immutable record of ownership, licensing, and transactional metadata, most national IP institutions do not interface

with them. The disconnect causes duplicated claims, evidentiary ambiguity and enforcement gaps, especially in cross-border contexts.

### **7.3 Legal and Procedural Gaps in Domestic IP Frameworks**

There are significant procedural gaps in the resolution of intellectual property disputes related to blockchain, apart from doctrinal differences. In India, the existing enforcement framework lacks the necessary technical and procedural mechanisms to effectively manage tokenized intellectual property rights. The Indian Copyright Office does not facilitate the provision of any technical interface such as APIs or blockchain-integrated portals for the registration, tracking, or validation of metadata related to non-fungible tokens (NFTs) or smart contracts. Also, there are no legislative provisions or procedural frameworks to address the taking down of infringing NFTs, the resolution of violations concerning smart contracts, or the authentication of claims about decentralized authorship. As a result, litigants are compelled to depend on antiquated frameworks established under the Copyright Act of 1957 and the Information Technology Act of 2000—both of which lack the capability to address the pseudonymity and immutability inherent in blockchain systems.

In the United States, although the legal framework is procedurally more agile, the enforcement of blockchain-IP claims remains disjointed. Federal courts have addressed notable NFT litigation, exemplified by *Hermès International v. Rothschild*, yet these instances are largely the exception rather than the standard. Inconsistent procedural standards for digital evidence, jurisdiction related to pseudonymous entities, and cross-platform enforcement issues hinder systemic coherence. Much of the legal clarity has been derived from case law rather than through proactive statutory or regulatory enhancements.

Within the European Union, the inconsistency in legal authority among member states worsens procedural fragmentation. While initiatives such as the EUIPO's blockchain pilot projects signify advancement, there is an absence of a cohesive enforcement protocol for cross-border NFT infringements. Legal remedies exhibit considerable variability, and procedural collaboration among national IP offices remains in a state of development, resulting in inconsistent enforcement of blockchain-related IP rights throughout the EU.

### **7.4 Inadequate International Coordination and Cross-Border Enforcement**

In view of the decentralized and borderless structure of blockchain technology, the effective implementation of intellectual property rights increasingly rests upon collaborative legal and institutional frameworks across different jurisdictions. Nonetheless, such cross-border mechanisms are still inadequately developed and remain fragmented. In the context of India, the legal framework currently does not engage in any multilateral or bilateral treaty arrangements that acknowledge token-based ownership or smart contract-enforced licensing. As a result, judicial bodies and enforcement agencies lack procedural direction when confronted with disputes involving blockchain-native assets or pseudonymous actors operating beyond the territorial boundaries of India.

Within the European Union, there exists an active policy discourse focused on the development of interoperable intellectual property registries and cross-jurisdictional enforcement frameworks—particularly in relation to the Digital Services Act and the Blockchain Strategy—yet practical implementation remains in nascent stages. Many EU-funded projects advocate for the incorporation of blockchain metadata into the management of intellectual property. However,

the treatment of NFT rights and smart licensing differs greatly between member states, making uniform enforcement unlikely.

The United States, despite expressing its willingness to litigate blockchain-related intellectual property cases within domestic courts, has not yet been able to develop formal structures that may facilitate the acknowledgment of smart contracts or NFTs among jurisdictions. As a result, enforcement takes place without a systemic approach and is mainly governed by judicial precedents and not directed by policy frameworks.

### 7.5 Normative Reform Pathways

The evolution of blockchain technology, as well as tokenization and smart licensing frameworks, calls for reforms in legal systems that are currently reactive, rigid, and more concerned about conformity. This section outlines five pathways for normative reform that help the transition of legal regimes from conventional IP enforcement models into those which respond to technology.

**Statutory Modernization:** National intellectual property laws need to be changed to specifically include tokenized rights, blockchain-backed licensing metadata, and decentralized authorship systems. The Copyright Act, 1957, in India does not deal with NFTs, smart contracts, cryptographic proof, and other useful tools. Likewise, the United States Copyright Act and the European Union Copyright Directive have a certain elasticity of interpretation without formally including token-based rights enhancements in their respective definitions or evidences. Incorporating blockchain related concepts directly in legislation will be necessary to achieve legal certainty in this area.

**Doctrinal Adaptation:** Intellectual property laws and rule need to be urgently reviewed to accommodate new use cases including AI-generated works, algorithmically derived expressions, and metadata-encoding licensing conditions. The emergence of decentralized and automated systems for creativity calls for new meanings of ‘authorship’, ‘originality’, and ‘fixation’. It is also important for smart contracts to have a clear view on their relevance to general contract law.

**Procedural Enablement:** There should not only be a change in law but also there should be an operational framework that can facilitate the effective enforcement of tokens. This consists of rapid NFT removal processes, metadata validation APIs for IP registries, and smart contract infringement dispute resolution mechanisms. The development of regulatory sandboxes for piloting such mechanisms on a limited scale, before full-scale implementation may prove to be beneficial.

**International Harmonization:** Given the virtually limitless nature of blockchain technology, unified global frameworks are extremely important. This involves the development of model laws, guidelines or treaties under WIPO for the uniform recognition of tokenized assets, smart licensing conditions, and blockchain-based provenance claims. To enable effective enforcement in a cross-border legal dispute, national IP offices and decentralized systems must interoperate.

**Judicial Education and Capacity Building:** In the end, adequate preparation must be undertaken by judicial and quasi-judicial bodies to understand and resolve disputes relating to blockchain. Various training modules and certification programs for handling digital evidence, interpreting smart contracts and the recognition of token-based authorship can be institutionalized for judges, tribunal members and officials in IP offices.

When taken together, these reform pathways can serve as a guide towards an IP regime that is intellectually robust, besides being technologically aligned, normatively sound and globally coherent. They form the foundation for a transition from piecemeal enforcement strategies to a

robust and scalable legal system adept at handling the complexities of decentralized generation and ownership.

## 8 Conclusion

The combination of blockchain technology with intellectual property law offers opportunities but also legal, technical and policy challenges. Decentralized systems offer powerful tools to track provenance and facilitate automated licensing and privacy-preserving assertion of rights. However, existing intellectual property (IP) frameworks—at national and international levels—appear ill-equipped to accommodate those innovations in a coherent and enforceable way.

This paper has explored how Non-Fungible Tokens (NFTs), InterPlanetary File System (IPFS), Smart Contracts, Zero-knowledge proofs (ZKPs), Decentralized Identifiers (DIDs) and other technologies are changing notions of ownership, attribution, and licensing of digital assets. The absence of structured data, incompatibility of statutes with blockchain, lack of cooperation between jurisdictions etc. have been highlighted as one of the major empirical and doctrinal gaps. The comparative analysis of India, the European Union (EU), and the United States (US) reveals varying levels of institutional preparedness wherein each faces certain challenges ranging from procedural stagnation to cross-border enforcement issues. Even with pilot interventions and judicial involvement, overall governance is still fragmented, unclear and reactive. To create a legally strong and technologically enabled IP ecosystem for digital asset management and resilient digital economy, the paper seeks the implementation of statutory reforms, processes and procedures, recognition for smart contracts, cross-border coordination, and judicial capacity building. It also endorses regulatory mechanisms, harmonized metadata strategies, and multistakeholder dialogues to close the normative-technological gap.

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