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The integration of blockchain technology with arbitration mechanisms: its efficacy and implementation in international arbitration

Muhammad Ayaan Shehryar[1],†,* and Areej Anwar[2],‡

1 Martens Rechtsanwälte, Munich, Germany
2 Esquare Legal, Dubai, United Arab Emirates
† Current address: Esquare Legal, Dubai, United Arab Emirates
‡ Current address: Barsols Legal Consultants, Islamabad, Pakistan

* Correspondence author; E-mail: ayaanshehryar13@gmail.com.

Highlights:

- Examining the suitability and legalities of utilizing blockchain technology in dispute resolution.
- Kleros Mechanism illustrates blockchain arbitration for cross-border dispute resolution.
- Comparison of the time frame for dispute resolution between traditional and blockchain arbitration.
- Exploring how blockchain can revolutionize enforcement mechanisms in international arbitration.
- Highlighting the necessity for developing hybrid models, incorporating blockchain in arbitration.

Abstract: The integration of blockchain technology in arbitration presents a paradigm shift of traditional justice towards decentralized justice, thereby challenging traditional legal frameworks by offering improved efficiency, transparency and autonomy. This article examines blockchain arbitration through the Kleros Mechanism, which utilizes smart contracts, crowdsourced jurors and token-based incentives to resolve disputes in a tamper-proof and decentralized manner. The integration of cryptographic validation, anonymized juror selection and multi-round appeal mechanisms addresses the gaps between traditional contracts and smart contracts on blockchain. The procedural fairness of blockchain mechanism is addressed by analyzing both objective and subjective criteria, and compliance of the Kleros Mechanism with traditional jurisprudential principles. Analysis of empirical data, supported by interviews, highlights the significant potential of blockchain technology in enhancing the efficiency of dispute resolution. Kleros, as an example, resolves disputes in an average of just 13.23 days and has less than 3 pending cases. However, enforcement of blockchain-based arbitral awards is challenged by traditional enforcement standards, including decentralized proceedings, anonymity of jurors, classification of the nature of arbitral awards, formal validity requirements, arbitrability and public policy considerations. The potential limitations of blockchain also have an impact on blockchain arbitration, including digital fragmentation, limitations of smart contracts including flexibility and automatic enforcement. To reconcile blockchain arbitration with international award enforcement

standards, the proposed measures include standard cryptographic validation of awards, model clauses specifying the seat of arbitration, hybrid mechanism with institutional oversight and jurisdictional compliance. This research presents a balanced approach between technological innovation and traditional legal frameworks, ultimately advancing the argument of a democratized and equitable future through decentralized justice.

Keywords: blockchain arbitration; decentralized justice; kleros mechanism; smart contracts enforcement; cross-border dispute resolution

1. Introduction

In the realm of international arbitration, there is a need to expedite time-consuming processes, particularly enforcement proceedings, by the integration of blockchain technology. Blockchain Arbitration presents itself as an alternative to expedite time-consuming processes by its attributes, such as its decentralized nature, in which no central regulating authority exists. Blockchain arbitration should not be conflated with conventional arbitration methods typically utilized by arbitral institutions. Rather, it presents a transformative approach, implemented on the blockchain.

A survey conducted by Deloitte polled a group of 1,386 senior executives across 12 different locations. These locations include Brazil, Canada, China, Germany, Hong Kong, Israel, Luxembourg, Singapore, Switzerland, United Arab Emirates, United Kingdom and United States (US). The survey was conducted at companies with an annual revenue of at least US$500 Million for US respondents and at least US$100 Million for respondents from other locations. The survey found that 71% of financial service providers either plan to use blockchain technology or are already using it [1]. This gives rise to the need of the hour, which is to formulate regulations that can decide the legalities for the utilization of blockchain technology.

The transactions on blockchain are registered on a distributed ledger as imputable copies on each node in the network, those transactions are based on a peer-to-peer network and are tamper-proof [2]. An ‘escrow mechanism’ is proposed by Satoshi Nakamoto (founder of Bitcoin) which protects the buyers from fraud and related harms [3,4]. In case a conflict arises between the buyer and seller during a transaction, the decision on where the money should be transferred will be made by the escrow service provider. Both the seller and the buyer should understand that the escrow service provider is a ‘trusted third party’. The transactions on the blockchain are transferred from one party to another by ‘smart contracts’—a self-executing program stored on a blockchain that automatically enforces the terms of contract when specific conditions are met. It operates based on pre-coded rules, ensuring transactions or actions occur transparently, securely, and without the need for intermediaries, making processes more efficient and tamper-proof [5].

The Kleros mechanism is a decentralized system for resolving disputes using blockchain technology. When a dispute arises, it is submitted to Kleros, and jurors (arbitrators) are randomly selected from a pool of participants by the mechanism itself. These jurors review the evidence provided by the parties and vote on the outcome. Jurors who align with the majority decision are rewarded, while those who vote unfairly may lose their staked tokens. This process ensures transparent, impartial, and efficient dispute resolution without relying on traditional courts or central authorities [6,7]. In the Kleros mechanism, the jurors are not conventional judges and the governing law is not derived from any

national legal framework. Instead, cases are adjudicated based on the specific circumstances presented on a case-by-case basis and the subjective interpretation of the arbitrator involved.

This paper will focus on identifying the gaps in 'traditional arbitration mechanisms', with a specific emphasis on the Kleros Mechanism as a primary example of blockchain integration in arbitration. Firstly, Kleros is presented as a form of decentralized arbitration, integrating the concept of blockchain arbitration and smart contracts to resolve disputes. Emphasis is provided on concepts like crowdsourced jurors, crypto economic incentives and automated execution. Secondly, the compliance of Kleros is validated with procedural fairness, both subjective and objective through Dimov's framework. Thirdly, the challenges to enforcement of blockchain-based arbitral awards are analyzed under the international enforcement standards, proposing methods of potentially complying with traditional arbitration mechanisms. Lastly, the limitations of blockchain and smart contracts are highlighted and potential reconciliation of those limitations is addressed in the context of blockchain arbitration.

The findings presented in this article are supplemented by interviews conducted with three experts in the field of blockchain. The selection of these experts was guided by their expertise in blockchain technology and dispute resolution, evidenced by their prior work in the blockchain sector. Among the experts, two are legal professionals (see Sections 4.3.4, 6.3.1 of this article) while the third is a researcher specializing in crypto economics, affiliated with the research department of Kleros (see Sections 4.2.5, 5.2.4, 5.2.7 of this article).

2. Research questions

The following are the research questions of this research:

(1) Can the use of blockchain technology in arbitration proceedings impact the efficiency of cross-border dispute resolution?

(2) Does the concept of blockchain arbitration comply with the rule of law requirements for it to be legalized as a method of arbitration?

(3) Should a new convention be legislated for enforcing blockchain-based arbitral awards or do traditional conventions (e.g. New York Convention) suffice for digital awards enforcement?

3. Research methodology

This study comprises both Qualitative and Quantitative legal research.

Qualitative research including, pure legal research, based on both primary and secondary sources, doctrinal legal research will be used to evaluate the existing laws and analyze the applicable treaties and conventions, with the gaps found in them. The primary sources of law, the enforced law (statutes, treaties and conventions) and secondary sources (books, articles and white papers) will be utilized and analyzed in depth to carry out a systematic study of the topic. The interviews of three experts are also incorporated regarding the utilization and practicality of blockchain in arbitration mechanisms, along with potential compliance and enforcement of blockchain-based arbitral awards. Furthermore, descriptive legal research will be used to describe the decentralized justice system and processes of blockchain, which includes its utilization in arbitral proceedings. Comparative legal research will be used to compare, firstly, the comparison of the decision-making process in a traditional arbitral setting and an online setting and secondly, the comparison of the rule of law requirements that are set forth to be fulfilled in

rendering an arbitral award with an award rendered using blockchain technology. In addition to that, analytical legal research will be used, firstly, to analyze the requirements for enforcing the arbitral awards—in an online setting, in the context of international commercial arbitration and secondly, for analysis of the requirements of enforcement of arbitral awards through blockchain and thirdly, for analysis on the issue of digital fragmentation potentially affecting blockchain arbitration.

Quantitative research focusing on empirical legal research includes, firstly, the data collected through different databases and smart contracts, regarding the nature of resolved and pending cases at Kleros, with the average dispute resolution time at Kleros. Secondly, it includes numerical data analysis by employing mathematical techniques to compare traditional dispute resolution time with the dispute resolution time in blockchain arbitration, by the example of Kleros Mechanism.

4. Introduction to Web3 blockchain and smart contracts

Web3 (Web 3.0, Web3 and Web3+ are denoted as Web3 for the purpose of this paper) is an evolution of the internet that provides decentralization (not regulated by a central authority), which enhances privacy and transparency, whereas the previous version Web 2.0 is characterized by centralized platforms (e.g., Facebook, Google) that facilitate user-generated content and social interaction but retain control over the stored data and utilization, often monetizing user information through advertisement. In contrast, Web3 is based on decentralization and grants users ownership of their data and digital assets. While Web 2.0 relies on third parties for trust and transactions, Web3 operates on trustless systems via smart contracts, enabling peer-to-peer interactions without any centralized oversight [8].

4.1. Transactions on blockchain and smart contracts

One of the fundamentals of this decentralization is ‘blockchain’, which provides a decentralized ledger (digital record), eliminating the need for intermediaries (third parties) in transactions. [9] Blockchain is explained by the founder of Bitcoin, that the transactions on blockchain are registered on a distributed ledger as imputable copies on each node in the network, those transactions are based on a peer-to-peer network (decentralized computing model where nodes interact directly without relying on a central server) and are tamper-proof (secure against manipulation). The identities of the parties are not known [emphasis added], however, a ‘routine escrow mechanism’ is proposed by Satoshi Nakamoto, which protects the buyers from fraud and related harms [3].

An escrow is a secure arrangement in which funds or assets are kept by an impartial third party until all the terms of an agreement are satisfied. This system safeguards both buyers and sellers by guaranteeing that payment is only disbursed once all parties have honored their commitments. In case a conflict arises between the buyer and seller during a transaction, the decision on where the money should be transferred will be made by the escrow service provider. Both the seller and the buyer should understand that the escrow service provider is a ‘trusted third party’, because it is not controlled by any party and prevents unilateral asset transfer until predefined conditions are algorithmically verified and met. As a result, there is no possibility of any theft of crypto tokens [4].

In short, the tokens or funds are stored in an escrow until the contract has been performed and subsequently, after the validation of the performance of the contract, the funds flow accordingly. This mechanism is depicted on the blockchain through a ‘smart contract’, which is a computer program [5]

that self-executes a digital agreement written in a code format, on a blockchain. It automatically enforces the terms of a deal when preset conditions are met [10].

Example—In case of buying a rare digital collectible (subject matter), instead of using a platform like eBay, which takes fees and controls the process, one pays via a smart contract—a self-executing program on the blockchain. The smart contract acts as a secure escrow that holds your payment in a locked digital vault until the collectible is delivered to the crypto wallet. Once blockchain verification confirms the transfer, the funds are automatically released to the creator, without the oversight of a financial institution or traditional intermediaries, thereby significantly reducing the chance of fraud and giving both buyer and seller full control over their transaction.

4.1.1. Illustration of blockchain technology utilization in transactions

Figure 1 below explains the practical utilization of blockchain transactions:

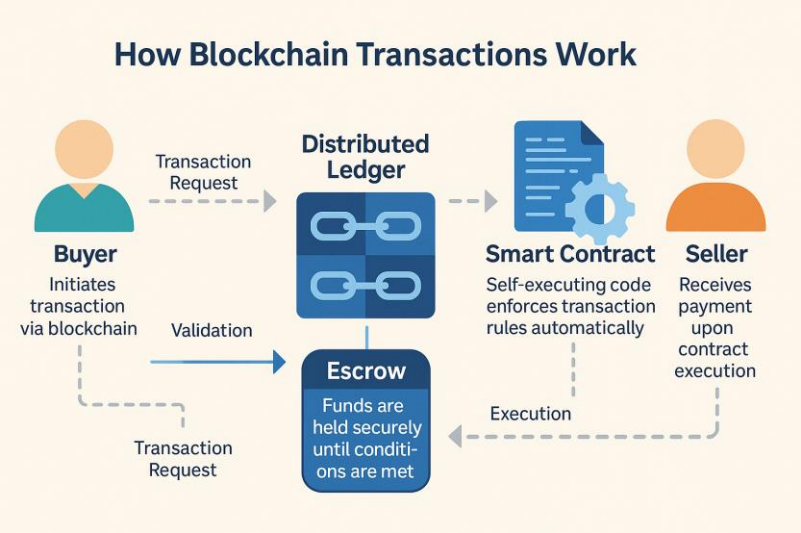

Figure 1. Working of transactions on blockchain [10].

The brief explanation of Figure 1 is that—firstly, the buyer requests to purchase a subject matter, using cryptocurrency and the transaction request is sent to the blockchain. The buyer and seller enter into a contract through a smart contract. Secondly, the transaction is registered on blockchain and recorded on a distributed ledger, there are multiple nodes attached to the ledger that validate the transfer, preventing fraud. Thirdly, a smart contract holds funds in escrow until conditions of automatic execution are met, which prevents the parties from unfairly withholding payment or delivery. Lastly, if the predefined conditions set by contracting parties are met, blockchain verifies the transfer and the smart contract is executed, hence releasing funds from escrow to the seller. In this way, the transaction is completed. No intermediary is involved, ensuring decentralization of transactions [10].

4.1.2. Blockchain transaction records validated in court and arbitration proceedings

Blockchain has been recognized as valid evidence to rely upon in arbitration proceedings in Spain, between a Spanish decentralized finance (DeFi) platform and the individual wallet holder regarding the transfer of the bamboos (tokens) from DeFi (respondent) to the individual's wallet (claimant). The award

rendered by the sole arbitrator, five days after initiating the arbitration, rendered the award in favour of the respondent and affirmed that the blockchain record that the claimant produced, itself showed that the bamboo had been transferred to his account [11]. The tribunal considered the records present on the blockchain, which further proves the authenticity of the evidence on the blockchain. This is a crucial step forward in international arbitration to validate the blockchain records without strictly applying the rules of evidence to them.

Besides arbitration proceedings, the Supreme Court of China, in the case of *Hangzhou Huatai Yimei Culture Media Co, Ltd v Shenzhen Daotong Technology Development Co Ltd*, recognized blockchain evidence, confirming the reliability of data obtained through blockchain technology [12]. The primary reason for recognizing blockchain records unconditionally as valid evidence is that every transaction has a specific hash code that can be traced back to the original transaction [emphasis added] and it is highly improbable that any sort of hacking can be done to blockchain records since it is decentralized.

The High Court of the United Kingdom, in the case of *Tulip Trading Limited v Bitcoin Association for BSV and others* has *inter alia* recognized the concept that, transactions with digital assets are recorded in a blockchain, in a ledger that records every transaction for the relevant digital asset. While it shows that a transaction has occurred and the location of the asset on the network, the identities of the parties involved remain undisclosed [13].

Furthermore, the High Court of New Zealand, in the case of *Ruscoe v Cryptopia*, recognized the significance of the internal ledger of Cryptopia, a cryptocurrency exchange, specifically its internal structured query language database, which keeps a definitive record of cryptocurrency transactions and holdings. The blockchain ledger was thus treated as a reliable and necessary mechanism for identifying and attributing proprietary interests in cryptocurrency holdings [14].

Lastly, the Hong Kong Court of First Instance, in the *Gatecoin* case, recognized the significance of the internal Exchange Ledger maintained by Gatecoin as a record of customer transactions and balances. The court noted that the ledger recorded details such as transaction type, amount, and wallet addresses, which provided a basis for determining the entitlement of customers [15].

The recognition of decentralized ledger and hash codes to trace the transactions on blockchain is prevalent across leading jurisdictions, from the analysis of the aforementioned cases. The debate that arises is what prevents the world from following a dispute resolution mechanism that has all the aforementioned qualities and is tamper-proof [emphasis added]. This debate was advanced by Kleros Mechanism of dispute resolution, which *inter alia* utilizes the aforementioned concept of transactions through blockchain to resolve cross-border disputes.

4.2. Introduction to Kleros court system

Kleros mechanism is a form of ADR, according to the definition given by the United Nations Commission on International Trade Law (hereinafter **"UNCITRAL"**), it falls within the domain of Online Dispute Resolution (hereinafter **"ODR"**), stating that *"[…] which can assist the parties in resolving the dispute in a simple, fast, flexible and secure manner, without the need for physical presence at a meeting or hearing […]"*[16].

Kleros Mechanism is a system based on the interplay of blockchain with 'crowdsourcing' to resolve disputes in an online setting. Crowdsourcing refers to the process of utilizing the collective intelligence and skills of a large group of people to solve technically complex disputes [17]. Kleros is designated as

the party's arbitrator on a smart contract. A brief about how Kleros works is explained from the case scenario of Alice and Bob, from the Kleros White and Yellow Paper, as follows: [6,7]

4.2.1. Parties to the dispute

Alice (claimant), a French entrepreneur, hired Bob (respondent), a Guatemalan programmer, to create a website on a Peer-to-Peer freelancing platform. Bob finished the project, but Alice was unhappy with the quality. A clause in their contract with Kleros court initiates the arbitration procedure if the claimant gives command for referring the case to Kleros Mechanism.

4.2.2. Arbitration panel selection

In Nairobi, Chief is a software developer who checks the Kleros Court website during his bus commute to find arbitration work, arbitrators are called 'jurors' in Kleros. He earns thousands of dollars per year as a juror in software development disputes by staking 2000 PNK tokens (crypto tokens used in Kleros). He specializes in the sub-court of Website Quality, which demands expertise in various technologies such as JavaScript, HTML, *etc.* He stakes the tokens and gets selected. The point to be noted here is that the identity of the parties from the arbitrator remains anonymous and vice versa [emphasis added]. The arbitrators selected will also not know the identity of each other. No one will know Chief's identity and Chief will not know anyone.

4.2.3. The decision

After three days of deliberation, the arbitrators ruled in favour of the claimant. The website was not delivered according to the quality and mutually agreed-upon terms and conditions. The money was transferred to the claimant via a smart contract, arbitrators were rewarded and the case was closed.

4.2.4. Interplay of crypto tokens with wisdom of crowd

The selection of arbitrators is based on staking a higher amount of PNK tokens, which prevents the inactive arbitrators from being selected and provides an incentive to arbitrators to vote correctly. However, the selection is still random. The dissenting arbitrators must pay a portion of their share to the unanimous (majority) ones. This portion is automatically deducted after the decision is rendered. Arbitrators who submit a unanimous decision, with the final ruling, are paid a fee determined by the sub-court. This is based on the Schelling Coin concept, where the reward or penalty depends on the consistency of votes with others. The arbitrable smart contract decides who pays the arbitration fee. Both parties are required to deposit tokens equal to the arbitration fee in the smart contract. In case one party fails to do so, the other party automatically wins. The winning party gets a refund of their deposit after the dispute is settled. The point to note here is that the dispute is being resolved efficiently by engaging the community and utilizing their expertise, which is the expansion in the scope of ADR [6].

Decentralized justice systems do not adhere to a uniform set of procedures. In addition to Kleros, there are other platforms like *Jur, Aragon, and Code Legit* that have developed their own protocols that enable blockchain disputes to be settled directly on the blockchain. These protocols are encoded as oracles (third-party sources, from which the smart contract extracts information) on smart contracts, they

enable one party to freeze smart contract executions and initiate the dispute resolution process [18]. The systems are decentralized, meaning no intermediaries are involved, and they use escrow mechanisms to guarantee enforcement on the blockchain [19]. The wisdom of the crowd is an essential and common feature in all of them. Although Kleros operates on the blockchain, it relies on people, not intelligent machines, to make decisions.

This article will analyze Kleros as an example of blockchain arbitration because *inter alia*, firstly, it has developed a quasi-judicial system, with different levels of sub-courts [20]. Secondly, it has an accessible appeal procedure for every case [20,21]. Thirdly, actual data is available to compare Kleros with the methods of traditional arbitration, which will be discussed in different sections of this article (see Sections 4.2.5, 5.2.4 and 5.2.7 of this article). Lastly, a practical application and use case of Kleros exists, demonstrating its utility in off-chain (blockchain) proceedings (see Section 6.1.3 of this article). These factors differentiate Kleros from the rest of the blockchain dispute resolution platforms by relatively greater similarity to traditional court systems, making it more convenient for the users and for qualitative study.

4.2.5. The appeal

There can be an appeal against the decision rendered by the jurors in Kleros. It is on the decision of the losing party whether it wishes to appeal against the impugned decision, as in a proper court. The appeal is programmed by using the formula that doubles the number of jurors from the previous round and adds one (n (No. of jurors in the previous round) x 2 + 1 = No. of jurors in the next appeal round). For Example, 3 jurors were present in the first-round decision of a case. When an appeal is made, it would be 3 × 2 +1 = 7. The (+1) is included to ensure that there is an odd number of arbitrators in each round. This prevents situations where an even number of arbitrators could align on one side while an equal number supports the opposite side, eliminating the possibility of a tie.

An appeal can be filed up to a maximum of 511 jurors in the appeal round. This is a conclusive limit and no appeals can exceed this number limit [7].

The authors of this paper conducted an interview [The interview was conducted on March 16, 2025, and all the quantitative data collected up to the interview date are conclusive] with **Dr. William George** [a Crypto-economics Researcher & Director Research at Kleros, Author of Kleros White and Yellow Paper] and the authors asked 3 questions. The First Question [see Section 5.2.4 of this article for Question 2 and Section 5.2.7 of this article for Question 3] is exhibited:

Question 1: What is the limit of Appeal at Kleros (*i.e.* maximum number of arbitrators arbitrating a single round)? In which case did Kleros have the highest number of appeals and how long did it take for that case to be resolved? What was the nature of those cases?

Answer: The current maximum number of jurors that can be drawn before a case becomes unappealable is 511, which means that no more than 511 jurors can arbitrate an appeal round at Kleros.

A. Longest case: The Kleros case that took the longest so far was **Case No. 1170**, which was one of the disputes about insurance against bugs in smart contracts [22]. It was appealed five times for a total of six voting rounds. The case lasted from 13 April 2022 to 11 June 2022 for a total of 59 days. The last voting round had 127 jurors and including all of the voting rounds together, a total of 246 jurors were drawn for the case.

B. Maximum number of jurors case: There were two cases **(Case No. 302 and 532)** at Kleros, which had 500 jurors in the first round [23]. When parties engage 500 jurors in a single round, it is understood

that there would be a single round and would be non-appealable, since on appeal, the maximum number of arbitrators can be 511.

The nature of **Case No. 532** was during the 2020 United States Presidential Election Omen Prediction, where voting was done to predict the winner of the elections, the question on which jurors voted on the question that *"Will Joe Biden win the 2020 United States presidential election?"* [23].

Case No. 302 was also on Omen Prediction, during COVID-19, where jurors voted on the question that "*Will there be a day with at least 1000 reported Corona death in the US in the first 14 days of July?"* [23].

It is evident from the collected data that, for an appeal round – not more than 5 appeals (6 voting rounds) have happened in the history of Kleros in a single case (Case No. 1170) [22]. Furthermore, without an appeal round (first round) – no more than 500 jurors were present in a single case (Case No. 302 and 532), those too, were political/social cases asking for opinions, rather than dispute cases [23]. Hence, the appeal mechanism of Kleros is detailed, articulated and certain.

4.2.6. Escrow mechanism examples of Kleros

(1) In marketing, a PR company may promise to secure a client's mention in a prestigious publication such as The New York Times. To ensure that the client's interests are protected, the payment for this service is held in Kleros Escrow. The funds will only be released to the PR agency once they have successfully delivered on their promise and obtained the desired mention [24].

(2) Video production is a common project for freelancers. They work with clients to agree on certain parameters such as video length, resolution, and editing quality. However, disputes can arise if the delivered video does not meet the agreed specifications. For instance, if the freelancer submits a video that is shorter than the minimum required length, such as 59 seconds instead of the agreed-upon 1 minute and 30 seconds, the client may initiate a dispute resolution. Kleros Escrow facilitates the resolution process by ensuring that if the delivered video does not meet the agreed standards, the funds are returned to the client [24].

4.2.7. Schelling coin mechanism and reward system

Schelling Coin Mechanism is a way for people to share information, like prices in a market. They get rewarded for being honest and for giving answers that are similar to the opinion of the majority. This helps make sure the information is correct without needing a central authority to oversee it [25].

Kleros is based on rewarding the jurors for the majority vote in line with the Schelling mechanism, meaning that a juror voting consistently with the majority jurors will be rewarded and PNK tokens will be added to the crypto wallet. However, if a juror does not vote consistently with the majority of jurors, in that case, his PNK tokens will be deducted for the wrong vote. This monetary incentive motivated the jurors to vote correctly and not dishonestly, while preventing the non-experts from registering as a juror [7]. For Example—as referred to in the scenario of Alice and Bob (see Sections 4.2.1–4.2.5 of this article), the jurors who voted consistently in favour of Alice (claimant) will be rewarded and those who voted inconsistently with the majority vote will lose their PNK tokens.

4.2.8. Illustration of the Kleros arbitration working mechanism

To summarize the working of the Kleros Mechanism, firstly, Alice and Bob signed a freelance agreement, with Kleros as a dispute resolution mechanism, having a Kleros Arbitration Clause. Bob

delivers the work, but Alice disputes the quality, so the case is referred to Kleros. Secondly, jurors (arbitrators) are selected anonymously, and they stake PNK tokens to adjudicate the case. Thirdly, jurors analyze evidence and vote, with the majority decision determining the outcome. Alice won the case because the quality of the website delivered by Bob was not up to standard. Lastly, after the decision of the jurors, Alice wins and the smart contract is executed in her favour, releasing the funds by automatic execution, unless an appeal is made. If an appeal is not made, this decision by the jurors would be final and binding. Furthermore, if an appeal is made, in that case, the losing party (Bob) can appeal, triggering a new round of voting with more jurors, according to the set formula. The decisions can be appealed up to 511 jurors. Once the parties stop appealing, the decision is enforced by the automatic execution of the smart contract [see Section 4.2.5]. Figure 2 regarding the working of Kleros has been depicted in the Yellow Paper of Kleros from the example of Alice and Bob, which is reproduced as under:

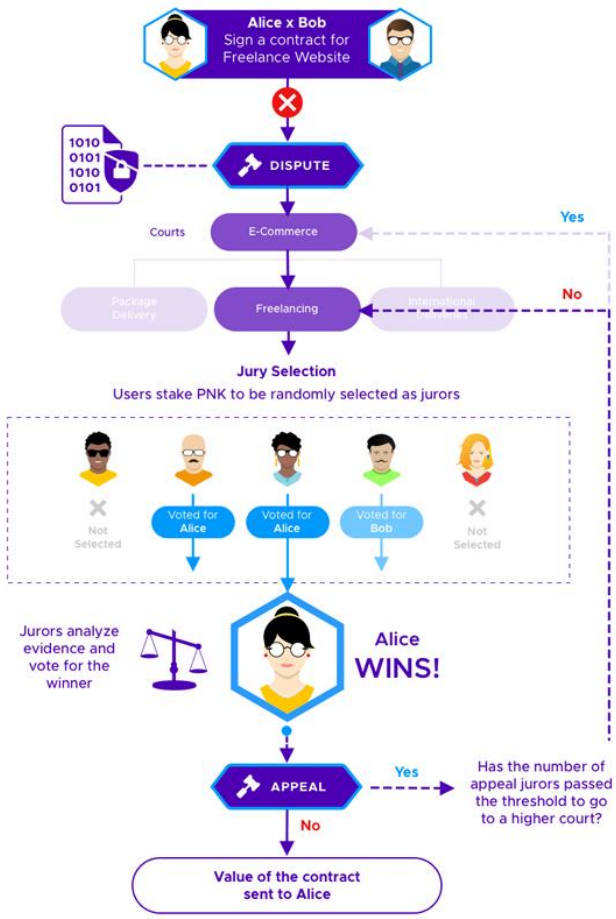

Figure 2. Working mechanism of Kleros arbitration from case institution till enforcement [7].

4.3. Analysis, critique of smart contract and presented solutions

The innovative advantages have been stated by the founder of Kleros in his book, *inter alia* that, firstly, blockchain has the advantage of rendering enforcement in countries that have weak institutions and are unable to enforce arbitral awards [26]. Secondly, all of our enforcement mechanisms are merely tools to be used when helpful, like a hammer or a screwdriver, each tool might apply in a different situation, just like tools, our enforcement mechanisms are subject to innovation [26]. Thirdly, Smart contracts are a

new mechanism for enforcing promises, allowing us to make credible commitments with each other on a blockchain, including commitments with strangers in other countries [26].

4.3.1. Critique on utilization of smart contracts as legal contracts

Web3 offers significant advantages, including decentralization, enhanced user control over data, improved privacy and security, *etc.,* through blockchain and smart contracts. However, there exist certain challenges such as limits to scalability, regulatory uncertainty, complex utilization mechanisms, *etc.* [9] The critique of the smart contracts is presented in three points [27].

Firstly, smart contracts are self-executing, hence automating actions on blockchain. However, they lack essential elements of a contract, such as consideration and mutual consent, making them unenforceable as a standalone agreement in the majority of jurisdictions. Secondly, their validity relies on the underlying legal agreements and courts prioritize physical contracts over smart codes during disputes, particularly if a smart contract contains errors/conflicts with the parties' intention in a contract. Lastly, they are technically just enforcement tools, a few jurisdictions recognize them as legally binding, however, they must still comply with traditional contract law principles of that specific jurisdiction to be admitted in court [27].

4.3.2. Response to critique and measures for compliance

In response to the aforementioned critique, parties should adopt some caveats while utilizing smart contracts, presented in order:

Firstly, Parties should enter into an agreement when they have consented to arbitration on blockchain in case of dispute (see Section 6.2 of this article for Model Kleros Clause in plausible compliance with this requirement). Besides that, on the point of consideration, if there is no consideration agreed upon, then there can be no utilization of blockchain, as it is based on the efficient transfer of tokens as a consideration in case of a contract on the blockchain (smart contract). Secondly, Parties should enter into a separate agreement depicting the same terms and conditions on which a smart contract is based, this will help them in referring to courts in case of any error in the smart contract coding. Lastly, while it is true that smart contracts are enforcement tools, it will be an exaggeration to categorize them as only enforcement tools, because they work on specific terms and conditions determined by parties. It is up to the parties to utilize that mechanism efficiently as a contract, with the application of technology. It would be unjust to ignore the role of humans operating it, who have defined the principles of the contract law, in line with the law of the land.

More specifically, Kleros Mechanism bridges the gap between physical contract and smart contract in line with the aforementioned critique because:

Firstly, in the mechanism, when the dispute arises, it already has a subject matter and a value that needs to be determined by the jurors, thereby resolving the matter of the essentials of a contract. Secondly, when a dispute is presented to the jurors, along with the evidence, the parties submit their contract as well, which can be a digital contract or a physical contract, for the arbitrators to determine terms and conditions. In this way, the issue of bugs in the smart contract does not arise as the enforcement is through Kleros itself, which has separate courts for specific purposes (see Section 5.2.7 of this article for different courts in Kleros and cases resolved). Further, Kleros jurors have the authority to decide the dispute, as the parties

have consented to the use of the Kleros mechanism to resolve their dispute. Lastly, jurisdictional reconciliation is an issue that Kleros faces in enforcement, however, the jurors base their decision on reason, which is subject to appeal and the jurors who vote in the majority (as in state courts) render a binding decision (see Sections 6.1.2–6.1.6 and Section 6.4 of this article for explanation of jurisdictional compliance and legal fragmentation issues).

4.3.3. Comparison of smart contract and real life/physical contract

The founder of Kleros has further stated in his book regarding the comparison of smart contracts with physical court-enforced contracts that smart contracts have many limitations, but we tend to forget that the courts have limitations as well and we should not compare smart contracts to an idealized version of court-enforced contracts [emphasis added] [26]. When both are analyzed critically, it becomes clear that court-enforced contracts have intrinsic limitations, such as, firstly, the court system is slow and many people wait for their turn to simply use the service of the courts. Secondly, the court is an external third party and asks the aggrieved party regarding quantification of damages, however aggrieved party has no incentive to be honest, therefore, the court can only predict the damages [26]. Therefore, while comparing both types of contracts, the pros and cons of both should be analyzed and the most suitable type should be used for the most suitable purpose.

4.3.4. Plausible detachment of smart contract from cryptocurrency

The authors of this paper had the privilege of interviewing **Barrister Safi Ullah Ghauri** [the Managing Partner of Esquare Legal. He has headed the Legal Departments of Web 3.0 companies in the EU, the USA and the MENA region. Moreover, he has a history of working on FIDIC contracts and complex international arbitration matters] and the authors asked 3 questions. The First Question [see Section 6.3.1 of this article for Questions 2 and 3] is exhibited:

Question 1: Do you think that blockchain can be utilized incorporating “smart contracts”, without the potential abuse vested with cryptocurrency? In other words, can the use of “mainstream cryptocurrency” be separated from smart contract utilization on blockchain?

Answer: Smart contracts are essentially self-executing code that enforces agreements automatically, and their operational integrity isn’t inherently tied to cryptocurrency. While blockchain networks require tokens for operational purposes (gas fees), this technical requirement can be effectively and easily separated from mainstream cryptocurrency involvement. Public networks like Ethereum need gas fees paid in native tokens to function, but this operational necessity differs from the actual purpose and functionality of smart contracts deployed on these networks. This can be solved through the use of permissioned/private blockchains, where gas fees can be eliminated or replaced with non-tradable internal tokens. There are even hybrid models and token abstraction mechanisms that allow users to interact with smart contracts using fiat currency, with backend systems handling any necessary token conversions.

Therefore, blockchain technology can be utilized for smart contract implementation without significant cryptocurrency market involvement, provided appropriate architectural choices are made for the deployment of smart contracts.

4.4. Conclusion of the section

The integration of blockchain in the justice system revolutionizes the justice system and makes it decentralized, integrating transparency, efficiency, and autonomy from centralized intermediaries. Kleros mechanism is used as an example to depict the working of a decentralized justice system and blockchain arbitration, which uses smart contracts, crowdsourced jurors and token-based incentives to resolve disputes through a tamper-proof, blockchain-driven arbitration process. The critique of smart contracts highlights challenges in aligning their regulation with traditional legal frameworks and jurisdictional compliance, however, the Kleros mechanism mitigates the highlighted concerns by embedding arbitration clauses and integrating evidentiary standards that bridge code and law [emphasis added]. Blockchain arbitration is at an evolving stage and it promises to democratize dispute resolution through scalability and potentially cross-jurisdictional regulatory compliance and uniform enforcement mechanisms for broader adoption.

5. Determining fairness of blockchain arbitration

Defining fairness presents a significant challenge within ethical discourse, as differing perspectives from philosophers such as John Stuart Mill, John Rawls, and Robert Nozick highlight a spectrum of interpretations, ranging from maximizing social benefits to adhering to just institutions and respecting natural rights. For example, the utilitarianism of John Stuart Mill suggests that an activity is considered fair if it increases overall societal benefits and reduces societal suffering [28]. In the view of John Rawls, an action is fair if, firstly, it adheres to the principles of a just institution and secondly, the individual acting willingly accepts the institution's guidelines [29]. Robert Nozick defines fairness as adherence to certain 'natural rights', including rights against harm from others, rights to choose and act freely and the right to own private property [30].

These broad definitions, however, are not sufficient to describe the word fairness. In the sections below, the analysis is presented between different segments of fairness and whether the method of blockchain arbitration, through the example of Kleros, complies with fairness requirements. More specifically, this section will discuss the procedural aspects of blockchain arbitration.

Procedural fairness is essential for developing and implementing the Kleros Mechanism. Firstly, it provides guidelines for the appeal guidelines of the Kleros mechanism, users are more inclined to engage with processes they perceive as fair. Secondly, procedural fairness enhances acceptance of Kleros system decisions, which builds trust among participants. Thirdly, governing bodies must adhere to procedural fairness standards when implementing Kleros (see Sections 6.1–6.4 of this article for potential implementation of Kleros in international commercial arbitration).

5.1. Types of procedural fairness

There are two types of procedural fairness, (a) objective and (b) subjective [31]. The following sections will discuss, firstly, objective procedural fairness, which refers to the criteria for determining whether a procedure contributes to an outcome based on justice. It will be explained by comparison of provisions from the European Union (hereinafter **"EU"**) directive of ADR, which applies to the whole EU [31,32]. Secondly, subjective procedural fairness is based on the subjective perception of an individual regarding

fairness of the procedure. It is based on human behavior and perception, rather than any objective criteria. The two different criteria of fairness will be analyzed and then compared with blockchain arbitration by utilizing the Kleros mechanism as an example to ascertain whether blockchain arbitration complies with fairness requirements [31].

5.2. Objective procedural fairness compliance with blockchain arbitration

This section discusses nine elements of objective procedural fairness (Section 2.2.1–2.2.9), based on Dimov's framework [Daniel Dimov is a specialized lawyer in Internet law. PhD (Leiden University) in the field of crowdsourced online dispute resolution. The framework of objective and subjective procedural fairness will be discussed through his published PhD thesis]. The framework includes Expertise, Independence, Impartiality, Transparency, Fair Hearing, Counterpoise, Ensuring Reasonable Length of Procedure, Providing Reasons and Voluntary Participation [33].

5.2.1. Expertise

Article 6(1)(a) of the EU Directive requires that the natural persons managing the ADR processes should have specialized skills for the management of consumer disputes and should have a strong understanding of legal principles [32]. This expertise is crucial for integrating fairness in ADR, particularly in scenarios concerning power imbalances between consumers and businesses, in which small claims can significantly impact a party, especially where consumers might lack understanding of the products or services that are available to them.

In contrast, when a juror registers on Kleros to arbitrate, Kleros does not have an expertise requirement, instead, it allows a juror to register based on the confidence of jurors in their own expertise. However, the expertise is tested when the juror delivers the decision (award). If the decision is against the majority vote, then that juror is penalized and loses their staked PNK tokens [34]. Therefore, economic incentive is tied to delivering the correct decision. It ensures that the juror who does not have expertise and adjudicates without it, gets penalized. In this way, it is highly unlikely that someone who does not have expertise would arbitrate the dispute, as this can lead to loss. In this way, Kleros ensures that a person with expertise registers as a juror in the relevant sub-court (see Sections 5.2.4 and 5.2.7 of this article for details regarding sub-courts and cases resolved).

5.2.2. Independence

Independence refers to the absence of any involvement from a third party and that there is no conflict of interest, ensuring that decision-making remains unaffected [35]. Article 6 (1) of the EU Directive states that the natural person in charge of ADR shall be independent [32]. The key factor that influences independence, *inter alia* is the professional engagement of a third party with any of the parties. Furthermore, the requirement that the third neutral party should be independent is an element of the right to fair trial, also set forth in the European Convention of Human Rights (hereinafter **"ECHR"**) [36].

Kleros Mechanism maintains independence for the jurors, as jurors are anonymous [34]. Neither the parties know who the juror is, nor the jurors know who the parties are, thereby ensuring complete independence. Moreover, jurors are selected randomly, based on a random number generation process [7]. Therefore, Kleros completely qualifies this requirement, even more than traditional courts, where parties may

know the judge and the judge might know the parties. Furthermore, the jurors also do not have a choice to select disputes based on their choice and are randomly allocated to them. In this way, it ensures that there is complete compliance with the independence requirement outlined in the EU directive and ECHR.

5.2.3. Impartiality

The impartiality in decision-making, particularly focusing on judges or neutral third parties, suggests that being impartial goes beyond being free from bias, it is also a mindset in which decision-makers consciously avoid inevitable factors including favoring any party, their interests, *etc.* [33]. This obligation is also vested in the Article 6(1)(e) of the EU directive [32].

Similarly, this connects closely with Kleros, a decentralized system designed for resolving conflicts. Kleros tackles concerns about fairness by using blockchain technology and a jury pool sourced from the Kleros community. Instead of relying solely on self-reported information, Kleros aims for justice by selecting jurors anonymously and offering cryptographic rewards. Jurors earn tokens for making fair decisions, which helps balance their interests with the need for impartiality [34]. Although jurors might have their own biases, the system is designed in such a way that encourages them to set aside their preconceived notions [7].

5.2.4. Transparency

Transparency refers to a dispute resolution that is understandable and clear, with a possibility of replication [34]. Article 7(1) and 7(2) of the EU directive impose two obligations on transparent proceedings, firstly, to make information publicly available and secondly, *to* publish reports with statistical information [32].

This is closely related to the blockchain dispute resolution platform Kleros, which utilizes the technology to ensure transparency. Kleros utilizes a public blockchain ledger to document everything that occurs in a case, from dispute submission and jury selection, to execution, ensuring all decisions are transparent and auditable. Furthermore, all the decisions in Kleros are publicly available [34]. As referred in this paper, Kleros maintains a list of data that can be viewed, studied and utilized further (The data indicated in this sub-section is public and can be searched by cryptographic hashes).

In the interview with **Dr. William George** (continuing from Section 4.2.5 of this article), the empirical data collected from Kleros ADR process was discussed along with the references indicating their existence through publicly available softwares, which is articulated:

Question 2: How many cases are resolved and pending within Kleros? What was the nature of major cases resolved?

Answer: There are versions of Kleros on two blockchains, (a) Ethereum Mainnet and (b) Gnosis Chain, having different cases registered on them. On both blockchains combined, there have been 2111 (approximately) cases [37].

On Ethereum Mainnet there have been 1660 total disputes with 1 pending case, 1012 of those disputes were related to Proof-of-Humanity, 304 of those disputes were related to the Tokens list, 21 disputes were connected to the Unslashed project, where Kleros determined if coverage buyers should be paid for bugs in certain smart contracts. 322 other cases (approximately) were scattered across other categories [37].

On Gnosis Chain there have been 451 total disputes with 1 pending case. 287 disputes [at least] were related to curation of blockchain data, including 90 related to tokens list. 73 (approximately) are customer-service disputes for the Argentinian crypto-exchange Lemon, 10 of these disputes were related to translation of documents between Chinese and English. 81 other cases (approximately) were scattered across other categories [38].

Therefore, Kleros complies with this requirement of publishing the data related to cases as well. Moreover, data is maintained on a public ledger, decentralized and more secure than Web 2.0 applications.

5.2.5. Fair hearing

The principle of fair hearing in dispute resolution highlights that all parties involved should have an equal chance to participate, present their case and respond to the opposing side. This right is enshrined in the ECHR as well as the EU directive [36]. The EU directive aims to prevent biased decisions and uphold procedural fairness [33].

This concept can be divided into two main components, firstly, Article 8(d) of the EU directive prescribes ensuring that all parties are officially notified when a dispute arises, allowing for meaningful engagement and secondly, Article 9(1)(a) guarantees that each side can present their evidence, review the submissions from the other side, and counterarguments within a fair timeframe [32].

Kleros upholds this framework by enabling its decentralized framework. Firstly, through notification requirements, Kleros uses smart contracts to promptly inform parties when a dispute arises, raising transparency and eliminating communication delays or errors and secondly, in terms of presenting and contesting cases, Kleros provides a structured, on-chain process where both parties can publicly submit their evidence and arguments [34].

Therefore, Kleros complies with this requirement of procedural fairness as well, by ensuring equal access to submissions, transparent processes and impartial jury selection. The blockchain-based system embeds deadlines, equity and tamper-proof records into smart contracts, replacing manual enforcement with verifiable and secure procedures.

5.2.6. Counterpoise

The counterpoise in dispute resolution is all about addressing those power imbalances that can exist between parties, such as financial struggles or a lack of technical expertise, that might hinder fair participation [33]. This principle is derived from the EU directive as well [32]. Article 8(a) ensures on-chain and off-chain accessibility of ADR procedures regardless of digital literacy or location (see Sections 6.1.2 and 6.1.5 of this article). Article 8(b) and 8(c) provide that legal representation is not compulsory and that the ADR procedure is for a nominal fee or free of charge for consumers [32]. Article 9(1)(b) provides that during the ADR procedure, parties are free not to engage counsel and can seek independent advice or assistance from any third party and any stage of arbitral proceedings [32].

These steps are crucial in making sure that financial limitations or technology challenges do not stand in the way of justice, however, Kleros functions online, which potentially excludes individuals lacking internet access. It addresses financial barriers in such a way that no jurors will be prone to rendering a decision in favour of a wealthier party because it is decentralized and anonymity would be maintained [emphasis added] [34]. The reliance on crowd-sourced jurors and straightforward code-based regulations

eliminates the necessity for clients to engage in legal representation. Additionally, Kleros facilitates participation through interfaces, designed for ease of use and open-source software, which helps bridge the technical skills gap.

5.2.7. Ensuring reasonable length of procedure

The length of the procedure highlights the importance of resolving disputes efficiently to maintain fairness. This requirement is also in line with the ECHR [36]. Article 8(e) of the EU directive requires that ADR entities complete cases within 90 days, allowing only limited extensions for particularly complex situations. The aim is to stop unfair outcomes caused by long periods of uncertainty [32].

Kleros uses blockchain to settle disagreements and tackles these holdups through its methods and decentralized decision-making. Unlike traditional ADR proceedings, which often get delayed by paperwork or manual tasks, Kleros uses smart contracts to set firm deadlines for each step. These cover submitting proof, allocating jury members, voting and giving final decisions. For example, when someone starts a dispute, the system sets due dates for answers and discussions, which cuts down on delays caused in regular off-chain proceedings. The International Chamber of Commerce (**"ICC"**) Rules directs both the tribunal and the parties to *"make every effort to conduct the arbitration expeditiously and cost-effectively, having regard to the complexity and value of the dispute"* [39]. Furthermore, ICC Rules also permits the tribunal to *"take into account such circumstances as it considers relevant, including the extent to which each party has conducted the arbitration in an expeditious and cost-effective manner"* [40].

These provisions only apply to the conduct of arbitrations and do not apply to enforcement proceedings, because it is a step that the winning party has to take after an arbitral award has been rendered. The enforcement proceedings are complex, and the time taken to enforce an award depends on the particular jurisdiction. The following is the time taken for prominent international tribunals for an award to be issued, without taking into account the time taken for the enforcement procedure in different national courts:

The average time taken for ICC cases to be resolved is 27 months [41]; for the London Court of International Arbitration, it is between 16 and 17 months [42]; for the Singapore International Arbitration Center is 13.8 months [43]; for the Hong Kong International Arbitration Centre, it is 15 months [44]; the Stokholm chamber of commerce decided cases involving a three-member tribunal within 12-18 months [45]; lastly, the median time taken for International Centre for Dispute Resolution is 9 months [46].

In contrast, Kleros not only meets the EU directive's 90-day rule, rather surpasses it, resolving disputes in just days or weeks [33]. This fact is further affirmed by the interview of **Dr. William George** and subsequent data collection, which was derived from publicly available sources (continuing from Section 4.2.5 and Section 5.2.4 of this article), as exhibited:

Question 3: What is the average time required to resolve cases using the Kleros mechanism?

Answer: Ethereum Mainnet has 24 courts (approximately) with 1660 total disputes, Gnosis Chain has 18 courts (approximately) with 451 total disputes. These combine into 2111 disputes in 42 courts (approximately) [47]. The average time required to resolve a dispute has been calculated using this data, along with the number of appeals on each case and hours/vote round, as a result the average dispute time in hours is calculated [47]. Average Dispute Time in Hours for 2111 disputes is 317.6170062 hours, when converted into days (317.6170062 /24), it is **13.234 days**.

Hence, the average time to resolve a case at Kleros is 13.234 days.

Note: This is an estimate, as there may still be some small imprecision in this data as it does not account for courts where the period times have been updated at some point, though for the vast majority of courts, the period lengths have always had their current values.

This time is inclusive of the enforcement (in contrast to the proceedings in traditional arbitral tribunals) because on blockchain, an award is enforced automatically, through a smart contract, right after it is rendered.

It is important to acknowledge that traditional arbitral tribunals often handle more complex disputes compared to those currently seen in Kleros, for example, construction and energy disputes. Although the subject matter may not be directly comparable, the key difference lies in the enforcement mechanisms, which are unique for different jurisdictions. Without national proceedings, the enforcement of arbitral awards cannot occur. However, blockchain arbitration eliminates the need for those proceedings.

Therefore, considering Kleros as an example of blockchain arbitration, it far surpasses any traditional arbitral tribunal and the time limit to resolve the dispute under the compared EU directive, which is 90 days.

5.2.8. Providing reasons

According to Article 9(c) of the EU directive, ADR institutions are required to provide, firstly, the outcome of the ADR procedure in writing or on a durable medium and secondly, the statement of grounds on which the decision is based [32,33]. However, the EU directive does not mention whether those grounds, also interpreted as reasons, should be lengthy or brief [33].

Kleros does not require juries to compose long legal reasons, rather, it preserves openness by utilizing non-alterable on-chain data that records every piece of evidence, case details and juror votes. This public ledger enables individuals to trace the decision-making process, thereby achieving the goals of the directive. Parties can look at juror interactions, evidence timestamps and voting trends to understand the results. Furthermore, the jurors must give both parties grounds for their decision [34]. Hence, the requirement of the EU directive is satisfied by providing the grounds of the ADR decision.

5.2.9. Voluntary participation

The idea of voluntary participation in ADR emphasizes that all parties must freely consent to go through and may withdraw at any time. Article 9(2) and 9(3) of the EU directive supports this by providing safeguards, such as, firstly, providing the opportunity to participate voluntarily [32]. Secondly, Article 9(2)(a) of the EU directive ensures that the parties can withdraw at any stage of proceedings if they are dissatisfied with the performance or operation of proceedings [32]. Thirdly, Article 9(2)(b) of the EU directive states that the procedure is non-binding and subject to court proceedings and the court may propose a different solution [32]. Fourthly, Article 9(2)(d) of the EU directive states that parties are allowed a reasonable time to deliberate about the proposed solution [32]. Lastly, Article 9(2)(c) prescribes that parties should be made aware of the consequences of ADR proceedings [32].

Kleros fulfils the requirement of voluntary participation as well because, unlike courts, parties have to agree beforehand on Kleros to arbitrate the dispute [34]. Furthermore, the EU directive mentions the ADR practice as a whole, which includes other types of ADR as well, such as mediation, conciliation, *etc.* Some

of the aspects are not binding to arbitration *inter alia,* withdrawal at any stage of proceedings. However, Kleros potentially meets the conditions for arbitration as it is a binding ADR method.

5.2.10. Example from data protection disputes

An example is derived from a recent scholarship, which analyzes the feasibility of arbitration in terms of data protection and privacy disputes, it *inter alia* advances five lines of argument [48]. Firstly, arbitration is positioned as uniquely suited to the inherently flexible and consensual nature of data protection laws, particularly the consent-based model, which emphasizes individual autonomy [48]. Secondly, the confidential character of arbitral proceedings is presented as a significant advantage, protecting sensitive personal information and commercial trade secrets from public exposure [48]. Thirdly, the complex and technical nature of data disputes necessitates specialized expertise [48]. Fourthly, the mechanism for cross-border enforcement of arbitral awards under the New York Convention is highlighted, which provides legal certainty and efficiency in resolving international data transfer disputes [48]. Lastly, arbitration is efficient because it has simpler processes and flexible timelines [48]. The conclusion drawn from this article is that flexibility, confidentiality, expertise, cross-border enforceability and procedural efficiency collectively establish arbitration as a superior and effective mechanism for resolving the complex, multi-jurisdictional and technically nuanced disputes characteristic of the data privacy field.

On the other hand, in blockchain arbitration, with the example of Kleros, firstly, there is complete party autonomy as well. Secondly, the proceedings are completely confidential, even steps ahead of traditional arbitration because neither the party knows the arbitrators, nor the arbitrator knows the parties. Thirdly, the expertise element is blockchain arbitration is yet to be tested, however, the financial reward and loss element in Kleros minimizes the possibility of a non-expert being involved in arbitrating a high-stakes dispute. Fourthly, the enforcement of awards under the New York Convention will be discussed later in this article (see Section 6 of this article). However, as a brief, in blockchain arbitration, the award is enforced automatically through smart contracts once it is rendered. This makes the enforcement process, a matter of seconds and steps ahead, as compared to traditional arbitration. Lastly, blockchain arbitration has relatively greater efficiency than traditional arbitration, as visualized through data, that the relatively most efficient traditional dispute resolution center from the collected data (*i.e.,* International Centre for Dispute Resolution) has a median time of 9 months for resolution of cases, whereas Kleros takes an average time of 13.234 days to resolve disputes, including enforcement (see Section 5.2.7 of this article). Therefore, there is potential for blockchain arbitration to be the future of dispute resolution in privacy disputes.

5.3. Summary of objective procedural fairness

Blockchain arbitration mechanism complies with procedural fairness principles under the mentioned EU Directive, demonstrating that decentralized ADR is compliant with the law that recognizes the fairness of traditional ADR. Dimov's nine elements including, expertise, independence, impartiality, transparency, fair hearing, counterpoise, reasonable procedure length, reasoned decisions and voluntary participation, provide a comprehensive criterion to determine the fairness of Kleros. Furthermore, Kleros utilizes crypto-economic incentives, anonymity and blockchain transparency to address procedural

challenges. Jurors are incentivized towards expertise and impartiality through token penalties (economic penalties), while anonymity (not revealing the identity of parties) and randomized selection ensure independence. Transparency is achieved by utilizing immutable public ledgers on blockchain and the utilization of smart contracts executes equitable participation and efficiency, thereby resolving disputes in a few days rather than months. Even though the working of Kleros relies on internet access, it mitigates power imbalances through low-cost and decentralized processes, due to which there is no prevalent party either due to inherent bias of jurors or other factors. The binding arbitration model of Kleros aligns with the EU directive's voluntary framework, requiring prior consent. The reimagining of arbitration through blockchain, by example from privacy and data protection disputes, positions Kleros as a transformative model for future arbitration systems, complying with procedural fairness requirements.

5.4. Subjective procedural fairness compliance with blockchain arbitration

Subjective procedural fairness is how people feel about the fairness of a process. These feelings depend on their cultural backgrounds, their personal beliefs, and their psychological influences [31]. There is a possibility that what is considered 'fair' by a person from Pakistan might not be considered the same by a person residing in Argentina. Dimov's framework for subjective procedural fairness overlaps with elements of objective procedural fairness, this is because due process is based on fairness, which is embedded in human nature through evolution [33]. Nevertheless, as evidenced by the name 'subjective', this concept may vary across different jurisdictions due to different influences and cultures, highlighting the necessity to reconcile those differences. There are further six elements that elaborate the subjective procedural fairness (Section 2.4.1–2.4.6) based on Dimov's framework, including Process Control, Decision Control, Consistency, Accuracy, Correctability and Ethicality.

The characteristics of Subjective Procedural Fairness are discussed below:

5.4.1. Process control

Process control refers to the control over the selection and development of information that constitutes the basis for making a decision [33].

Kleros integrates process control into its system in such a way that participants submit evidence directly onto the blockchain for jurors to evaluate. In a contractual dispute, both parties may upload relevant documents, shaping the information jurors consider. This indicates that organizing evidence enhances the sense of fairness and transparency, thereby complying with the requirements of process control.

5.4.2. Control of decision

Decision control is about whether people have the ability to agree to or reject the results rendered by a third party when resolving disagreements [34].

This idea is important because it influences their perception of fairness in the process. For example, in mediation, the individuals involved maintain the power to make their own decisions, which typically feels fairer to them. In contrast, adjudication involves a third party making the final binding decisions, which can feel less fair since the individuals have less control over the outcome.

Kleros addresses this challenge by combining aspects of adjudication with features that boost perceived fairness. Although Kleros uses third-party jurors, similar to arbitration, it lessens the

drawbacks of limited decision control through, firstly, a transparent process, in which every piece of evidence, juror vote and ruling is documented on the blockchain, allowing parties to see how decisions were made. This level of openness mimics the accountability found in mediation, building trust even when the outcomes are binding and secondly, the appeal procedure enables the parties to have the option to contest rulings by taking disputes to larger, randomized juror groups, which adds a layer of indirect control over the final decision (See Section 4.2.5 of this article for details of appeal mechanism under Kleros and the maximum number of jurors in the appeal rounds).

5.4.3. Consistency

Consistently refers to the consistent application of procedure across different cases over time [33].

By its design, Kleros ensures procedural consistency through smart contracts that lay out the rules for submitting evidence, selecting jurors and setting voting timelines. Every dispute is managed by the same automated system to ensure there is no change based on human input. Jurors are selected randomly, voting times are fixed, and results are handled by computer code to ensure fairness. This method agrees with research showing the value of being consistent. People trust the system more when they see it handles each situation the same way, which minimizes concerns about the procedure being biased or unfair.

5.4.4. Accuracy

Using accurate and trustworthy information is of utmost importance for making fair decisions. Accuracy is construed as relying on procedures based on accurate information rather than inaccurate information [34].

Kleros ensures evidence integrity by having participants submit their evidence, such as documents, codes and timestamps them straight onto a blockchain ledger, which cannot be changed. This ensures that the information is accurate and unaltered, so jurors reviewing the case see unaltered and verifiable data.

5.4.5. Correctability

The concept of correctability is defined as the ability to correct the decision, after the party challenges it and considers it to be unfair [34].

In Kleros, in addition to the appeal procedure, all appeals are recorded permanently, so everyone can see how decisions are changed, which builds trust by solving worries about inconsistency. The formula for appeal is predefined in Kleros (see Section 4.2.5 of this article for the predefined appeal procedure embedded in the Kleros Mechanism). This approach is vital for users who need fair and affordable ways to resolve disputes.

5.4.6. Ethicality

Ethicality refers to how well procedures align with personal and cultural ethical standards. This alignment plays a crucial role in how fairness is perceived and it can vary significantly from one society to another [33].

Kleros tackles these ethical challenges head-on with its decentralized, global approach. By bringing together jurors from various cultural backgrounds, Kleros naturally weaves in a wide array of ethical viewpoints, which helps minimize bias that might come from viewing things through just one cultural

lens. For example, in a case involving practices, jurors from places with different norms, like Pakistan and the United States would collaboratively assess the evidence based on the specific context of the dispute, striking a balance between local ethics and universal fairness principles.

5.5. Summary of subjective procedural fairness

The blockchain arbitration systems, by the example of Kleros, uphold subjective procedural fairness *inter alia* by addressing six components, namely, process control, decision control, consistency, accuracy, correctability, and ethicality. Subjective fairness depends on psychological factors and has no objective criteria, it is achieved through mechanisms that prioritize autonomy, transparency and cultural sensitivity. Process control is ensured by allowing parties to directly submit evidence to the blockchain, which is the basis for decisions of jurors. Decision control is depicted through transparent records after the deliberation of jurors and structured appeals processes. Consistency is maintained through the utilization of smart contracts that execute standardized procedures for the submission of evidence, selection of jurors, and timelines, eliminating human discretion. Accuracy is maintained through tamper-proof documentation of evidence on blockchain, ensuring the access of jurors to unaltered information. Correctability is ensured through predefined appeal protocols that enable disputing parties to challenge the rulings while protecting procedural integrity. Ethicality is addressed with the help of a juror pool from across the globe, integrating cross-cultural ideas and perspectives, thereby aligning with fairness principles. By incorporating the aforementioned elements into the decentralized framework of Kleros, it effectively integrates subjective fairness standards. This illustrates how technology can promote fairness while potentially improving the blockchain dispute resolution system.

5.6. Conclusion of the section

The Kleros mechanism of blockchain arbitration complies with both objective and subjective procedural fairness standards under the EU directive and ECHR, which is further explained by Dimov's framework. Dimov's nine elements of objective fairness include expertise, independence, impartiality, transparency, fair hearing, counterpoise, reasonable procedure length, reasoned decisions and voluntary participation. These elements are incorporated in Kleros by addressing gaps in traditional ADR methods, including the incorporation of crypto-economic incentives, anonymity and transparency. Dimov's six elements of subjective procedural fairness include process control, decision control, consistency, accuracy, correctability and ethicality, which are incorporated in Kleros through decentralization, culturally diverse juror pools and tamper-proof automation of process through smart contracts. The efficiency of Kleros in resolving disputes is depicted through a data set, collected by publicly available data, which depicts that an average dispute resolution takes around 13.234 days to be fully resolved and enforced**.** This model of blockchain arbitration is transformative for future arbitration models, aligning with traditional jurisprudential principles and technological advancements.

6. The need for the conciliation of methods of blockchain arbitration with the convention on the recognition and enforcement of foreign arbitral awards

The Convention on the Recognition and Enforcement of Foreign Arbitral Awards, of June 10, 1958 (hereinafter the **"New York Convention"**), is concerned with the enforcement of arbitral awards in

contracting states. The convention is made to give effect to the arbitral awards after they are rendered by the tribunal. It provides a uniform framework for the recognition and enforcement of arbitral awards. The crux of the New York Convention is that, the awards will only be enforced when certain procedural rights are upheld by the tribunal. The courts ensure, in this way, that the arbitral awards rendered in compliance with the convention can be enforced in the countries that are signatories, even if the losing party is non-compliant [49]. Therefore, compliance with the New York Convention is necessary for blockchain-based/Kleros-based arbitral awards to be enforced in international commercial arbitration.

6.1. Analysis and reconciliation of requirements of blockchain arbitration with New York convention

There are certain provisions of the New York Convention (abbreviated **"NYC"** or **"the Convention"**) that will be analyzed and compared with the concepts of blockchain arbitration, to determine whether blockchain arbitration potentially complies with NYC.

Note: The issues that otherwise exist in traditional arbitration, apart from the specific context of blockchain arbitration, are not within the scope of this article. The purpose of this article is to analyze the provisions of NYC in the context of blockchain arbitration and does not delve into the various subjective contexts of traditional arbitration, which also encompass political considerations, issues such as jurisdictional conflicts in enforcement proceedings, divergent judicial attitudes among NYC signatories, *etc.*

This section, will analyze, firstly, the application of NYC to e-commerce/small scale disputes, secondly, the relevance of NYC after the arbitral award has automatically been executed by a smart contract, thirdly, whether blockchain based award qualifies as a foreign or domestic arbitral award under the NYC, fourthly, whether blockchain arbitration complies with formal validity requirements under NYC, fifthly, the requirements of arbitrability of subject matter in blockchain arbitration in line with the NYC and lastly, the interplay of blockchain arbitration with public policy considerations under NYC.

6.1.1. The application of NYC to E-commerce disputes

The first issue is determining which law applies to consumer disputes and whether NYC also applies to the enforcement of awards rendered in e-commerce.

The legal relationship of parties in e-commerce is complicated by the absence of an international legal framework of universal application that establishes clear jurisdictional rules governing e-commerce transactions [49]. This issue demands separate discussion and needs to be regulated differently from blockchain arbitration, since this paper focuses on determining the enforceability of awards in the context of international commercial arbitration. Furthermore, different contracting states of the NYC, particularly, the member states of the EU, have explicitly excluded arbitral awards arising from consumer disputes from the scope of application of the convention [49].

Under the legal frameworks of these states, a consumer cannot validly enter into an arbitration agreement, or such agreements are only enforceable if certain conditions are met. Consequently, the enforcement of an arbitral award against a consumer may prove to be problematic or entirely unfeasible. In any case, individual consumers could not benefit from the favourable procedural regime established by the NYC [49].

Note: The scope of this article is limited to arbitration of commercial disputes rendered using blockchain technology and not individual consumer disputes in e-commerce.

6.1.2. The application of NYC after automatic enforcement of a smart contract

The second issue that arises is that in Kleros, awards rendered by jurors are automatically enforced through smart contracts, then what would be the relevance of NYC once the award has already been executed.

The solution to this question was presented in a conference paper on April 6, 2018 [50]. According to the paper, if a party wishes to challenge the execution of a smart contract after its effects have been fully realized, they can seek the assistance of a state judge or an arbitral tribunal. This option is not excluded by the technological irreversibility or immutability of the blockchain. Although it is impossible to delete a block once it has been added to the chain, the law can reverse the effects of such a transfer. This can be done by ordering a 'Reverse Transfer' which can be carried out by a national court, just like in the case of real-world contracts [50]. The mentioned concept of 'Reverse Transfer' is in context of **on-chain enforcement**, which is linked to smart contract and is self-executable in nature. For **off-chain enforcement**, this concept is not applicable as it is not self-executable and an order by a state judge is primarily required for enforcement.

Similarly, in the context of Kleros, it is important to observe that the party pursuing judicial review will generally be the party that did not succeed in its claim. Due to the self-executing nature of the smart contract involved, the funds are automatically allocated to the successful party, thereby shifting the advantage to the party deemed to be correct within the Kleros framework. This stands in contrast to traditional arbitration, where the winning party may encounter additional challenges in enforcing their awarded judgment. The aggrieved party (losing party) can refer to courts for a reverse transfer (enforcement) [51].

Note: The concept of 'Reverse Transfer' concerns disputes on Kleros involving the transfer of funds/crypto tokens. The disputes regarding specific performance of contract or injunctive relief are not within the scope of this article.

6.1.3. The recognition of blockchain based arbitral award as a foreign arbitral award

The third issue that arises is whether a blockchain-based arbitral award can be recognized as a 'foreign arbitral award' or will it be classified as a 'domestic arbitral award'. This question is of utmost importance, since according to Article I and the objectives of NYC, it only applies to the former and not the latter [52].

The decisions rendered on blockchain are not made in the territory of any state, but rather in an online setting, specifically in Kleros, where the location of jurors is not known. Decentralized justice is delocalized and can be rendered from anywhere in the world. As a result, it is uncertain to determine the criteria of a foreign or domestic arbitral award in the case of Kleros arbitration.

Contrary to the provided reasoning, a case from September 2020, in Kleros arbitration, has been recognized by a Mexican civil court [53]. In this case, which is reported by Kleros through a complete case record, a Mexican court enforced for the first time an arbitral award relying on the Kleros protocol. This situation arose in a case where the parties to a real estate leasing agreement over a property located in the state of Jalisco, Mexico, agreed to have a sole arbitrator resolve their dispute in connection with

that agreement using Kleros to render the decision. The traditional arbitrator (which was separate from the Kleros protocol) acted as an interface between the parties and Kleros, by referring the case to three anonymous jurors under Kleros arbitration and it was a case of domestic nature [emphasis added]. The sole arbitrator incorporated the Kleros decision in the award. Subsequently, the landlord sought enforcement of the award before a Mexican state court and the Mexican courts recognized the award on 28 May 2021 [53].

As a result, there is a precedent of enforcement of an arbitral award under Kleros, in off-chain domestic arbitration as well. However, this is a unique precedent, requiring further jurisprudential development.

6.1.4. Compliance of blockchain-based arbitral awards with formal validity and signature requirements of NYC

The fourth issue that arises is whether the decisions rendered by Kleros fulfill the formal validity requirements under the NYC.

Firstly, Article II (1) of the Convention provides that an agreement under which the parties undertake to submit to arbitration should be in writing [52]. The agreement in Kleros is not in writing as it used to be in 1958, when this convention was signed. Article II (2) provides that an agreement in writing shall include an arbitration agreement or clause, (a) signed by the parties and (b) contained in an exchange of letters or telegrams [52]. However, the arbitration agreement in Kleros is neither (a) a physically signed document nor (b) exchanged in telegrams or letters.

The Convention itself is not conclusive of incorporating Kleros if it is analyzed verbatim. However, UNCITRAL has issued a recommendation that Article II (2) is not exhaustive, signifying that letters and telegrams include other derivatives as well [54]. The UNCITRAL Model Law seeks to reconcile that gap by expressly stating in [Option 1] Article 7 (3) that, "*An arbitration agreement is in writing if its content is recorded in any form, whether or not the arbitration agreement or contract has been concluded orally, by conduct, or by other means*" [55]. Therefore, after this interpretation, it is safe to assume that agreement to arbitrate as per the Kleros mechanism will fulfill the purposes of Article II of NYC.

Secondly, Article IV (1) of the Convention provides that at the time of enforcement of the award, (a) a duly authenticated original award or a duly certified copy of the award and (b) the original arbitration agreement or a fully certified copy shall be provided [52]. In Kleros, there is no physical award or agreement, that can be used as a certified copy, all the documents are electronic. The sub-question that arises is regarding the purpose of the condition of originality in NYC. The objective and purpose of enforcing this condition is to verify the awards and to prevent alteration [56].

Kleros incorporates a 'cryptographic hash function', which is a unique code, different for every award. This code cannot be used for more than a single award (see unique hash mentioned in Sections 5.2.4 of this article). Kleros also incorporates a suitable signature, which certifies that the award is rendered by the blockchain technology in the Kleros mechanism. The cryptographic hash function and decentralized ledger of blockchain have been recognized as *inter alia* imputable by courts in major jurisdictions, such as the UK, China, New Zealand, Hong Kong and Spain (see Section 4.1.2 of this article). According to the objectives and purposes of Article IV of NYC, these requirements should be sufficient to prove the authenticity of the award [56]. Hence, this requirement can also be interpreted to comply with the NYC.

Note: Further technical analysis of the blockchain technology with regard to cryptographic functions is not within the scope of this article.

6.1.5. Arbitrability of subject matter in blockchain-based arbitration

The fifth issue that arises is regarding the arbitrability of the subject matter. Article V (2)(a) of NYC provides that the recognition of an award can be refused if the subject matter is not capable of settlement under the law of that country (place) where recognition and enforcement is sought [52]. However, there is no place of arbitration when Kleros decisions are rendered, rather, they are held in a delocalized space, without the application of a standard law.

According to Professor Gary Born, the law of the place of arbitration plays a central role in defining a legal framework of arbitral proceedings [57]. The law of place defines the limits of party autonomy within a specific domain. For arbitration to be considered delocalized, it must still be allowed under the laws of the country where enforcement of the delocalized award is sought [57].

In the case of 'on-chain arbitration' (as explained in Section 6.1.2 of this article), the parties would refer to the national courts if a party files for a reverse transfer. In that case, the law of the place that orders the reverse transfer, should technically apply. The case of 'off-chain arbitration' would be more technical, as delocalization would impact the determination of the place of arbitration.

Guidance can be sought to determine the law applicable to enforcement in the case of *Enka v Chubb*, by the United Kingdom Supreme Court [58]. According to the court, firstly, the express choice of governing law for the contract will generally apply to an arbitration agreement which forms part of the contract [58]. Secondly, in the absence of an express or implied choice of law of the parties, the default rule is the system of law with which the arbitration agreement is most closely connected [58]. Thirdly, where the parties have chosen a seat of arbitration, the law of arbitration will generally be the law of the seat, even if this differs from the law applicable to the parties' substantive contractual obligations [58]. According to this explanation, the parties should either specify which law would apply to their contract or what is the seat of arbitration [emphasis added]. The explanation related to the closest connection of the arbitration agreement will most likely be invalid in the case of Kleros, as it is held in a delocalized manner and in cyberspace, thereby not in a defined territory of a state.

Furthermore, in Kleros, the jurors are anonymous and might not have the knowledge of these rules and specific laws concerning specific countries (for example, which law would apply if the seat of arbitration is France, *etc.*). There has to be a standard law and set of procedures that would apply to Kleros awards by the courts for enforcement purposes, as, firstly, jurors will not have the technical understanding of laws since they can be non-lawyers (non-experts), unlike court judges and secondly, for the purpose of uniformity. In addition to the specific requirements of blockchain arbitration, there is also the challenge of legal fragmentation, which would apply to blockchain regulations and affects both on-chain and off-chain arbitration concepts [59]. As a result, in the context of Article V (2)(a) of NYC, the Kleros mechanism might not entirely reconcile.

6.1.6. Public policy considerations regarding enforcement of blockchain-based awards

The sixth issue that arises is related to the public policy considerations as enshrined in Article V (2)(b) of NYC [52]. It states that recognition or enforcement of an award can be refused if it would be contrary to the public policy of that country [52]. Public policy is further classified into 'Substantive public policy', which refers to the substance of arbitrators' determination rather than procedural aspects.

'Procedural public policy' is mainly concerned with the procedural aspects, such as notice requirements and online hearings, *etc.*

Note: Procedural Public Policy requirements inter alia notice requirement and issue of face to face hearings and other grounds mentioned in Article V (1) of the New York Convention will not be discussed in this article.

Substantive public policy is regarding the arbitrability of the subject matter of dispute, of which enforcement is sought (e.g., a contract for the sale of prohibited drugs that cannot be sold in the place of enforcement) [59]. The problem can potentially arise during the enforcement of an award rendered in on-chain arbitration, which is rendered on an illegal subject matter. The award will automatically be enforced through the smart contract, whereas during the reverse transfer, the court would have to nullify the award and order a recovery of funds, *etc.* (see Section 6.1.2 of this article for elaboration on the concept of 'Reverse Transfer').

To qualify as legal under the national law, the parties would first have to choose a national law that would apply (which would be inconvenient for non-technical arbitrators in the Kleros mechanism) and render a decision according to that. The parties, in the first place, cannot enter into a contract of illegal subject matter. The extent of delocalization of the Kleros award must be regulated and narrowed down for the purposes of acceptance and uniformity.

6.2. Model Kleros clause to reconcile with NYC

To reconcile with the requirements of the NYC, so that Kleros-based awards can be enforced, the elements of a Model Kleros Clause have been proposed in an article published on the Kleros website: [60]

"(i) the agreement to arbitrate under the Kleros protocol;(ii) the law of the contract; (iii) the law of the arbitration agreement; (iv) the place of the arbitration;(v) the language of the proceedings; and (vi) that the decision will be final and binding following either a certain number of appeals and/or the lapse of a certain length of time".

These explanations would be elaborative for the domestic courts to not refuse the enforcement of Kleros-based arbitral awards since it mentions, (a) party autonomy to arbitrate under Kleros, (b) law of contract/arbitration agreement/place (in line with *Enka v. Chub*), (c) language of proceedings and (d) Kleros can have appeals up to 512 jurors, so parties should limit a specific No. of appeal rounds *inter alia* for the purpose of certainty (see Section 4.2.5 of this article). However, the challenge of legal fragmentation would persist on a jurisdiction-by-jurisdiction basis, necessitating specific model clauses tailored to each jurisdiction and aligned with the relevant laws (see Section 6.4.1 of this article for the concept of legal fragmentation and its applicability to blockchain regulations).

6.3. Is there a need for a new convention for the enforcement of digital awards?

This section will entail, firstly, the opinion of experts directly and indirectly linked with the utilization of blockchain in commercial arbitration and secondly, the opinion of authors regarding the need for a new convention for the enforcement of blockchain-based arbitral awards.

6.3.1. Opinion of experts

The authors of this paper referred to two experts in the field of arbitration and technology for their insights and asked them linked questions to the enforcement of awards and the incorporation of technology in arbitration. The views of both experts are produced *verbatim* as under:

Question 2 from the interview of **Barrister Safi Ullah Ghauri** (continuing from Section 4.3.4 of this article) is as under:

Question 2: What is your opinion on the Pros and Cons of incorporating Blockchain in international arbitration mechanisms? Specifically focusing on automated enforcement of the Smart Contract on Blockchain.

Answer: Primary Benefits: Blockchain technology is all about automated enforcement of the terms of agreements that is more efficient, as it cuts out costly intermediary processes and reduces delays in their enforcement. Contracts are the main subject of automation in that they instantly act as if they were authorized when a certain condition is met. Imagine that a possible result of the automation of the whole process would be that smart contracts can immediately execute a predetermined outcome solely based on the verification of certain prerequisites, thus revolutionizing the traditional post-arbitral award enforcement process. This autonomous feature is especially useful for disputes arising from different countries as they can avoid multijurisdictional enforcement actions provided for in the NYC.

Challenges: Despite its benefits, there are some major drawbacks. One important issue is the will of the parties to include binary logic to premises, which cannot deal with all the areas that are required to be addressed in arbitration proceedings. Blockchain transactions have immutability features and whilst they are good for the sake of transparency, they can backfire when the arbitral awards need to be amended or face any number of real-world valid issues. Besides, technology runs into the risk of jurisdiction because some legal frameworks do not recognize automated enforcement which may cause conflicts between what the technology wants to do and what the local laws dictate.

These two aspects should raise fundamental questions about the shared space of vested public policy and the usage of automatic enforcement in international arbitration as stipulated under Article V of the NYC. Smart contracts should be created in such a way as to allow automatic cooling-off periods, appeal rights and other procedural safeguards that are inherent in international arbitration laws. It should also be noted that the automated enforcement mechanism should cover both asset location and accessibility. Eventually, we'll have to rely on a hybrid model where complex arbitrations don't turn into *"flash loans"*.

The authors of this paper further had the privilege of interviewing **Mr. Rana Sajjad** [the Managing Partner at Triage Law, a Lahore-based commercial and arbitration law firm, and the Founder & President of the Center for International Investment and Commercial Arbitration (CIICA), Pakistan's first international arbitration center. He is a dual-qualified lawyer licensed as an Advocate of the Supreme Court of Pakistan and a member of the New York Bar. He is also a Fellow of the Chartered Institute of Arbitrators (CIArb) and an accredited mediator of the Singapore International Mediation Institute (SIMI)] is articulated as:

Question 1: In your opinion—Is the world in need of a new convention for arbitral award enforcement of awards in context of Blockchain Arbitration, to replace the New York Convention 1958?

Answer: For wider adoption and faster implementation, appropriate additions/amendments could be proposed in the current draft of the New York Convention after developing a consensus amongst signatory States.

6.3.2. Analysis of opinion of experts

The authors of this paper carefully considered the arguments of experts, including the interviewees and from the cited literature. The authors are of the opinion that NYC can reconcile with methods of blockchain arbitration with interpretations in favour of enforcing blockchain-based awards, not limited to interpretations recognizing digital signatures, compliance with designating a seat of arbitration and law governing the contract, careful consideration regarding principles of public policy of the selected jurisdiction, arbitration of legal subject matter capable of arbitration. However, the grey area would still exist, not limited to recognition of the awards rendered by anonymous arbitrators and reverse transfer after the award has been executed.

However, a better way to include blockchain arbitration in NYC would be to include it in a separate annex to the NYC. The reason for this is, firstly, not to alter the text of the original convention, which can cause problems in the interpretation of law during regular arbitration proceedings. Blockchain arbitration should be dealt with separately because some processes require exclusivity, such as the concept of reverse transfer. Secondly, the states that expressly consent (become signatory) to the separate annex should be allowed to comply with the requirements of NYC, amendments would be more contentious for member states, as they may alter the original obligations under NYC, whereas in adding annexures, member states are free to choose their consent in signature and ratification.

6.4. Additional considerations for effective blockchain arbitration regulations

The concept of blockchain arbitration cannot be understood completely in abstract, rather, the specific complications within the realm of blockchain and smart contracts would otherwise (apart from the discussion on NYC) also be relevant to consider the limitations on blockchain arbitration. These limitations can potentially delve into the fundamental legal implications and challenges that arise in the context of decentralized dispute resolution mechanisms. This section will firstly address the individual legislations by states, leading to digital fragmentation, secondly, the possibility of automatic enforcement of smart contracts as a potential limitation in complex disputes and thirdly, the technical limitation of smart contracts and applicability of those limitations on blockchain arbitration.

6.4.1. Individual domestic legislations lead to different visualizations of blockchain

Blockchain can be complicated for the states to regulate uniformly, it can be perceived differently in its legal and political meaning [61]. Even within one country, different states might have different interpretations [62]. For example, in the United States, the Uniform Electronic Transactions Act (the **"UETA"**) was enacted in 1999 to remove barriers in electronic commerce by establishing the legal equivalence of electronic records and signatures with their paper counterparts. It was adopted by forty-seven states and the District of Columbia, though with varying interpretations and amendments. States such as Arizona, Nevada, and Tennessee later updated their versions of UETA to explicitly include blockchain technology and smart contracts within the scope of electronic records. However, these states adopted differing definitions of key terms like 'blockchain' and 'smart contract', leading to potential inconsistencies. For instance, Arizona emphasized immutability and uncensored truth, while Nevada focused on consistency and non-repudiation [62]. By this example, it is evident that different states recognized decentralized technology

in a different manner, by individual attributes. However, the end goal remained uniform, which was to regulate electronic records.

A similar issue of jurisdictional fragmentation in tokenized litigation finance has been addressed in legal scholarship focusing on third-party funding through cryptocurrency [63]. There is a pressing need for jurisdictional reconciliation and regulatory harmonization due to the fragmented regulatory landscape. Major jurisdictions, including the United States, England & Wales, the European Union, Singapore, and Switzerland, have each established distinct and at times conflicting frameworks for classifying and governing security tokens [63]. This disparity poses a significant challenge to the inherently global and borderless nature of blockchain-based offerings. The solution to dispute resolution of security tokens is suggested to embed arbitration into the smart contracts themselves, pointing to Kleros and other blockchain dispute resolution platforms as a key example of a decentralized 'digital court' that could provide effective resolution [63].

This also applies in the case of blockchain arbitration and specifically in Kleros, where different countries have to uniformly implement blockchain regulations, for them to be uniformly accepted throughout. The ultimate goal of blockchain arbitration is to enhance the effectiveness of enforcement mechanisms by utilizing smart contracts, which can only be achieved if there is a uniform and non-selective acceptance. For instance, if a state does not recognize the award rendered by anonymous jurors as just (which remains an area to be explored), whereas in any other state, anonymous jurors are recognized as more transparent than traditional methods of arbitration, it can lead to a conflict between jurisdictions and legal fragmentation, as a result making blockchain arbitration effective only in selective jurisdictions.

A unique perspective on different states adopting unilateral domestic measures in regulating the digital economy is termed as 'digital nationalism' and 'digital protectionism', with the reason to enforce domestic measures being to assert digital sovereignty and to prevent foreign dominance in digital markets [64]. However, such unilateral measures risk fragmenting global digital trade, creating barriers to cross-border data flows, and potentially triggering trade retaliations [64]. The middle ground approach between unilateral digital protectionism and idealistic multilateralism is suggested as 'digital plurilateralism' or 'unilateral multilateralism'. This strategy involves forming sector-specific, multi-party agreements, such as on the digital economy [64].

A similar approach, as of digital plurilateralism is required, if any method of blockchain arbitration is to be uniformly implemented, because blockchain is uniform and functions the same way in every jurisdiction, in the absence of any specific regulation. Specifically in the context of blockchain arbitration, assuming that if an arbitral award rendered by Kleros in the case of Alice and Bob (see Section 4.2 of this article) is recognized by Mexico but not by any other state, then the enforcement of blockchain-based arbitral awards will be a dilemma, in the state which do not recognize or has adverse regulations for blockchain arbitration—derived from digital nationalism. Therefore, if the complete potential of blockchain arbitration is to be recognized, then the progressive way for states would be to shift their economic policies towards uniformity in the domain of blockchain technology and decentralized justice, thereby leading to digital plurilateralism, at least in specific sectors of innovation.

6.4.2. Automatic enforcement of blockchain arbitral awards can be viewed as a limitation

The most apparent limitation of smart contracts can be in complex disputes, such as a construction contract, which involves multi-party, cross-border transactions involving a web of interconnected agreements. The functionality of smart contracts may be limited to resolving simple and single-issue disputes [65].

In the context of blockchain arbitration, particularly with Kleros and the use of on-chain arbitration, the limitations typically associated with smart contracts can actually be perceived as an advantage. This is due to the fact that, alongside the deployed smart contracts, there are three or more jurors involved in deciding a case. These jurors will render a decision, which will ultimately determine the enforcement of the award in favor of one of the parties. The smart contract itself is not being enforced independently, instead, it is the decision of the jurors, facilitated through the smart contract, which is being enforced. As a result, in complex disputes, jurors will render a decision, analogous to that in traditional arbitrations, thereby facilitating the resolution of such disputes in accordance with established blockchain arbitration procedures, and the enforcement will be relatively efficient because the decision of the jurors will be enforced on-chain, right after being rendered. A potential concern arises when a party refers to the court for a 'reverse transfer'. In this situation, court proceedings will be analogous to traditional award enforcement, however, unlike traditional enforcement, where the award is upheld, blockchain arbitration may result in the reversal of the executed award. This implication suggests that the comprehensive capabilities of blockchain technology remain largely untapped and not fully realized within the current frameworks and applications.

6.4.3. Blockchain arbitration can potentially address technical limitations of smart contracts

Three technical limitations of smart contracts are prevalent in discussion, in the context of complex construction disputes. Firstly, their inherent rigidity and lack of flexibility prevent the alteration of terms or the incorporation of open-ended obligations, for example, the difference between terms, such as 'good faith' and 'best efforts', which are essential in cross-border projects [65]. Secondly, smart contracts lack retroactivity, meaning they can only govern disputes if implemented at the inception of a transaction and throughout its duration, rendering them ineffective when an amendment is required [65]. Thirdly, the implementation of smart contracts is hampered by a significant lack of infrastructure and human resources, requiring perfect code and technologically savvy personnel to avoid errors [65].

While these limitations generally apply to smart contracts, they can only come into play in blockchain arbitration, when the case is transmitted to jurors for dispute resolution. During the dispute resolution stage, neither party can amend the agreement or smart contract. The parties involved can, however, at the evidence stage, submit their written submissions to the jurors, based on which the jurors will render their decision. Essentially, the issues of interpretation and negotiation of terms in smart contracts and ensuring that perfection in coding exists at the pre-blockchain arbitration stage, between parties, are similar to traditional arbitration. Furthermore, the addition of jurors in blockchain arbitration decreases the probability of errors not being detected in smart contracts or the will of parties, while formulating a smart contract, not being enforced. Minor and major errors can even exist in traditional contracts, however, it is always up to the arbitrator/judge to interpret the contract, which is similar to the case in blockchain arbitration. Additionally, a proposal regarding keeping track of amendments that ought to be done in smart contracts, before initiating dispute resolution, can be made by a duly-signed

digital or print record with both parties, ultimately assisting parties to agree on amended terms and before the execution of a smart contract, assisting them to enforce a new smart contract, with the amendments incorporated. Lastly, it is essential to acknowledge the current shortcomings in both the quality and quantity of training in smart contract deployment and drafting. However, these challenges can be effectively addressed by providing specialized education focused on blockchain technology, particularly at the intersection of legal contract drafting and blockchain.

6.5. Conclusion of the section

The enforcement of blockchain-based arbitral awards under NYC has transformative potential but is faced with complex legal challenges, not limited to, the applicability of relevant law under NYC, automatic execution of smart contracts, the possibility and legal standing of reverse transfer under NYC, the category of classification of blockchain-based arbitral award under NYC, formal validity under NYC, arbitrability of subject matter and public policy considerations. While cryptographic validation addresses formal validity requirements, there is difficulty in reconciling public policy considerations and the arbitrability of subject matter adjudicated under blockchain arbitration, especially where delocalized processes intersect with national legal frameworks. Ultimately, to reconcile NYC and decentralized technology, there is a need for an adaptive legal framework with uniform enforcement principles. Moreover, the fragmented regulatory landscape, where individual domestic legislations lead to divergent legal classifications of blockchain technology, creates significant challenges for the uniform recognition and enforcement of blockchain arbitration awards. Additionally, the automatic enforcement of awards through smart contracts can be a limitation in complex disputes, however, the integration of human jurors in blockchain arbitration can effectively mitigate the inherent technical rigidities of smart contracts. This hybrid approach of combining algorithmic execution with human adjudication not only addresses the shortcomings of smart contracts but also offers a potential path toward resolving disputes in a manner that could achieve broader jurisdictional acceptance.

7. Recommendations

Henry Ford's [the Founder of Ford Motor Company and a pioneer in making automobiles and pioneering a system that launched the mass production and sale of affordable automobiles to the public] quote: "If I had asked people what they wanted, they would have said faster horses" [66].

This analogy applies to the integration of blockchain arbitration in the justice system as well, as the general public lacks awareness regarding the transformative potential of blockchain technology. However, transformative solutions often exceed public imagination when they materialize. Blockchain technology has attributes such as efficiency and transparency, which can demonstrate its necessity, rendering traditional mechanisms [faster horses] of a bygone era.

To effectively integrate blockchain arbitration concepts in commercial arbitration—to ensure compliance, *inter alia* following are a combination of recommendations combining technical, procedural and legal considerations:

A. Regarding formal validity requirements of the NYC: Digital signatures on an arbitral award should be weighed equally as physical signatures [duly certified copies] and arbitrations on the blockchain should be compliant with the recording of arbitration agreement in a tamper-proof digital

format (e.g., cryptographic hash-linked agreements) to satisfy formal validity requirements. The terms 'electronic awards' and 'decentralized arbitration' should be expressly mentioned in NYC. Protocols for cryptographic signatures on blockchain should be developed and standardized for uniformity.

B. Regarding recognition of blockchain-based arbitral awards as *'foreign'* under the NYC: The place and seat of arbitration should be clarified by the parties in the arbitration agreement (e.g., the arbitration shall be deemed seated in [X jurisdiction]). This would help the jurors decide the case according to the law specified and would be helpful for the courts to counter-check, on a reverse transfer request, whether an arbitral award is a 'foreign award' or 'domestic award' for the purposes of NYC. Moreover, guidance should be taken from the case of the Mexican court's enforcement of a Kleros-based award, which recognized a blockchain-based award as 'foreign' if seated outside their territory.

C. Regarding procedural safeguards: Appeal rounds in blockchain arbitration should be structured, giving parties equal opportunity to present their case and complying with fairness requirements. The limit of appeal rounds should also be fixed and justified, in line with the practice of the majority stakeholder states.

D. Mitigating public policy concerns: Integrate blockchain oracles to cross-verify awards (algorithmic compliance check) against predefined criteria, to integrate real-world knowledge in blockchain. Moreover, mandatory training for Kleros jurors should be organized on fundamental legal principles such as arbitrability and public policy, to minimize the risk of non-compliance with jurisdictional requirements.

E. Technical enhancements to smart contracts**:** Smart contracts should be programmed in a way to freeze assets, when a party challenges the decision, even after internal appeal procedures have elapsed, mandating manual intervention by courts referred to as 'reverse transfer'. However, a party should only be allowed to refer to courts once all the internal remedies have elapsed and/or there is a complex question of law involved.

F. Integration of hybrid blockchain-based system with traditional arbitration**:** Blockchain arbitration should be combined with institutional commercial arbitration (e.g., International Chamber of Commerce, Permanent Court of Arbitration, *etc.*). For example, Kleros can be used for initial fact-finding and automated enforcement until a specific stage of the proceedings, but reserve appeal can be referred to the institutional tribunals for legal review. This would automate and enhance the efficiency of the working of institutional arbitrations.

G. Preventing legal fragmentation arising from different enforcement proceedings: In the realm of 'on-chain enforcement', which concerns reverse transfer and 'off-chain enforcement,' similar to traditional arbitration award enforcement procedures, there exists a significant likelihood of legal fragmentation both across jurisdictions and within an individual jurisdiction. To mitigate this concern, particularly arising from different enforcement mechanisms, it is imperative to incorporate specific annexes into NYC, clarifying the processes. Furthermore, a uniform clarification of the processes that member states are required to adopt should be established to ensure consistency and prevent legal fragmentation.

8. Future research

Future research should incorporate, firstly, the legal recognition of blockchain technology across multiple jurisdictions, similar to the uniform implementation of NYC. Secondly, gaps should be explored in the enforcement of award, rendered by anonymous jurors, including the surrounding jurisprudential principles. Thirdly, mechanisms for 'reverse transfer' should be developed because once an award has been executed

and tokens are transferred to the wallet of the prevailing party, there is a possibility of non-presence of that party in regular court proceedings and especially, the gap exists in the cross-border cases (e.g. both parties from different states) where request for 'reverse transfer' will be made. Fourthly, the possibility and limitations of an off-chain arbitrator acting as an interface between Kleros and parties should be explored, just as in the aforementioned case of Mexican court, which enforced the Kleros-based case. Fifthly, the legality of the hearing mechanism in Kleros should be explored because all the decisions are made based on written submissions, with no requirement of a hearing, however, some states require a hearing to ensure the fundamental right of fair trial to their citizens. Lastly, the reconciliation of legal fragmentation should be explored, in order to identify the essential provisions that each jurisdiction needs to ensure for the effective implementation of blockchain arbitration.

9. Conclusion

The Kleros mechanism of blockchain arbitration depicts a paradigm shift in dispute resolution and presents it as a revolution for future ADR by combining decentralized technology with traditional jurisprudential principles.

Firstly, Kleros is defined as decentralized justice through smart contracts and crowdsourced jurors, thereby automatically executing the decision after it is rendered by jurors. The critique of smart contracts is also explored and measures are proposed for compliance with traditional ADR mechanisms. The integration of escrow mechanisms and crypto-economic incentives in smart contracts, such as the Schelling coin reward system, ensures efficiency and transparency, thereby resolving disputes. This whole mechanism is explained by the example of a dispute in a freelancing contract between Alice and Bob, which is adjudicated without intermediaries.

Secondly, the compliance of Kleros with the objective and subjective procedural fairness criterion is demonstrated. The objective criteria align with the cited EU directive standards and ECHR requirements of fair trial. The subjective criteria address cross-jurisdictional concerns, including the subjective ability to perceive justice and address it relatively. The fairness of Kleros in the context of the average time resolution of a case (*i.e.*, 13.234 days) potentially exceeds the efficiency of any other traditional ADR system.

Thirdly, enforcement challenges in NYC are highlighted, particularly the decentralization of justice and formal validity requirements. It further addresses the arbitrability of disputes, public policy concerns, the classification of blockchain-based awards as foreign or domestic and the reverse enforcement of an arbitral award, once it has been executed by a smart contract. The landmark case of the Mexican court's recognition of Kleros-based award was discussed, which was enforced while being of a domestic nature, concerning landlord and tenant, thereby setting a precedent for the enforcement of blockchain-based awards. Additionally, hybrid models are proposed, which potentially help blockchain arbitration mechanisms to reconcile with traditional arbitration mechanisms.

Lastly, the issues are explored, which would otherwise apply to blockchain arbitration apart from the NYC, including the legal fragmentation relating to blockchain, technical limitations and the ability of smart contracts to reconcile with complex arbitration disputes. However, the integration of jurors within blockchain arbitration effectively mitigates the limitations of smart contracts. Whereas, the recognition of the complete potential of blockchain arbitration is contingent upon achieving greater regulatory harmonization through cooperative international frameworks, moving beyond unilateral digital protectionism toward the approach of digital plurilateralism.

10. Supplementary data

The authors confirm that the supplementary data are available within this article.

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Authors' contribution

Conceptualization, Muhammad Ayaan Shehryar and Areej Anwar; methodology, Muhammad Ayaan Shehryar; software, Muhammad Ayaan Shehryar; formal analysis, Muhammad Ayaan Shehryar and Areej Anwar; investigation, Muhammad Ayaan Shehryar; writing—original draft preparation, Muhammad Ayaan Shehryar and Areej Anwar; writing—review and editing, Muhammad Ayaan Shehryar; visualization, Muhammad Ayaan Shehryar. All authors have read and agreed to the published version of the manuscript

Conflicts of interests

The authors declare no conflict of interest.

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