Argumentation in Trust Services within a Blockchain Environment

DOI: http://doi.org/

Argumentation in Trust Services within a Blockchain Environment

Liuwen Yu[1,3,4][0000−0002−7200−6001], Mirko Zichichi[2,3,4][0000−0002−4159−4269], Réka Markovich[1][0000−0002−2488−2293], and Amro Najjar[1][0000−0001−7784−6176]

[1] University of Luxembourg, Luxembourg
[2] Universidad Politécnica de Madrid, Spain
[3] University of Bologna, Italy
[4] University of Turin, Italy

Abstract. Both argumentation and trust concern multi-lateral uncertainties, while argumentation owns the ability to enhance trust in many ways. In the field of trust service where the trustee administers financial assets on behalf of principals, trust is an indispensable element. Often, the trustees withhold the investment plans and of which the decision-making process from their principals such that these services lack of transparency documentation, traceability, and inclusive decision-making mechanisms. In this paper, we integrate formal argumentation within a blockchain framework. Both argumentation and blockchain have distinctive features that complement each other. They together make the decision-making of the trustees transparent and traceable in order to gain trust and confidence in principals. We introduce three possible architectures and we evaluate and compare them considering different technical, financial, and legal aspects. Specifically, we discuss the role of argumentation in building trust between trustees and their principals.

Keywords: trust services · argumentation · negotiation · blockchain · smart contracts · artificial intelligence

1 Introduction

Trust service is concerned as persons or organization that acts on behalf of another person or persons to deal with the tasks involves finances, i.e., managing the assets, where trust from trustors plays a crucial role in entering into the contractual relations with trustee. Fund management, as a strand of trust services, is meant that the fund managers, i.e., trustees, are in the position of a fiduciary and put their principals' interest ahead of their own to construct a portfolio of securities (e.g., stock, bonds, mutual funds, etc.), with a duty to preserve good faith and trust. In general, fund management mainly has a two-stage procedure. At the first stage fund managers are supposed to perform an evaluation of the selected securities on account of their expertise. At a second stage, the transactions based on the first stage are executed. As a matter of course, trust problem will emerge in both stages. On the one hand, the seeds of distrust of such fiduciary may be planted from the difference between the principal's and the fund managers' expertise, as well as the reservation and lack of documentation of the decision-making process of investment plans. The legislators have already taken this problem into account, they can (and does[5]) declare the principal's right to check the fiduciary's relevant activities in order to give weight to this duty by its intended controllability. On the other hand, weather the transactions are executed as planed is also the original of distrust.

In this study, we propose an integrated framework that incorporates formal argumentation within a blockchain environment for making the decision-making processes of fund management transparent and traceable. As suggested by both academics and industries, smart contracts within blockchain technology can also be engaged in the core activities in the securities market [24,61], proven by the surge of Decentralized Finance (DeFi) [68]. The involvement of smart contracts and blockchain can address the second concern, i.e., make the transactions transparent and auditable. Nevertheless, blockchain for transactions alone does not address the first trust problem, it is actually used only to trace the output of such a decision-making process. The principals still don't have access to why the given transaction happened and whether it happened indeed in his best interest. To this sense, trust can be understood as a relational attribute between a social actor and /or institutions [8], and trust is also a technique for dealing with uncertainty regarding other parties' actions and communications [31]. We argue that formal argumentation and trust share a common function: they both deal with changes and uncertainties in complex social environment [45]. We aim to show that formal argumentation is suited for modelling the decision-making process of fund management, which is multi-lateral interaction and reasoning based on incomplete and inconsistent information to help explain why a claim or a decision is made. In the fund management case, information incorporating the different fund managers' opinions is provided by different conflict-resolution techniques: argumentation is used to decide whether to buy, sell or hold securities, and negotiation to determine the quantities and investment timing, and thus to provide explanations. By integrating argumentation with blockchain, a reasoning system put in place for making these decisions could be featured with auditability, transparency, traceability and explainability, which all serve to enhance reliability and trust—in such an industry which is named after it.

Our proposal is a framework integrating different methodologies based on different considerations:

(i) First we consider the ecosystem of the trust services, the fund management (at the securities market) to see the roles of the parties and their relation, especially that of the fund managers. This is what we start with in Section 2 as a motivation.

(ii) The technical environment for the solution we propose is blockchain and smart-contracts given that their application in the trading itself on the securities market is rising [24,51]. The expertise of the fund managers and their decision based on that triggers the transaction, that is, the smart contract's execution. The interface giving external input needed for the smart contract's execution—for some reason, for instance, the human expertise's irreplaceability—is called (blockchain) oracle. The blockchain systems and their reliance on oracles involve some considerations

[5] For instance, the 6:315. § of the Hungarian Civil Code (Act V of 2013) says: *The principal and the beneficiary shall have the right to check the fiduciary's activities relating to asset management.*

the understanding of which is needed for the proper involvement of the methodologies we propose, thus we introduce shortly what oracles are in the blockchain environment and how they are supposed to work in Section 3.

(iii) In order to optimize the involved expertise of investing the principal's money, we count with more than one fund managers. These fund managers might, of course, have different opinions about selling or buying, what, when and how much. However, at the end of the day, they need one decision: the smart contract needs one input. To optimize this decision-making process, its traceability in the computational environment and its integration into the blockchain environment, we propose using formal argumentation and negotiation in the multi-agent systems setup. To have this paper self-contained, we introduce these methodologies and discuss their relevance and applicability in the current process in Section 4.

(iv) Integrating formal argumentation and multi-agent negotiation for creating the proper external input triggering the transaction's smart contract leads us to the framework we call Intelligent Human-input-based Blockchain Oracle (IHiBO). We consider three possible architectures in the blockchain framework, for each we have a different way to integrate argumentation and negotiation in the set of blockchain framework, evaluate and compare them regarding different technical and legal aspects in Section 5, we don't only consider traceability, verifiability, execution overhead costs and possible failure, but also the trade secret, and privacy issues related to each architecture.

Afterwards, we give the discussion, and not only the related works but also the consideration of our contribution and future perspectives.

2 Motivation

In this section, we generally talk about the procedure of fund management (at the securities market) and the roles of the parties and their relation, in order to show that the decision-making process can be suited into argumentation modeling.

Fund managers play an important role in the investment and financial world, they provide investors with peace of mind, knowing their money is in the hands of an expert [11]. However, the reality is not always as one wished, investors tend to know but they don't, in reality, where their money goes, why, and how much is the real profit. In portfolio management, the core duties of fund managers under AIFMD[6] and UCITSD[7] is to perform portfolio management and risk management on behalf of their investors. The fund can be managed by one person, by two people as co-managers, or by a team of three or more people. Fund managers primarily research and determine the best stocks, bonds, or other securities to fit the strategy of the fund, then buy and sell them. Since the fund managers are responsible for the success of the fund, they must also research

[6] Directive 2011/61/EU of the European Parliament and of the Council of 8 June 2011 on Alternative Investment Fund Managers (AIFMD.http://data.europa.eu/eli/dir/2011/61/oj)

[7] Directive 2009/65/EC of the European Parliament and of the Council of 13 July 2009 on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS). http://data.europa.eu/eli/dir/2009/65/oj

companies, and study the financial industry and the economy. Keeping up to date on trends in the industry helps the fund managers make key decisions that are consistent with the fund's goals [15]. The main characteristic of investing in a fund is trusting the investment management decisions to the professionals.

The process of portfolio management on the manager side is formally defined as follows [16][17]: *Portfolio management is a dynamic decision process, whereby a business's list of active new product (and development) projects is constantly up-dated and revised. In this process, new projects are evaluated, selected and prioritized; existing projects may be killed or de-prioritized. The portfolio decision process is characterized by uncertain and changing information, dynamic opportunities, multiple goals and strategic considerations, multiple decision-makers and locations. The portfolio decision process encompasses or overlaps a number of decision-making processes within the business, making Go/Kill decisions on individual projects on an on-going basis, and developing a new product strategy for the business.*

A possible simplified process of fund investment management includes the following activities. Firstly, the investors pool their money together. Then fund managers gather information and conduct investment research, prepare the specific plan for the investment portfolio. According to their research and the final decision of investment plan, fund managers invest securities on behalf of their clients (investors). The investment generates returns and the returns would be passed down to investors.

3 Formal Argumentation and Negotiation

In section 2, we show that fund managers conduct the securities transactions directly, such behavior creates a sense of insecurity in clients, how and why the fund managers make the investment plans and actions need to be explained and modeled. In the second move of fund management described in Fig.1, various managers might have different investment plans based on their own expertise and research that may conflict with each other. We present the solution proposals in this section to resolve the conflicts by formal argumentation and negotiation.

Formal argumentation or computational argumentation in artificial intelligence (AI) is a formalism for representing and reasoning with incomplete and inconsistent information. A wide variety of reasoning and dialogical activities can be captured by argumentation models in a formal and still quite intuitive way, allowing the integrationof different concrete techniques and the development of applications that humans can trust. Dung's work in 1995 illustrates an argumentation system consisting of a set of arguments and the relation (attacks) between them [21]. Argumentation semantics are defined later by Baroni and Giacomin for gathering acceptable arguments lying on different criterias [7], in a way that somehow emulates the way humans tackle such a complex task [1,5,50]. Formal argumentation also can be used for modeling the dynamic interactions among agents which is particularly at stake in a multi-agent context: the system evolves as the agents put forward new arguments or retract arguments and relations [10,19,36]. There are lots of variants of Dung's original framework, extending the theory with preference [2,30], support [14,71,72], probabilities [27,35], etc. In this section, we use agent abstract argumentation which is introduced in one of the authors' latest work [70], and autonomous negotiation for dealing with conflicting information raised by agents.

3.1 Agent Argumentation

We generalize argumentation frameworks studied by Dung (1995), which are directed graphs, where the nodes are arguments, and the arrows correspond to the attack relation.

Definition 1 (Argumentation framework [20]). *An* argumentation framework *(AF) is a pair $\langle \mathscr{A}, \rightarrow \rangle$ where $\mathscr{A}$ is a set called arguments, and $\rightarrow \subseteq \mathscr{A} \times \mathscr{A}$ is a binary relation over $\mathscr{A}$ called attack. For a set $S \subseteq \mathscr{A}$ and an argument $a \in \mathscr{A}$, we say that S attacks a if there exists $b \in S$ such that b attacks a, a attacks S if there exists $b \in S$ such that a attacks b, $a^- = \{b \in \mathscr{A} | b \text{ attacks } a\}$, $S^-_{out} = \{a \in \mathscr{A} \backslash S | \ a \text{ attacks } S\ \}$.*

Dung's admissibility-based semantics is based on the concept of defense. A set of arguments defends another argument if they attack all its attackers.

Definition 2 (Admissible [20]). *Let $\langle \mathscr{A}, \rightarrow \rangle$ be an AF. $E \subseteq \mathscr{A}$ is* conflict-free *iff there are no arguments a and b in E such that a attacks b. $E \subseteq \mathscr{A}$* defends *c iff for all arguments b attacking c, there is an argument a in E such that a attacks b. $E \subseteq \mathscr{A}$ is* admissible *iff it is conflict-free and defends all its elements.*

For their principle-based analysis, Baroni and Giacomin define semantics as a function from argumentation frameworks to sets of subsets of arguments.

Definition 3 (Dung semantics [7]). *A Dung semantics is a function σ that associates with an argumentation framework $AF = \langle \mathscr{A}, \rightarrow \rangle$, a set of subsets of $\mathscr{A}$, the elements of $\sigma(AF)$ are called extensions.*

Dung distinguishes several definitions of extension.

Definition 4 (Extensions [20]). *Let $\langle \mathscr{A}, \rightarrow \rangle$ be an AF. $E \subseteq \mathscr{A}$ is a* complete extension *iff it is admissible and it contains all arguments it defends, i.e., $E = \{a | E \text{ defends } a\}$. $E \subseteq \mathscr{A}$ is a* grounded extension *iff it is the smallest (for set inclusion) complete extension. $E \subseteq \mathscr{A}$ is a* preferred extension *iff it is a largest (for set inclusion) complete extension. $E \subseteq \mathscr{A}$ is a* stable extension *iff it is conflict-free and it attacks each argument which does not belong to E.*

Each kind of extension may be seen as an acceptability semantics that formally rules the argument evaluation process. In this article, we use $\sigma \in \{c, g, p, s\}$ to represent Dung semantics {complete, grounded, preferred, stable}.

An agent argumentation framework extends an argumentation framework with a set of agents and a relation associating arguments with agents. Note that an argument can belong to one agent or multiple agents.

Definition 5 (Agent argumentation framework [72]). *An* agent argumentation framework *(AAF) is a 4-tuple $\langle \mathscr{A}, \rightarrow, \mathscr{S}, \sqsubset \rangle$ where $\mathscr{A}$ is a set of arguments, $\rightarrow \subseteq \mathscr{A} \times \mathscr{A}$ is a binary relation over $\mathscr{A}$ called attack, $\mathscr{S}$ is a set of agents or sources, $\sqsubset \subseteq \mathscr{A} \times \mathscr{S}$ is a binary relation associating arguments with agents. $\mathscr{A}_\alpha = \{a \in \mathscr{A} | a \sqsubset \alpha\}$ for all arguments that belong to agent α, $\mathscr{S}_a = \{\alpha | a \sqsubset \alpha\}$ for all agents that have argument a.*

Social agent semantics [70] For the decision making of fund management, we use so-called social semantics, which is based on a reduction to preference-based argumentation by for each argument counting the number of agents that have the argument. It thus interprets agent argumentation as a kind of voting, as studied in social choice theory or judgment aggregation, this is also closed to fund management.

We first give the definition of a preference-based argumentation framework.

Definition 6 (Preference-based argumentation framework [30]). *A preference-based argumentation framework (PAF) is a 3-tuple* $\langle \mathscr{A}, \rightarrow, \succ \rangle$ *where* $\mathscr{A}$ *is a set of arguments,* $\rightarrow \subseteq \mathscr{A} \times \mathscr{A}$ *is a binary attack relation,* $\succ$ *is a partial order (irreflexive and transitive) over* $\mathscr{A}$ *, called preference relation.*

There are two different reductions of preference being first introduced[3], after which there are two more reductions [63]. We refer to those papers for an explanation and motivation, while users should select one reduction according to their particular application, one can refer to the principle-based approach to distinguish these reductions [63,70].

Definition 7 (Reductions of PAF to AF (PR)). *Given an* $PAF = \langle \mathscr{A}, \rightarrow, \succ \rangle$*:*

- $PR_1(PAF) = \langle \mathscr{A}, \rightarrow' \rangle$, *where* $\rightarrow' = \{a \rightarrow' b | a \rightarrow b, b \not\succ a\}$.
- $PR_2(PAF) = \langle \mathscr{A}, \rightarrow' \rangle$, *where* $\rightarrow' = \{(a \rightarrow' b | a \rightarrow b, b \not\succ a \text{ or } b \rightarrow a, \text{ not } a \rightarrow b, a \succ b\}$.
- $PR_3(PAF) = \langle \mathscr{A}, \rightarrow' \rangle$, *where* $\rightarrow' = \{(a \rightarrow' b | (a \rightarrow b, b \not\succ a \text{ or } a \rightarrow b, \text{ not } b \rightarrow a\}$.
- $PR_4(PAF) = \langle \mathscr{A}, \rightarrow' \rangle$, *where* $\rightarrow' = \{a \rightarrow' b | a \rightarrow b, b \not\succ a, \text{ or } b \rightarrow a, \text{ not } a \rightarrow b, a \succ b, \text{ or } a \rightarrow b, \text{ not } b \rightarrow a\}$.

In social agent semantics, an argument is preferred to another argument if it belongs to more agents. The reduction from AAF to PAF is used as an intermediary step for social agent semantics.

Definition 8 (Social Reductions of AAF to PAF (SAP)). *Given an* $AAF = \langle \mathscr{A}, \rightarrow, \mathscr{S}, \sqsubset \rangle$, $SAP(AAF) = \langle \mathscr{A}, \rightarrow, \succ \rangle$ *with* $\succ = \{a \succ b || \mathscr{S}_a| > |\mathscr{S}_b|\}$.

Definition 9 (Social Reductions of AAF to AF (SR)). *Given an* $AAF = \langle \mathscr{A}, \rightarrow, \mathscr{S}, \sqsubset \rangle$, $SR_i(AAF) = PR_i(SAP(AAF))$, PR_i *is one of the four reductions of PAF to AF, where the semantics* $\delta(AAF) = \sigma(SR_i(AAF)) = \sigma(PR_i(SAP(AAF)))$ *for* $i \in \{1,2,3,4\}$.

3.2 Autonomous Agents and Negotiation

A software agent is a software that acts on behalf of another actor (often a human user) to perform a task or achieve a given goal [69]. Agents are designed to be bound to individual perspectives [58]. This makes agents good candidates to represent the subjectivity and nuances of different expert opinions. Multi-agent systems [66] provide a distributed platform capable of implementing intelligence in decentralized ecosystems such as blockchain-based systems where agents are capable, using well-established conflict-resolution mechanisms (e.g. negotiation), of helping the different stakeholders finding agreements that satisfy their often conflicting interests.

In his influential book, Dean Pruitt provides one of negotiation's most widely accepted definitions: "Negotiation is the process by which a joint decision is made by two or more parties. The parties first verbalize contradictory demands and then move towards agreement by a process of concession making or search for new alternatives" [52]. The problem being negotiated, or the topic under discussion (e.g. car purchase) can be usually divided into issues (also called attributes). Some negotiations involve only single issue (e.g. car price) whereas others involve multiple issues (e.g. price and delivery time). Negotiators may not only disagree on the value assigned to each issue, the priority given to each issue can differ from one negotiator to another and hence this can be a source of both divergence and convergence [54]. Automated negotiation is one taking place among autonomous agents [28]. Autonomous negotiation has a protocol. The latter is the set of rules that governs the interactions during a negotiation session (also called a thread). Whereas the negotiation protocol defines what is the set of possible actions that can be taken during a negotiation session, an agent has a decision model [23,40] that allows the agent to (i) evaluate the value of an offer received from the opponent (e.g., using a utility function), (ii) decide whether it is acceptable (also called acceptance condition [6]), and (iii) determine what to do next (known as the negotiation strategy [23]). Automated negotiation has been applied to solve conflicts and reach agreements in several domains including cloud and service provisioning [41], smart grid and power distribution [62], and trading and stock market [67].

3.3 Conflict Resolution

The process of portfolio management fits well with argumentation theory in artificial intelligence. The decision can be seen as being based on arguments and counter-arguments. Argumentation, as the result, can be useful for deriving decisions and explaining a choice already made. Managers provide their arguments from their own research to identify promising stocks with different level of accuracy and thereby make different portfolio choices which are likely to be incomplete and inconsistent.

The fictitious simple example (the real life cases would be much more complex) is as follows. Manager α and β hold the arguments a: *To buy the stocks, since the company just donated to charities that is beneficial to good commercial reputation*, while another manager γ at the same time is against to buy the stocks, he holds the arguments b_1 and b_2, b_1 is *To sell the stocks, since there is evidence that the leader is under accusations of charity fraud*, and b_2 is *To sell the stocks, since the company has poor sales performance.* However, manager α brings out the argument c_1 *The official has clarified the accusations collapsed*, and β brings c_2 *The company is going to adopt a new technology which will bring huge benefit.*

Based on the above, we can build an agent argumentation framework on the left side of Fig.1, $AAF = \langle \mathscr{A}, \rightarrow, \mathscr{S}, \sqsubset \rangle$ where $\mathscr{A} = \{a, b_1, b_2, c_1, c_2\}$, $\rightarrow = \{(b_1,a), (b_2,a), (c_1,b_1), (c_2,b_2), (a,b_1), (a,b_2)\}$, $\mathscr{S} = \{\alpha, \beta, \gamma\}$, $\sqsubset = \{(a,\alpha), (a,\beta), (b_1,\gamma), (b_2,\gamma)$ $, (c_1,\alpha)$ $, (c_2,\beta)\}$. Since $|\mathscr{S}_a|$ it the most preferrred, we get the corresponding PAF where $a \succ b_1, b_2, c_1, c_2$, and giving the four reductions from PAF to AF, we have the only AF on the right side (without the preference below) of Fig.1. Then we can calculate the only acceptable set $\{a, c_1, c_2\}$. The set tells the final decision is to buy the stocks. One thing needs to be noticed: argumentation does not always provide a definite outcome. Depending on the decision making process, different protocols can be specified in advance for such cases: e.g. to roll back or to assign weights to the arguments and the relation among them (so that these cannot be always equal).

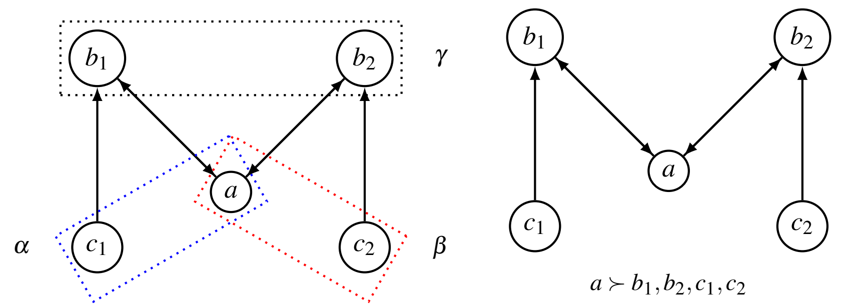

Fig. 1. Social reduction

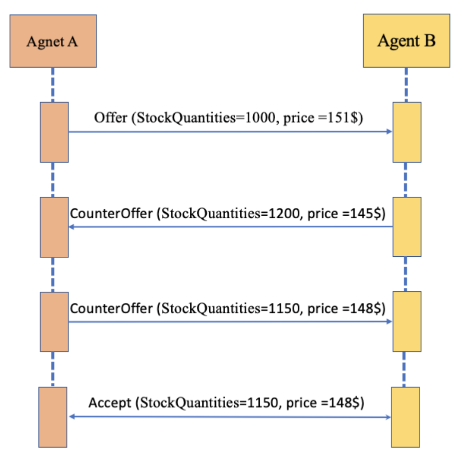

Fig. 2. Negotiation Sequence to Decide The Quantities and The Price

After deciding to sell the stocks, the next problem is the numbers of stocks to sell and the sell timing. Here the computational automated negotiation comes into play. To illustrate how it works, we give an example of the negotiation sequence based on the on the quantities of stocks to sell. The negotiation process is based on the alternating offer protocol [55]. Agents can bid new offers to the opponent ($Offer()$ function). When receiving an offer, and agent can accept it using $accept()$ function or reject it and propose a counter-offer (with the $CounterOffer()$ function). In the example, we have a manager *A*, i.e., agent *A*, and manager *B*, i.e., agent *B*. Agent *A* proposes to sell 1000 stocks at the price of 151$, while agent *B* counteroffers to sell 1200 stocks at the price of 145$, then agent *A* proposes to sell 1150 stocks at the price of 148$. The final offer given by *A* is accepted by both parties which means they come to an agreement.

4 Blockchain in Financial Agreements and Architectures

The tamper-resistant property of DLTs enables a favourable environment for storing information that can be later audited. For the fund management use case we are dealing with, we refer to a generic smart contract based operation of security transaction, implemented using different kinds of the systems/technologies. In this subsection, we outline the potential of distributed ledger technologies (DLTs) to revolutionize financial agreements and a particular instance of how fund managers trade securities on behalf of their clients on blockchain platform.

4.1 Distributed Ledger Technologies

There is a growing body of work generated on the design and utilization principles for blockchain and DLTs [33]. The underlying premise of blockchain and its various applications is the elimination of untrustworthy third parties such that the users themselves are the authority of maintaining the ledgers which are immutable. The immutability of blockchains also enhances the distributed trust since it is nearly impossible to tamper any transactions stored in blockchains and all the historical transactions are auditable and traceable [73]. In the case of the blockchain, the ledger is organized into chronologically ordered blocks where each block is sequentially linked to the previous one [42]. When the majority of network nodes execute the exact same protocol, such as in the Bitcoin network, the blockchain is cryptographically guaranteed to be tamper-proof and unforgeable. A feature that some DLTs enable is the possibility to execute smart contracts, firstly introduced by the Ethereum blockchain [13], which is reshaping the conventional commercial industries [32,73,74]. Smart contracts consist of instructions that, once deployed on the ledger, cannot be altered and thus allowing the outcome of their execution to be always the same for anyone who runs it (i.e. the DLT network nodes). Usually, the possible instructions of a smart contract are embedded in the DLT protocol and their execution can only involve data coming from other smart contracts or from the user's inputs, e.g. smart contracts cannot fetch a webpage on the Internet. This "closure" ensures the execution of smart contracts to be more resistant to attacks with a higher degree of certainty, thus making the whole system more secure [73]. However, it also leads to a very restricted use case where DLTs are actually closed networks like a computer with no Internet connection. This obviously limits the possible usage of these technologies, since the vast majority of the possible smart contract applications would require real-time information from the network external world.

In order for smart contracts to operate in the real world, data must flow in both directions and thus the high demand for applications gave birth to blockcahin oracles. These third-party systems act as a bridge that connects the DLT network and the "outside" world, providing the ability to retrieve, verify and digest the data into smart contracts.

Oracles can be implemented as: (i) software, by far the most widely used, they interact with the information needed from online sources; (ii) hardware, retrieve data from the physical world directly through scanners sensors; (iii) human, interacting with individuals. In all cases their off-chain execution is either centralized, i.e. coming from a single source, or decentralized, consensus-based multitude of sources [9].

4.2 Decentralized Finance

Both scholars and industries have examined the commercial implications of DLTs and smart contracts, for instance, the financial services of tokenized securities settlement and clearing[29]. The advent of DLTs has the potential to restructure this paradigm by breaking the stigma, only apparently immutable, of centrality and of central counterparties (CCPs) [51]. Decentralized Financial Market Infrastructures (dFMI) [24] *are consortium entities whose members are comprised of the main participants in a market, organized in a peer-to-peer model, which is governed by dFMI participants themselves rather than a central intermediary.* In some applications smart contracts can take on a role similar to that previously played CCPs, e.g. acting as a margin calculating agent and taking on the task of transferring collateral. Although in a different way, the smart contract can be used to resolve disputes in the event of non-compliance with payment [39]. Alternatively, smart contracts can support the central counterparty, which can maintain the business model by leveraging the blockchain to calculate and update collateral as well as manage funds, thus relying on financial cryptography. A concrete application of DLTs for the trading of securities by fund managers is Lianjiaorong, a blockchain AssetBacked securitization platform, built by the Bank of Communications in China [47]. The blockchain is maintained by original stock holders, trust companies, investors, rating agencies, accountants, lawyers, regulators and it links funds and assets on the ledger, realizing the credit penetration of the securities business system.

4.3 Blockchain Architectures

In this subsection we deal with the operation that is the outcome of the negotiation and argumentation processes seen above, i.e. the decision, that is given as input to a smart contract, e.g., buy a stock. We refer to this smart contract as the “TransactionSC”. In the following, we compare three different architectures that can take form in our blockchain framework, for reaching the decision to give as input to the TransactionSC (Figure 3). We take as reference Table 1 for comparing the three architectures.

1. Centralized Oracle The first architecture we consider is the simplest one, where argumentation and negotiation phases do not involve any blockchain process, neither a smart contract execution. These are executed in a “centralized” environment, e.g. a web platform or an internal firm application. Each decision coming after the negotiation will be given as input to the TransactionSC by a single service in this environment, that provides the role of an oracle.

A discriminating factor in choosing one architecture over another is where the information needed for execution is stored. In the case of this architecture, i.e. using a

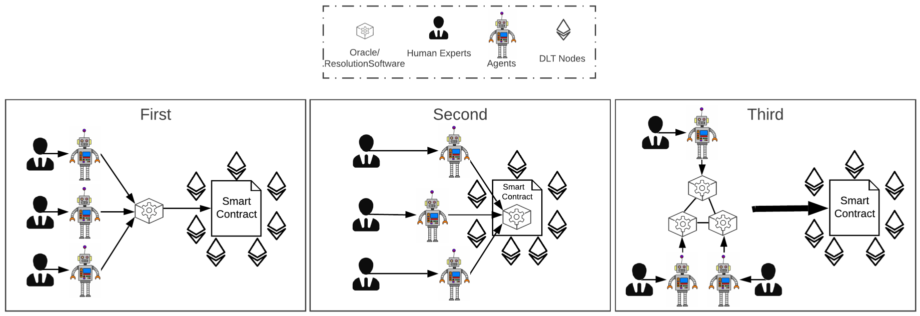

Fig. 3. IHiBO with three architectures

classical centralised oracle, the complete execution of the conflict resolution would be scarcely verifiable, because only the results would be stored on the blockchain. It would also be highly susceptible to a single point of failure.

2. Smart Contract Argumentation and Negotiation In the second architecture, argumentation and negotiation are directly implemented as smart contracts, and thus are executed following the blockchain protocol. It means that the human experts, through their agent software, directly interact with the blockchain for giving in input the data for constructing the argumentation graph and then for enacting the negotiation functions that are expressed as smart contract instructions.

The argumentation graph (and all the data needed for execution too) is necessary for the execution of the whole process, so it is constantly updated. This information only needs to be stored on the ledger in the case of this architecture. The disadvantages of storing large amounts of data on-chain are many, mainly, the high transaction cost [32] and the almost impractical deployment latency [75]. However, the advantage of this architecture is that trade execution would be fully tracked and verifiable, as execution would be done completely through smart contracts in the blockchain.

3. Decentralized Oracle Finally, the third architecture we consider consists of a network of agents that execute a distributed software independently of the blockchain protocol and that limit the execution of the smart contract instructions to only a few steps, necessary to be trustworthy. The implementation of such network consists in the so called "layer two" solution [25], where the same principle of decentralization of DLTs is applied. Indeed, an instance of such layer two solution would be the use of a second DLT with different features in respect to the "main" one [56] where to write the negotiation outcome, e.g. consensus mechanism, or faster operations execution.

A good compromise between the two architectures would be the use of this architecture, i.e. a decentralised oracle, over the others to perform the argumentation, negotiation and interaction with TransactionSC. The data needed to execute these processes, such as the argumentation graph, would be stored in a lower cost secondary DLT or other layer two technology that preserves the immutability of the data. The execution of the negotiation could take place outside the chain and then be "committed" [25] on the main chain using a hash function to be immutable and therefore verifiable. It would not be susceptible to a single point of failure and the cost of execution overhead would be favourable compared to the second architecture.

Table 1. Comparison between the three architectures considered.

	Argumentation Graph Off-chain	Negotiation Execution Tracing	No Single Point of Failure	No Execution Overhead Costs	Tamper-resistant	Verifiability	Privacy
Architecture 1 **Centralized**	✓	×	×	✓	×	×	✓✓
Architecture 2 **Smart Contract**	×	✓✓	✓	×	✓✓	✓✓	×
Architecture 3 **Decentralized**	✓	✓	✓	×	✓✓	✓✓	✓

5 Intelligent Human-input-based Blockchain Oracle (IHiBO)

In this section, we propose IHiBO, that leverages blockchain and smart contracts framework, which provides a favourable environment with their salient properties, i.e., auditability, traceability and transparency. IHiBO can deal with the potentially inconsistent information input by human experts: we explained how the system may manage the information by argumentation and negotiation considering three possible architectures.

5.1 Combining Formal Argumentation and Negotiation with the Blockchain Framework for Transparency

Argumentation has the ability to provide various ways for explaining why a claim or a decision is made. In this section, the IHiBO we propose might have particular relevance in cases where the decision making process about what data should be fed in the smart contract needs to be transparent: for fund management, the investors don't know what exactly happens to their money, and especially why, so the question whether the fund managers do fulfill their legal and ethical commitment of acting in the best interest of the investor might remain unanswered.

In general, the transparency that can be gained due to the proposed intelligent oracle architecture could be highly valuable in any trust services. The concept of the fiduciary is based on—as the name of these services show—trust: it requires being bound both legally and ethically to operate and use its expertise in the investor's best interests on the fiduciary's side, and it requires trust on the investor's side to believe in that the fiduciary has done and will do so. This trust can be, to some extent, replaced by intelligent, decentralized solutions providing full transparency of, for instance, fund management: not only the transactions can be fully traced but the expert opinion input and the decision mechanism too. By implementing argumentation and negotiation phases through oracles into smart contract or make them on a side-chain can generate more transparency for investors: investors can know how the final decision is made at the end of reasoning. This could be highly relevant for the investor practicing his right to check the fiduciary's activities in the case of an asset management contract. From Explainable AI perspective, Architecture 2 and Architecture 3 offer an explanation to how a specific decisions has been made.

5.2 Legal Considerations

Next to the technical and financial aspects, legal considerations should also be taken into account when comparing the different architectures. While our motivation is to provide transparency regarding the decision-making process to the principal to gain some insights whether the work of the fiduciary indeed happens according to his best interest, the transparency one should gain with using DLTs is subject to serious limitations.

On one hand, the the principal's right to check is not limitless, it concerns strictly the processes of managing his assets, but more importantly, given the characteristics of DLTs, a(n unwantedly) broader audience would be involved in the disclosure of information if one chose not the appropriate architecture, threatening trade secrets and involving privacy problems.

On the other hand, once the application of DLTs become widespread in the securities market, mandatory disclosure rules motivated by anti-tax avoidance should be aligned with the new technology [61]. Indeed, DLT-based automated disclosure may lead to the release of information that is too fast, limiting the ability of investors to properly speculating. Thus, mandatory disclosure requirements would still be necessary, but the enforcement of such provisions and detection of violations redesigned using DLTs and smart contract would have to deal with the necessity of stakeholders.

Architecture 3 seems to be the best option from these point of view too: in contrast to the public, permissionless verification that DLTs usually employ while smart contracts are executed, layer two solutions usually move this process off-chain. This definitely poses security issues compared to a protocol executed completely on-chain, however there are currently some viable solutions proposed that address this issue [24]. For instance, an application might be the use of a permissioned sidechain. In this case, information that would clash with trade secrets and privacy would be stored on that permissioned chain and maintained by the participants who have been nominated for this, e.g. joint data controllers as permissioned blockchain operators [37]. Through the use of commitments on the main chain [25], i.e., the permissionless one, the necessary steps for verification are implemented, and once the fiduciaries operating the sidechain reveal part of the information to the principals, the latter can verify its validity on-chain [56].

5.3 IHiBO Direction

We argue that a layer two solution, the decentralized oracle solution in Architecture 3, provides the proper mid ground in terms of cost of execution, for latency and fees, and verifiability of the complete process. Indeed, there might be use cases where some data should not be disclosed, and an argumentation and negotiation architecture based on a full execution on smart contracts would not allow it. In the other extreme case, for a centralized oracle, the entire process behind a decision made could be concealed or its log could be altered. In a decentralized oracle architecture the complete execution could be logged off-chain and then committed on-chain, making it impossible to alter the logs, while not disclosing these entirely [25]. Members of the management body[8] shall have adequate access to information and documents which are needed to oversee and monitor management decision-making[9]. In our second and third architectures, each execution of all the smart contracts can be audited, validated and maintained by every participants, thus reduce the time and fee of extra work of surveillance, which will in turn reduce potential corruption or conflicts of interests.

6 Discussion

IHiBO can develop the degree of trust in several ways. As argued by Walton, it seems to be more generally acknowledged now that we do have to rely on experts, and that such sources of evidence should be given at least some weight in deciding what to do in practical matters [65]. In our case study, managers play the role of experts and the professional certificate of them as well as their past creditable experience could be part of the backup of trustworthiness of the source information, and we calculate the weight of the arguments in the parallel of voting theory, i.e. to count the number of supporting managers. Formal argumentation systems have been computationally implemented that can be used to model arguments from expert opinion and to evaluate them when they are nested within related arguments in a larger body of evidence. One such system is ASPIC+ [49]. ASPIC+ is based on a Dung-style abstract argumentation framework that determines the success of argument attacks and that compares conflicts in arguments at the points where they conflict [21]. Our adoption of agent argumentation is also originated from Dung's framework, while we extend it with the role of agents and associated relation with arguments. Such that together with blockchain technology, investors are in a clear position to audit the source of arguments, and the way they communicated.

Another way to gain and restore trust from investors is to make the resources and decision-making process explicit, our case can be considered as a good example of the use of argumentation for favouring trust. Being skillful and sophisticated could be

[8] Art. 4(8) MiFID II: 'management body' means the body or bodies of an investment firm, market operator or data reporting services provider, which are appointed in accordance with national law, which oversee and monitor management decision-making and include persons who effectively direct the business of the entity.

[9] DIRECTIVE 2014/65/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 May 2014 on markets in financial instruments and amending Directive 2002/92/EC and Directive 2011/61/EU

not enough for the requirement of managers. Especially when they are in corporation, other problems may arise to obtaining trust, like reliability and agency problems. For instance, problems arising from managers' unwillingness and lack of incentives to act in the principal's best interests, rather than from a lack of expertise. In our case design, investors have the advantages to audit the resources of the information, thus such risks could be mitigated.

Falcone and Castelfranchi relate trust explicitly to the goals of agents, and consider trust to be concerned with whether another agent can and will perform an action that will enable the first agent to achieve its goals [22]. In the case of fund management, fund managers are sharing the same goal——gain interests for the investors. In the study case, agents must coordinate and communicate with their own information to reach an agreement. In this scenario, the requirement to reach trust is to ensure and audit the trustworthiness of a source of information within an argument which is then to be decided to be accepted or not. We ensure the trustworthiness of the information by counting the values or the numbers of support from agent to arguments to ensure the resources based on somehow voting theory.

On the other hand, the adoption of blockchain and DLT has been under consideration for several years both from economic and legal aspects [26,51]. However, most of them only consider the transaction process, i.e. how to use these technologies for clearing and settlement, and some propose to use smart contracts to conduct the functions of CCP or central securities depository (CSD) [10] [44]. In our work, we pay attention to the pre-trading phase, where the investment decisions made by the trust services are extremely crucial to investors. As discussed above, the decision-making process is traceable and immutable on blockchain. As a result, the entire reasoning decision and transaction process are transparent and investors can gain maximum confidence and thus trust for the trust services.

7 Related work

Our methodology is a hybrid of decision-making based on formal argumentation, autonomous negotiation, blockchain, smart contracts, and oracles, all of these are serving for the trust service, thus, we need to look at the related work from multiple perspectives. To the best of our knowledge, there is no mature work on adopting argumentation in the financial world. The only work we can find is to use argumentation as a convincing tool in order to gain the stakeholders' support and trust; it also mentions that argumentation is a communicative interaction which conducts the claims as propositions, e.g. "You should invest in Treasury Bonds" [46].

There is influential work on argumentation and trust has been done. First of all, trust in information sources has been used in argumentative reasoning. This is also true with respect to the exchange of arguments in social interaction. When people argue with other parties, trying to make their arguments accepted to reach a final agreement,

[10] CSDs operate the infrastructure that enables the securities settlement, allow the registration and safekeeping of securities, allow the settlement of securities in exchange for cash, track how many securities have been issued and by whom, track each change in the ownership of these securities

they also evaluate the arguments proposed by the opponents in the discussion. In the earlier work on argumentation theory, people only focus on the relation among arguments, i.e. the arguments are considered to be accepted or not depending on the attacks against them [53]. Neither the information sources nor their trustworthiness degree are considered. In recent years, the area has seen a number of proposals [38,48,57,60,64] to introduce the trust component in the evaluation process of arguments. Argumentation also has been used to reason about trust evaluations. Trust is a process of critical judgement rather than a blind altitude where argumentation can come into play as a powerful tool to reason about trust, making sure such trust is well-built. In their earlier work, Parsons et al suggest argumentation might play a role which tracks the origin of information used in reasoning, thus it can provide provenance in trust [48]. Later the same authors develop a general system of argumentation that can represent trust information, and be used in combination with a trust network, using the trustworthiness of the information sources as a measure of the probability that information is true [59].

In the IHiBO architecture, we use the oracles requiring input which involves human intervention. Human oracles are rarely applied [18]. The rare existing ones are applied in applications with binary inputs, i.e., they only take input by one of two possibilities, typically ”yes” or ”no” [43]. This greatly narrows the scope of questions the answer to which we could rely on human experts. There can be cases where the missing input is not binary, but contains further and different types of data, while the generation of input of some smart contracts requires in particular human subjective judgment. The advantage of human assessment is also apparent in situations where contractual performance must be evaluated holistically, rather than by simple measurement of specific parameters.

8 Conclusion and Future Perspectives

The main contribution of this paper is proposing an integrated framework which incorporates formal argumentation and negotiation within a blockchain. These techniques have distinctive features that complement each other. They together make the decision-making processes of fund management transparent and traceable. As a result, our methodology enhances trust from principals to trust services, especially the famous form of trust, i.e., knowledge-based trust [34], which is grounded when knowing the other (fund management) sufficiently well so that the behavior of managers can be understood and predicted more accurately. Our motivation came from trust services, so we explained our idea in a fund management scenario, but our proposal is not bound to this domain.

One follow-up possible work is to provide and adapt to a high level of adaptability in the decisions of the fund management. For instance, to define different investment scenarios according to the investors' preferences, attitude (aggressive or moderate) and the financial environment (e.g. bull or bear market), including the possibility to forecast the status of the financial market for the next investment period, in order to select the ones which will bring the biggest interests. Besides, we plan to explore the combination of negotiation and argumentation. For instance, here we adopt a simplified example on fund investment, the real life relying on existing works proposing argumentation-based negotiation is a useful next step since exchanging justified information among agents gives them enough knowledge to try and reach a common understanding much faster [12].

Another possible work could be to investigate the integration of consensus mechanisms for a layer two solution to the dispute resolution phase, in order to narrow the gap between blockchain and argumentation as well as negotiation, since there is no specialized blockchain yet that has a protocol that integrates reasoning. For instance, if there is a blockchain based on *Proof of Stake* (instead of *Proof of Work*), validators need to vote to validate a transaction based on a reasoning process where each validator has a different set of knowledge data.

Lastly, we also plan to rely on the recent advances of the domain of Explainable AI [4] to explore how we can make the decision-making process presented in this paper explainable for different types of users (experts, non-experts, etc.) and for different purposes (e.g. transparency, debugging, etc.).

Acknowledgements

This work has received funding from the EU H2020 research and innovation programme under the Marie Skłodowska-Curie Actions Innovative Training Networks European Joint Doctorate grant agreement No 814177 Law, Science and Technology Joint Doctorate - Rights of Internet of Everything.

References

1. Leila Amgoud and Claudette Cayrol. Inferring from inconsistency in preference-based argumentation frameworks. *Journal of Automated Reasoning*, 29(2):125–169, 2002.
2. Leila Amgoud and Claudette Cayrol. On the acceptability of arguments in preference-based argumentation. *CoRR*, abs/1301.7358, 2013.
3. Leila Amgoud and Srdjan Vesic. Rich preference-based argumentation frameworks. *International Journal of Approximate Reasoning*, 55(2):585–606, 2014.
4. Sule Anjomshoae, Amro Najjar, Davide Calvaresi, and Kary Främling. Explainable agents and robots: Results from a systematic literature review. In *18th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2019), Montreal, Canada, May 13–17, 2019*, pages 1078–1088. International Foundation for Autonomous Agents and Multiagent Systems, 2019.
5. Katie Atkinson, Pietro Baroni, Massimiliano Giacomin, Anthony Hunter, Henry Prakken, Chris Reed, Guillermo Simari, Matthias Thimm, and Serena Villata. Towards artificial argumentation. *AI magazine*, 38(3):25–36, 2017.
6. Tim Baarslag, Koen Hindriks, and Catholijn Jonker. Acceptance conditions in automated negotiation. In *Complex Automated Negotiations: Theories, Models, and Software Competitions*, pages 95–111. Springer, 2013.
7. Pietro Baroni and Massimiliano Giacomin. On principle-based evaluation of extension-based argumentation semantics. *Artificial Intelligence*, 171(10-15):675–700, 2007.
8. Moritz Becker and Balázs Bodó. Trust in blockchain-based systems. *Internet Policy Review*, 10(2), 2021.
9. Abdeljalil Beniiche. A study of blockchain oracles. *arXiv preprint arXiv:2004.07140*, 2020.

10. Guido Boella, Souhila Kaci, and Leendert Van Der Torre. Dynamics in argumentation with single extensions: Abstraction principles and the grounded extension. In *European Conference on Symbolic and Quantitative Approaches to Reasoning and Uncertainty*, pages 107–118. Springer, 2009.
11. Paul M Bosse, Douglas M Grim, and CFA Frank Chism. Duty, opportunity, mastery: Investment committee best practices, 2017.
12. Luís Brito, Paulo Novais, and José Neves. The logic behind negotiation: from pre-argument reasoning to argument-based negotiation. In *Intelligent agent software engineering*, pages 137–159. IGI Global, 2003.
13. Vitalik Buterin et al. Ethereum white paper, 2013.
14. Claudette Cayrol and Marie-Christine Lagasquie-Schiex. On the acceptability of arguments in bipolar argumentation frameworks. In *European Conference on Symbolic and Quantitative Approaches to Reasoning and Uncertainty*, pages 378–389. Springer, 2005.
15. James Chen. Fund manager, 2021.
16. Robert G Cooper, Scott J Edgett, and Elko J Kleinschmidt. Portfolio management in new product development: Lessons from the leaders—i. *Research-Technology Management*, 40(5):16–28, 1997.
17. Robert Gravlin Cooper. *Winning at new products*. Addison-Wesley Reading, MA, 1986.
18. Matija Damjan. The interface between blockchain and the real world. *Ragion pratica*, pages 379–406, 2018.
19. Sylvie Doutre and Jean-Guy Mailly. Constraints and changes: A survey of abstract argumentation dynamics. *Argument & Computation*, 9(3):223–248, 2018.
20. Phan M. Dung. On the acceptability of arguments and its fundamental role in non-monotonic reasoning, logic programming and n-person games. *Artificial Intelligence*, 77:321–357, 1995.
21. Phan Minh Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial intelligence*, 77(2):321–357, 1995.
22. Rino Falcone and Cristiano Castelfranchi. Social trust: A cognitive approach. In *Trust and deception in virtual societies*, pages 55–90. Springer, 2001.
23. Peyman Faratin, Carles Sierra, and Nick R Jennings. Negotiation decision functions for autonomous agents. *Robotics and Autonomous Systems*, 24(3-4):159–182, 1998.
24. Sara Feenan, Daniel Heller, Alexander Lipton, Massimo Morini, Rhomaios Ram, Robert Sams, Tim Swanson, Stanley Yong, and Diana Barrero Zalles. Decentralized financial market infrastructures. *The Journal of FinTech, Forthcoming*, 2020.
25. Lewis Gudgeon, Pedro Moreno-Sanchez, Stefanie Roos, Patrick McCorry, and Arthur Gervais. Sok: Layer-two blockchain protocols. In *International Conference on Financial Cryptography and Data Security*, pages 201–226. Springer, 2020.
26. Sebastiaan Niels Hooghiemstra. Distributed ledger technology ('dlt') and its impact (on the regulation of) european investment funds. *Available at SSRN 3735886*, 2020.
27. Anthony Hunter and Matthias Thimm. Probabilistic reasoning with abstract argumentation frameworks. *Journal of Artificial Intelligence Research*, 59:565–611, 2017.
28. Nicholas R Jennings, Peyman Faratin, Alessio R Lomuscio, Simon Parsons, Carles Sierra, and Michael Wooldridge. Automated negotiation: prospects, methods and challenges. *International Journal of Group Decision and Negotiation*, 10(2):199–215, 2001.
29. Johannes Rude Jensen, Victor von Wachter, and Omri Ross. An introduction to decentralized finance (defi). *Complex Systems Informatics and Modeling Quarterly*, (26):46–54, 2021.
30. Souhila Kaci and Leendert van der Torre. Preference-based argumentation: Arguments supporting multiple values. *International Journal of Approximate Reasoning*, 48(3):730–751, 2008.

31. Andrew Koster, Jordi Sabater-Mir, and Marco Schorlemmer. Argumentation and trust. In *Agreement Technologies*, pages 441–451. Springer, 2013.
32. Yeşem Kurt Peker, Xavier Rodriguez, James Ericsson, Suk Jin Lee, and Alfredo J Perez. A cost analysis of internet of things sensor data storage on blockchain via smart contracts. *Electronics*, 9(2):244, 2020.
33. Olga Labazova. Towards a framework for evaluation of blockchain implementations. 2019.
34. Roy J Lewicki and Barbara Benedict Bunker. Developing and maintaining trust in working relationships.‖ in rm kramer and tr tyler (eds.), trust in organizations: Frontiers of theory and research, 1996.
35. Hengfei Li, Nir Oren, and Timothy J Norman. Probabilistic argumentation frameworks. In *International Workshop on Theorie and Applications of Formal Argumentation*, pages 1–16. Springer, 2011.
36. Beishui Liao, Li Jin, and Robert C Koons. Dynamics of argumentation systems: A division-based method. *Artificial Intelligence*, 175(11):1790–1814, 2011.
37. Tom Lyons, L Courcelas, and K Timsit. Blockchain and the gdpr. In *The European Union Blockchain Observatory and Forum*, 2018.
38. Paul-Amaury Matt, Maxime Morge, and Francesca Toni. Combining statistics and arguments to compute trust. In *Proceedings of the 9th International Conference on Autonomous Agents and Multiagent Systems: volume 1-Volume 1*, pages 209–216. Citeseer, 2010.
39. Massimo Morini. Managing derivatives on a blockchain. a financial market professional implementation. *A Financial Market Professional Implementation (May 5, 2017)*, 2017.
40. A Najjar. *Multi-agent negotiation for qoe-aware cloud elasticity management*. PhD thesis, PhD thesis, École nationale supérieure des mines de Saint-Étienne, 2015.
41. Amro Najjar, Xavier Serpaggi, Christophe Gravier, and Olivier Boissier. Multi-agent negotiation for user-centric elasticity management in the cloud. In *2013 IEEE/ACM 6th International Conference on Utility and Cloud Computing*, pages 357–362. IEEE, 2013.
42. Satoshi Nakamoto. Bitcoin: A peer-to-peer electronic cash system, 2008.
43. Keerthi Nelaturu, John Adler, Marco Merlini, Ryan Berryhill, Neil Veira, Zissis Poulos, and Andreas Veneris. On public crowdsource-based mechanisms for a decentralized blockchain oracle. *IEEE Transactions on Engineering Management*, 67(4):1444–1458, 2020.
44. Simona-Vasilica Oprea, Adela Bâra, and Anca Ioana Andreescu. Two novel blockchain-based market settlement mechanisms embedded into smart contracts for securely trading renewable energy. *IEEE Access*, 8:212548–212556, 2020.
45. Fabio Paglieri. Trust, argumentation and technology. *Argument Comput.*, 5(2-3):119–122, 2014.
46. Rudy Palmieri. Regaining trust through argumentation in the context of the current financial-economic crisis. *Studies in Communication Sciences*, 9(2):59–78, 2009.
47. Wenxuan Pan and Meikang Qiu. Application of blockchain in asset-backed securitization. In *2020 IEEE 6th Intl Conference on Big Data Security on Cloud (BigDataSecurity), IEEE Intl Conference on High Performance and Smart Computing,(HPSC) and IEEE Intl Conference on Intelligent Data and Security (IDS)*, pages 71–76. IEEE, 2020.
48. Simon Parsons, Peter McBurney, and Elizabeth Sklar. Reasoning about trust using argumentation: A position paper. In *International Workshop on Argumentation in Multi-Agent Systems*, pages 159–170. Springer, 2010.
49. Henry Prakken. An overview of formal models of argumentation and their application in philosophy. *Studies in logic*, 4(1):65–86, 2011.
50. Henry Prakken and Giovanni Sartor. Argument-based extended logic programming with defeasible priorities. *Journal of applied non-classical logics*, 7(1-2):25–75, 1997.
51. Randy Priem. Distributed ledger technology for securities clearing and settlement: benefits, risks, and regulatory implications. *Financial Innovation*, 6(1):1–25, 2020.

52. Dean G Pruitt. *Negotiation behavior*. Academic Press, 2013.
53. Iyad Rahwan and Guillermo R Simari. *Argumentation in artificial intelligence*, volume 47. Springer, 2009.
54. Howard Raiffa. *Negotiation analysis: The science and art of collaborative decision making*. Harvard University Press, 2007.
55. Ariel Rubinstein. Perfect equilibrium in a bargaining model. *Econometrica: Journal of the Econometric Society*, pages 97–109, 1982.
56. Amritraj Singh, Kelly Click, Reza M Parizi, Qi Zhang, Ali Dehghantanha, and Kim-Kwang Raymond Choo. Sidechain technologies in blockchain networks: An examination and state-of-the-art review. *Journal of Network and Computer Applications*, 149:102471, 2020.
57. Ruben Stranders, Mathijs de Weerdt, and Cees Witteveen. Fuzzy argumentation for trust. In *International Workshop on Computational Logic in Multi-Agent Systems*, pages 214–230. Springer, 2007.
58. Katia P Sycara. Multiagent systems. *AI magazine*, 19(2):79–79, 1998.
59. Yuqing Tang, Kai Cai, Elizabeth Sklar, Peter McBurney, and Simon Parsons. A system of argumentation for reasoning about trust. In *Proceedings of the 8th European Workshop on Multi-Agent Systems, Paris, France*, 2010.
60. WT Luke Teacy, Jigar Patel, Nicholas R Jennings, and Michael Luck. Travos: Trust and reputation in the context of inaccurate information sources. *Autonomous Agents and Multi-Agent Systems*, 12(2):183–198, 2006.
61. Muthukkumarasamy Thuvarakan. Regulatory changes for redesigned securities markets with distributed ledger technology. *The Knowledge Engineering Review*, 35, 2020.
62. Rijo Jackson Tom, Suresh Sankaranarayanan, and Joel JPC Rodrigues. Agent negotiation in an iot-fog based power distribution system for demand reduction. *Sustainable Energy Technologies and Assessments*, 38:100653, 2020.
63. Leon van der Torre and Srdjan Vesic. The principle-based approach to abstract argumentation semantics. *FLAP*, 4(8), 2017.
64. Serena Villata, Guido Boella, Dov M Gabbay, and Leendert Van Der Torre. Arguing about the trustworthiness of the information sources. In *European Conference on Symbolic and Quantitative Approaches to Reasoning and Uncertainty*, pages 74–85. Springer, 2011.
65. Douglas Walton. On a razor's edge: Evaluating arguments from expert opinion. *Argument & computation*, 5(2-3):139–159, 2014.
66. Gerhard Weiss. *Multiagent Systems*. MIT Press, 2013.
67. Michael P Wellman, Amy Greenwald, and Peter Stone. *Autonomous bidding agents: Strategies and lessons from the trading agent competition*. Mit Press, 2007.
68. Sam M Werner, Daniel Perez, Lewis Gudgeon, Ariah Klages-Mundt, Dominik Harz, and William J Knottenbelt. Sok: Decentralized finance (defi). *arXiv preprint arXiv:2101.08778*, 2021.
69. Michael Wooldridge. *An introduction to multiagent systems*. John wiley & sons, 2009.
70. Liuwen Yu, Dongheng Chen, Lisha Qiao, Yiqi Shen, and Leendert van der Torre. A principle-based analysis of abstract agent argumentation semantics. 2021. under review.
71. Liuwen Yu, Réka Markovich, and Leendert Van Der Torre. Interpretations of support among arguments. In *Legal Knowledge and Information Systems*, pages 194–203. IOS Press, 2020.
72. Liuwen Yu and Leendert van der Torre. A principle-based approach to bipolar argumentation. In *NMR 2020 Workshop Notes*, page 227, 2020.
73. Zibin Zheng, Shaoan Xie, Hong-Ning Dai, Weili Chen, Xiangping Chen, Jian Weng, and Muhammad Imran. An overview on smart contracts: Challenges, advances and platforms. *Future Generation Computer Systems*, 105:475–491, 2020.

74. Mirko Zichichi, Stefano Ferretti, Gabriele D'Angelo, and Víctor Rodríguez-Doncel. Personal data access control through distributed authorization. In *2020 IEEE 19th International Symposium on Network Computing and Applications (NCA)*, pages 1–4. IEEE, 2020.
75. Mirko Zichichi, Stefano Ferretti, and Gabriele D'angelo. A framework based on distributed ledger technologies for data management and services in intelligent transportation systems. *IEEE Access*, 8:100384–100402, 2020.