Blockchain-enabled Peer-to-peer Value Capture: a Fair Transaction Mechanism

Kamal Bouhassoune, Sam Goundar and Abdelkrim Haqiq, *Member, IAENG*

***Abstract* - Blockchain technology significantly enhances cooperative behaviors across various industries by providing transparency and fairness in value distribution. This paper develops a novel blockchain-enabled peer-to-peer value capture mechanism using cooperative game theory. Specifically, we employ the Shapley value concept to design and implement a fair transaction mechanism through blockchain smart contracts. Comprehensive numerical simulations demonstrate the proposed model's transparency, fairness, and distributed efficiency. Our findings indicate substantial theoretical and practical implications, offering enterprises and cooperative networks an automated, transparent, and equitable method for capturing and distributing value.**

***Index Terms* - Blockchain, Cooperative game theory, Shapley value, Smart contracts, Value capture.**

I. Introduction

Trust remains essential in multi-party collaborations, as cooperative endeavors inherently involve the creation, exchange, and capture of value among participants. More than a decade ago, blockchain technology emerged as a groundbreaking solution for decentralized digital value exchange, underpinning cryptocurrencies such as Bitcoin [1]. Blockchain technology provides a robust infrastructure enabling transparent and immutable transactions within peer-to-peer networks, fostering decentralized trust, cooperative behavior and currency [2].

Blockchain significantly promotes cooperative behavior through several inherent mechanisms: first, shared resources like computing power and data storage encourage peer-to-peer cooperation; second, built-in consensus and incentive mechanisms reinforce cooperative network integrity; third, transparent and verifiable transactions increase participants' trust and willingness to cooperate [3].

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K. Bouhassoune is a PhD researcher at Hassan First University, Faculty of Sciences and Techniques, in the Department of Mathematics, Computer Science and Applications, within the Computer, Networks, Mobility and Modeling Laboratory (IR2M), BP : 577, Route de Casablanca, 26000, Settat, Morocco (e-mail: k.bouhassoune@uhp.ac.ma, ORCID: https://orcid.org/0000-0001-5848-5619).

S. Goundar is a professor at RMIT University, School of Computing, in the Department of Science, Engineering and Technology, Handi Resco Building, 521 Kim Ma, Ba Dinh District, Hanoi, Vietnam (e-mail: sam.goundar@rmit.edu.vn, ORCID : https://orcid.org/0000-0001-6465-1097).

A. Haqiq is a professor at Hassan First University, Faculty of Sciences and Techniques, in the Department of the Mathematics, Computer Science and Applications, and the director of the Computer, Networks, Mobility and Modeling Laboratory (IR2M), BP : 577, Route de Casablanca, 26000, Settat, Morocco (e-mail: abdelkrim.haqiq@uhp.ac.ma, ORCID: https://orcid.org/0000-0002-8857-6586).

While previous research predominantly emphasizes blockchain's capacity for value creation [4], the mechanisms and framework necessary to explicitly capture and fairly distribute value have not been adequately addressed. Traditional value-capture methods often result in inefficiencies, disputes, and uneven distribution outcomes, challenging cooperative stability and fairness.

To bridge these gaps, this study integrates cooperative game theory, particularly the Shapley value concept with blockchain smart contracts (Figure 1). The Shapley value has proven particularly suitable for modeling equitable distributions in cooperative networks due to its fairness properties, symmetry, and efficiency. Embedding the Shapley value within blockchain smart contracts can automate enforce equitable value distribution, and significantly enhance transparency and fairness [5].

Specifically, our primary research contributions include:

1) Developing a blockchain-based smart contract model that leverages the Shapley value to enable fair and transparent peer-to-peer value capture.
2) Conducting extensive evaluations of the model through comprehensive numerical simulations grounded in realistic scenarios.
3) Clearly demonstrating the transparency, fairness, and practical feasibility of the proposed blockchain-enabled cooperative mechanism in comparison to traditional approaches.

Our findings significantly advance research in blockchain applications, cooperative game theory, and peer-to-peer value creation and capture. Organizations can leverage our proposed method as a practical solution for transparent, automated, and fair cooperative value distribution.

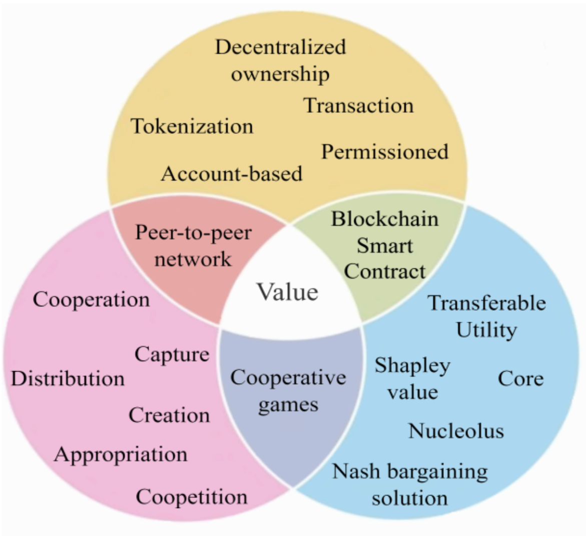

Fig. 1. Value, cooperative groups and blockchain smart contracts.

The remainder of the paper is organized as follows: Section 2 provides background knowledge and motivation; Section 3 describes the cooperative game theory-based methodology; Section 4 details blockchain smart contract modeling; Section 5 comprehensively evaluates the model through numerical simulations; Section 6 discusses theoretical and practical implications; and Section 7 concludes the paper with insights and future research directions.

II. Background

A. Blockchain smart contract

Blockchains are decentralized, peer-to-peer networks that enable secure, reliable storage and transmission of data without the need for centralizing authority. In public blockchain systems, nodes collectively uphold a decentralized source of truth, driven by individual engagement and consensus building.

Blockchain operates as an evolving record-keeping system that integrates peer-to-peer expansion, cryptographic, consensus and incentive secured mechanisms [6]. This architecture ensures an immutable chain of verified transactions, safeguarding data integrity across interconnected blocks [7].

Technology's foundational role in decentralizing digital currencies has evolved to support programmable frameworks through the advent of smart contracts, expanding its applicability across diverse domains. Smart contracts are immutable, and executable programs deployed on a blockchain, encapsulating predefined conditions. These self-executing contracts are automatically enforced by blockchain nodes when predefined conditions are met, ensuring trustless and transparent execution.

Despite debates regarding the practical significance of smart contracts [8], where quantum computing advancements amplify existing threats to blockchain security, exposing new vulnerabilities and heightening imminent quantum attack risks [9]. The decentralized and verifiable self-executing nature of smart contracts underpin a robust implementation of common business logic. The intrinsic capabilities of blockchain technology, particularly in facilitating smart contracts and digital assets, pave the way for next-generation conditional payment systems on a decentralized ledger [10]. These systems leverage the immutable and transparent nature of blockchain to ensure secure, automated and trustless transactions.

Smart contracts can be categorized into two primary types: (i) smart contracts for enhancement, encompassing modeling-driven and optimization-driven functionalities, which focus on refining system efficiency and design; and (ii) smart contracts for application, including resource-driven and cross-organizational collaboration-driven capabilities, which enable resource allocation and foster cooperative interactions [11]. These classifications highlight the versatility of smart contracts in addressing both technical optimization and practical use cases, reinforcing their role in advancing decentralized systems.

Blockchain and smart contracts have multiple applications :

- In finance, blockchain technologies are considered a game changer on a par with Artificial Intelligence. They are both considered Financial Technologies with substantial perspectives in trading, mobile payment, asset custody transactions [12], and Central Bank Digital Currencies (CDBC) [13].
- In the construction industry, efficiency, trust, and fairness hold the top positions as appealing factors to use blockchain and smart contracts [14]. Transaction, information, and process management would fall within blockchain applications, especially through concrete areas of the construction industry [15].
- In the supply chain sector, disintermediation, traceability, non-repudiation, trustless, tamper-resistance, and transparency by design are valuable capacities of blockchains and smart contracts to support supply chain activities [16].

Above and beyond blockchain applications in industries, enterprise blockchains have emerged in conjunction with substantive projects within early adopter firms [17]. According to the openness and decentralization of its peer-to-peer network, blockchain can be (*i*) public (or permissionless), (*ii*) private (or permissioned), (*iii*) hybrid or consortium. Permissioned blockchains, in particular, are tailored to enterprise needs, as they offer a level of trust to generate value for cooperative business models [18].

B. Value concepts

Within strategic management, value constitutes a core concept characterized by an intrinsic distinction between value creation and value capture. Value creation represents a participant's strategic process of augmenting value through resource deployment, wherein perceived benefits systematically exceed incurred efforts. Conversely, value capture denotes the procedural securing of financial or nonfinancial returns derived from created value [19]. The concept of value capture has been advanced in the form of a theoretical framework, drawing upon the principles of cooperative games [20].

Blockchains serve as catalysts for realizing a decentralized Internet architecture, enabling peer-to-peer exchange of fungible assets (e.g., cryptocurrencies) and non-fungible tokens (NFTs). Numerous states and governments have regulated cryptocurrency exchanges [21], particularly as tokenization redefines the foundations of trust in digital transactions [22].

This disruptive paradigm heralds a transition from the "Internet of Information" to the "Internet of Value" defined as the instantaneous peer-to-peer transfer of monetizable assets across trustless networks absent intermediaries [23]. Such value transfer extends Internet functionality to a domain where asset exchange achieves parity with contemporary data transmission in trustworthiness, intuitiveness, and cost efficiency [24].

C. Research motivations

Current blockchain literature predominantly emphasizes value creation while neglecting value capture frameworks. Existing research examines blockchain's capacity to generate business model innovation through: (*i*) extended access domains (new resources/stakeholders), (*ii*) cost reduction (value transfer, information, verification, controls, infrastructure), (*iii*) capability reinforcement, (*iv*) novel business practices, and (v) social-base enrichment [25] [26]. Methodologically, studies have primarily applied non-cooperative game theory to blockchains [27], they focused on intra-blockchain mechanics such as mining protocols, security requirements, consensus algorithms [28], and incentive structures [29].

This creates a significant gap where value capture remains conflated with creation dynamics rather than receiving dedicated analytical attention.

Yet value capture constitutes a strategic imperative that directly shapes organizational decisions and business relationship governance [30]. In cooperative settings, capturing value inherently represents a multiparty devolutionary act that risks generating intra-group distrust. Traditional third-party enforcement (e.g., coercive authorities) proves incompatible with maintaining cooperative integrity, transactional autonomy, and data sovereignty.

We assume that blockchain smart contracts address this concern by enabling value capture mechanisms with four essential properties: observability, ensuring real-time transparency of contribution metrics; privity, granting participants exclusive access to distribution terms; verifiability, providing mathematically auditable fairness in allocation; and enforceability, guaranteeing automated execution without intermediaries [31].

III. Methodology

A. Cooperative Game Theory

Game theory formally examines strategic interactions among rational decision-makers, it analyzes how individuals or entities optimize strategy selection in response to anticipated actions of others. This analytical framework characterizes games through several constitutive elements:

- A **player** is a rational decision-maker demonstrating explicit commitment to the game, possessing the ability to assess uncertainty, and exhibiting the capacity to optimize strategic gameplay [32].
- A **strategy** is characterized as a decision-making and action plan that a player follows in order to achieve a predetermined outcome.
- **Utility** represents a numerical function mapping player preference within game-theoretic frameworks. It quantifies the satisfaction or benefit derived by a player from distinct outcomes.
- The **value** refers to the expected payoff that a player can achieve from a game, considering the strategies of all players. It is particularly relevant in cooperative games, and it denotes the worth of a player or a coalition.

Solution concepts for marketplace modeling are formally established within game theory [33], where competitive equilibrium characterizes pure competition, while the core and value respectively quantify coalitional power and division fairness. Cooperative game theory analyzes payoff distributions resulting from multi-party cooperation, enabling binding agreements and coalition formation to resolve allocation problems, including cost distribution and benefit sharing. It has three principal solution concepts [34]:

- The core represents feasible allocations where no coalition benefits by leaving from the grand coalition.
- The nucleolus minimizes maximal dissatisfaction among coalitions.
- and the Shapley value provides an axiomatic method for distributing total payoffs across all cooperating players.

Transferable Utility (TU) games constitute a specialized class where utility is exchangeable between players, with each incremental unit maintaining constant marginal value regardless of recipient. Crucially, coalition valuations remain independent of external players, while binding distribution agreements become enforceable [35].

This class of games requires players to share both a common utility metric and a transfer medium (e.g., money or credit) that enables lossless utility exchange and establishing frictionless cooperative value redistribution.

B. Shapley value

Shapley and Shubik formalize value as a distribution principle wherein, under transferable utility assumptions, it objectively quantifies each player's expected marginal contribution to coalitions in n-player cooperative games [33] [36].

Formally, a cooperative and TU game (N, ϑ) comprises :

A player set N :

$$N = \{p_1, p_2, p_3, p_4, \dots, p_{i-1}, p_i, p_{i+1}, \dots, p_n\} \quad (1)$$

A characteristic function $\vartheta(\,)$ assigns each coalition $S \subseteq N$ a guaranteed value $\vartheta(S)$, which can be determined independently of the actions of players outside the coalition. Here, S is a subset of N that does not include player p_i

$$N = \underbrace{\{p_1, p_2, p_3, p_4, \dots, p_{i-1}}_{|S|}, p_i, \underbrace{p_{i+1}, \dots, p_n\}}_{|N|-|S|-1} \quad (2)$$

The probability of a particular coalition S occurring during the computation of the Shapley value is

$$\frac{|S|!\,(|N|-|S|-1)!}{N!} \quad (3)$$

- |N| is the total number of participants in the game.
- |S| is the size of the subset S, i.e., the number of players in the coalition S.
- |S|! represents the number of possible orders of players in S.
- |N|−|S|−1 is the number of players outside of S and excluding the player p_i (the remaining players in the game).
- (|N|−|S|−1)! represents the number of possible orders for the remaining players.
- |N|! is the factorial of the total number of players and serves as a normalizing factor, it represents the number of potential arrangements for all the players in N.

The marginal contribution to the worth when player p_i accesses the coalition S is:

$$\vartheta(S \cup \{i\}) - \vartheta(S) \quad (4)$$

The Shapley value for player p_i is defined as the mathematical expectation of their marginal contributions across all coalition permutations. It establishes their ex-ante equilibrium payoff in the cooperative and transferable utility game (n, ϑ) :

$$\varphi_i(\vartheta) = \sum_{S \subseteq N \setminus \{p_i\}} \frac{|S|!\,(|N|-|S|-1)!}{|N|!} [\vartheta(S \cup \{i\}) - \vartheta(S)] \quad (5)$$

This solution concept provides a unique allocation in finite TU games that satisfies three axioms: symmetry (indistinguishable players receive equal payoffs), efficiency (total value distribution), and additivity (linear aggregation across games) [37]. Though classically premised on uniform cooperation willingness, recent extensions generalize the Shapley value to accommodate heterogeneous groups and pairwise preferences [38].

IV. Blockchain and Game Modeling

In a blockchain-based game, as illustrated in Table I :

- a "game network" mirrors a permissioned, account-based blockchain where participants engage and cooperate within a peer-to-peer structure;
- a "player" is represented by a peer node in this network, and the shared objective, or "utility," is the collective capture of value, similar to how blockchain participants cooperate for mutual gain.
- the "grand coalition" encompasses the full permissioned blockchain network;
- the "Shapley value" aligns with the mechanism used for distributing value across the blockchain;
- and lastly, the "automated" decision process in the game corresponds to smart contracts, which autonomously execute predefined rules.

TABLE I
Cooperative and TU game meets blockchain technology

Cooperative game	Blockchain framework
Game network	Permissioned and account-based
Player	Node (peer)
Utility	Join capture of value
Shapley value	Value capture solution concept
Automation	Smart contract

A. Assumptions

We assume the following assumptions:

1) The players are involved in an n-player cooperative and transferable utility game, each joining player has the same understanding and measure of utility.
2) All players have the same understanding of value measure. Each member has a known single initial contribution.
3) Players are considered nodes in a permissioned and account-based blockchain.
4) Access and security are guaranteed by the governance policies and rules as defined in the account-based and permissioned blockchain.
5) Created and captured values are positive.

B. Blockchain smart contract

Resources and tools provided in the Accord Project [39] have been used for smart contract modeling. It is a non-profit initiative that offers an open-source ecosystem for the development of smart legal contracts. It positions smart agreements as a means to reduce friction and transaction costs in the management of enterprise relationships. To this end, the project supports the creation, sharing, execution, and management of enforceable, machine-readable agreements. It also provides a platform-neutral development environment, facilitating broad applicability across different technological infrastructures.

Smart contract modeling

The agreement for value capture as illustrated in Figure 2 contains the following classes:

1) *ValueCapture_SmartContract*, the main class with attributes describing cooperation, members' attributes, and their single initial contribution. It includes the expected payoff of each player.
2) *Payoff* carries the monetary aspect of value capture.
3) *TokenShare,* which is a class that handles the resulting token for the value capture.
4) *ValueCaptureEvent* for the event that triggers the act or the willingness to value capture.
5) *Contract* class, with contact terms, obligations, and counterparties.
6) *Transaction* class for distribution acts.

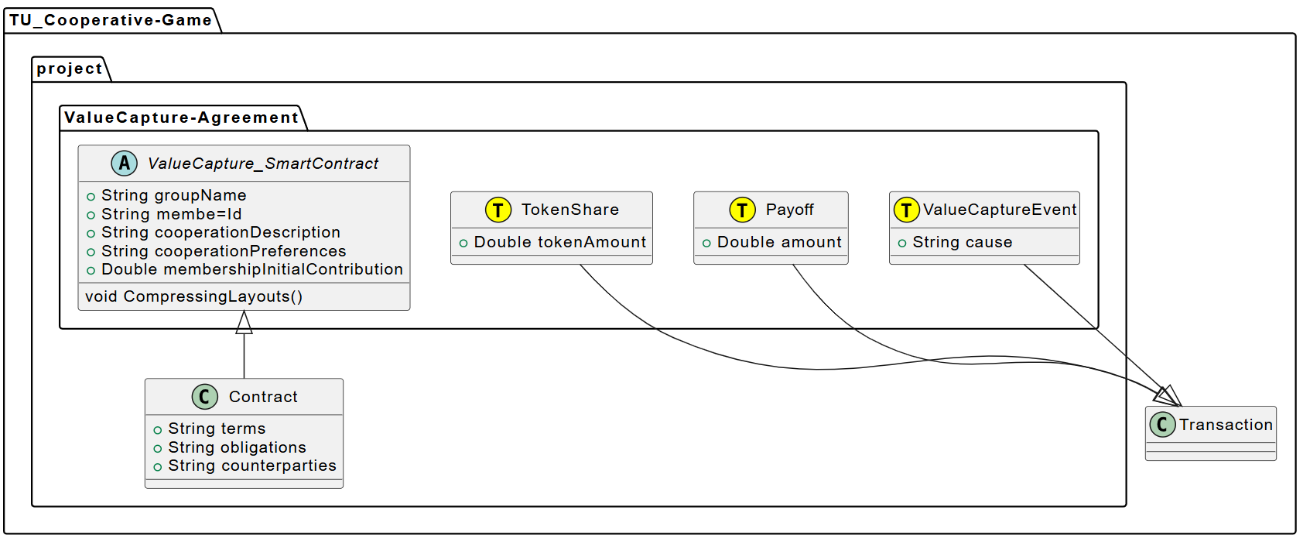

Fig. 2. Value capture modeling via smart contracts (Accord Project template).

For reference, data structures using the Accord Project templates are provided in appendix A.

Shapley value algorithm

Algorithm 1 implements the core function for value capture using Shapley value calculation for each player.

Algorithm 1 : Shapely value based smart contract

Require :
N : Total number of players
v(S) : Return the value of a coalition S ⊆ N
Ic(i) : Initial contribution for player p_i
Ensure : Shapley value allocation

```
# Initialize and store Shapley values for each player
    ShapleyValue = {}
    for each i in N
        ShapleyValue (i) = 0

# Compute Shapley values for each player p_i
    for i in N
        for each subset S in pos_subsets (N - {i}):
# Calculate the marginal contribution
    marginal_contribution = v(S ∪ {i}) - v(S) – Ic(i)

# Weight based on the size of the subset
    weight = fact(|S|) * fact(|N| - |S| - 1) / fact(|N|)

# Cumulate the weighted marginal contribution
    ShapleyValue (i) += weight * marginal_contribution

# Helper functions
Function pos_subsets(players): return all possible subsets
Function fact(n): return the factorial of a number n
```

V. Numerical simulations

A. Simulation with empirical dataset

In this experiment, the primary focus was on conceptual validation. We considered a six-player game (n=6) and three scenarios with different initial contributions for each player. Figure 3 illustrates the game with the first scenario values.

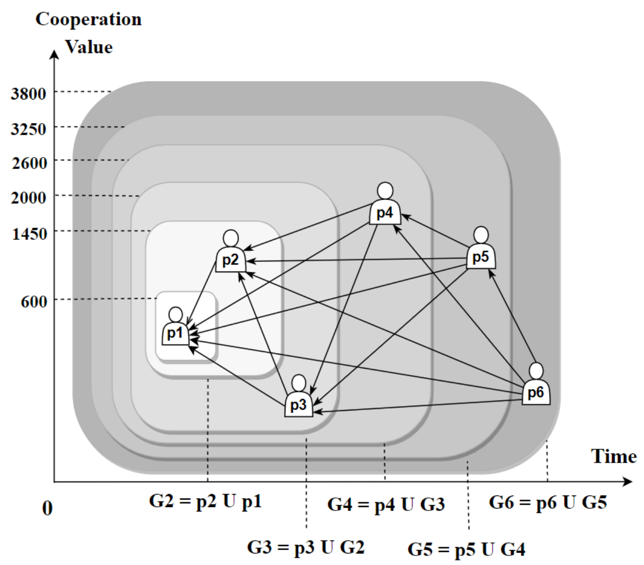

Fig. 3. Cooperative game formation with six participants.

Appendix B contains empirically derived data for the three scenarios, collected from observations in the French information technology sector. The observations reveal a positive correlation between the value of cooperation and participants' initial contributions. Additionally, the cooperation value exhibits a measurable increase with the experience level of new participants.

The expected payoff $\varphi_i(\vartheta)$ for each player p_i is defined as the average over all possible permutations by which the grand coalition can be formed from the empty coalition. Shapley values, presented in Table II, were computed using Python 3.11.8 with itertools and math from the standard library, and pandas 2.2.2 for data handling and aggregation.

TABLE II
Shapley values of the six-player game
(a) scenario 1, (b) scenario 2, and (c) scenario 3

(a)

Player p_i / Initial contribution / Group	p1 600	p2 600	p3 600	p4 600	p5 750	p6 850
G1 = p1	600	-	-	-	-	-
G2 = p2 ∪ G1	725	725	-	-	-	-
G3 = p3 ∪ G2	700	675	625	-	-	-
G4 = p4 ∪ G3	662.5	612.5	637.5	687.5	-	-
G5 = p5 ∪ G4	615	590	590	665	790	-
G6 = p6 ∪ G5	665	666.6	655	630.5	677.5	505

(b)

Player p_i / Initial contribution / Group	p1 600	p2 600	p3 400	p4 400	p5 750	p6 850
G1 = p1	600	-	-	-	-	-
G2 = p2 ∪ G1	680	480	-	-	-	-
G3 = p3 ∪ G2	626.6	506.6	466.6	-	-	-
G4 = p4 ∪ G3	580	473.3	493.3	533.3	-	-
G5 = p5 ∪ G4	542.5	472.5	472.5	532.5	580	-
G6 = p6 ∪ G5	546	517.3	498	478.6	562	438

(c)

Player p_i / Initial contribution / Group	p1 600	p2 1200	p3 400	p4 1200	p5 750	p6 1400
G1 = p1	600	-	-	-	-	-
G2 = p2 ∪ G1	715	1315	-	-	-	-
G3 = p3 ∪ G2	913.3	1178.3	708.3	-	-	-
G4 = p4 ∪ G3	844.1	974.1	742.5	1079.1	-	-
G5 = p5 ∪ G4	852.5	967.5	767.5	1072.5	890	-
G6 = p6 ∪ G5	884.6	1007	830.6	956.8	890	750.6

From an individual perspective, joining a growing cooperative group with an intended-to-be-fair transactional mechanism does not necessarily mean a steadily increasing payoff and auspicious capture of value for all players.

In the first scenario, the payoffs of player p_2 and p_3 exhibit a declining trend as the group expands from two to five participants, ultimately falling below their initial individual contributions. Notably, player p_6, despite possessing the highest initial contribution among all participants, begins cooperation with the lowest expected payoff, a counter intuitive outcome that underscores the complexity of equitable distribution in growing coalitions.

The implementation of a blockchain-based tokenized system addresses these challenges by providing:

- Immutable payoff tracking: Every player's contribution and reward are recorded on an auditable, tamper-proof ledger.

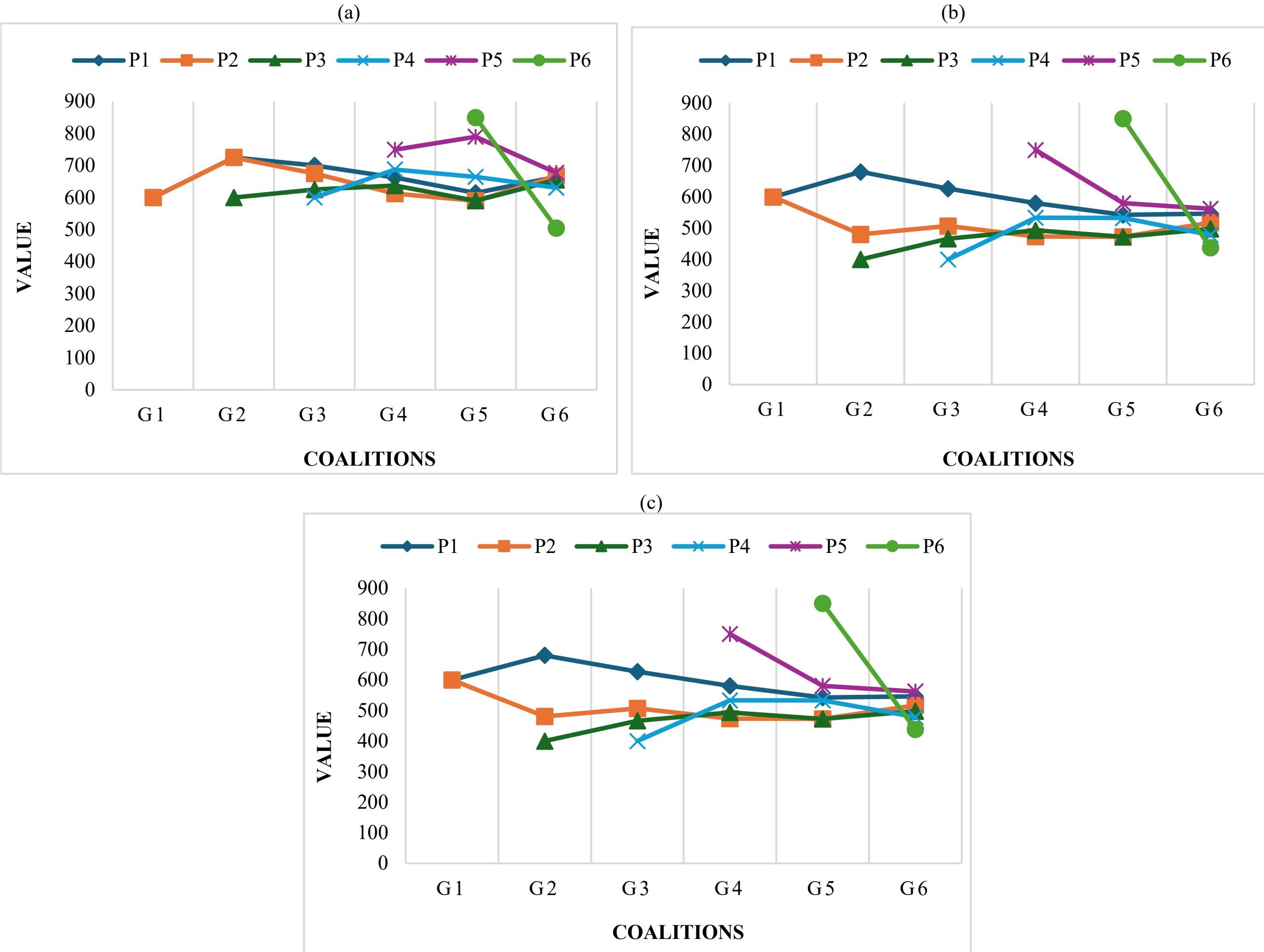

Fig. 4. Graphical presentation of the six-player game with varying initial contributions: (a) scenario 1, (b) scenario 2, and (c) scenario 3.

- Self-enforcing fairness: Smart contracts autonomously execute payoff calculations and distributions according to the predefined mechanism, eliminating reliance on third-party enforcement or participant compliance.

From the collective perspective, the trends illustrated in Figure 4 demonstrate that the peer-to-peer value capture framework and its underlying transaction mechanism foster stable cooperative behavior. The Shapley value solution concept proves instrumental in this regard, ensuring payoff convergence is both mathematically fair and empirically robust across all scenarios.

B. Simulation with extended dataset and results

To underline the significance and practical implications of our results, we expanded our simulations to reflect larger and more realistic cooperative groups (30-player scenario) based on extended data from the information technology industry. These extended simulations reinforce the robustness of the Shapley-value smart contract mechanism and model its scalability. Compared to traditional centralized or informal cooperative distribution methods which often lead to opacity, disputes, and inefficiencies, our blockchain-based mechanism consistently delivered fairer, verifiable, and automated outcomes

To provide the rigorous, comprehensive evaluation required, we conducted additional numerical experiments specifically targeting detailed aspects of model performance, scalability, and effectiveness. Table III shows that we extended our simulations to include various cooperative configurations reflective of real-world blockchain consortiums, including configurations of 10, 20, and 30 cooperative members with varying distributions and growth patterns.

TABLE III
GROWTH PATTERNS AND BIASES IN THE THIRTY-PLAYER GAME

Scenario	Growth pattern	Early-player bias	Late-player bias
1. Linear growth	Linear	High (+266%)	Low (+52%)
2. Moderate gains	Diminishing returns	Low (-25%)	Mild (+15%)
3. High synergy	Exponential	Extreme (+60%)	Penalized (-20%)

Detailed performance metrics were evaluated to assess the efficacy and fairness of the proposed framework. Key aspects of the analysis included:

- Captured value dynamics under smart contract settlement, examined across varying network sizes. This metric quantifies the efficiency of value distribution and the system's scalability.
- Fairness deviation analysis, standard deviation and variance to evaluate the equitable allocation of resources among participants. These metrics provide

a quantitative assessment of distributional fairness, ensuring that no single entity gains disproportionate advantage.

To enhance interpretability, Figures 5 and 6 provide graphical summaries of our findings. Figure 5 depicts the relationship between network size and captured value efficiency, revealing critical scalability trends. Figure 6 compares fairness deviations across cooperation scenarios, exposing systemic biases and equilibrium states. These visualizations distill complex dynamics into actionable insights, reinforcing the study's analytical rigor.

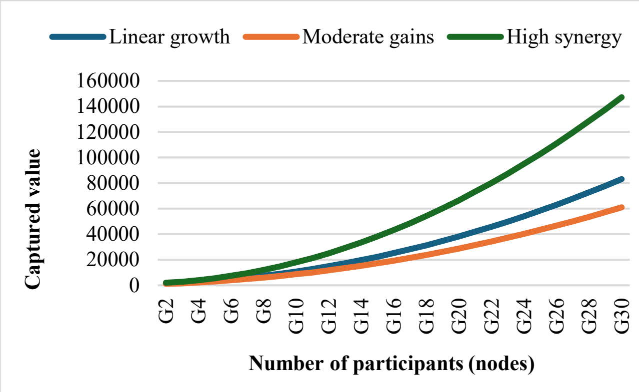

Fig. 5. Cumulative captured value vs cooperative group size.

Our examination of cumulative value capture and fairness deviation reveals three distinct growth patterns across operational scenarios. Scenario 1 illustrates ideal market conditions, exhibiting steady linear growth that reflects perfectly proportional value capture relative to participant contributions. This establishes an important theoretical benchmark for equitable distribution. Scenario 2 presents a more constrained growth trajectory, where the accumulation of value follows a characteristic pattern of diminishing returns, a phenomenon particularly relevant in resource constrained environments or highly competitive markets.
Most notably, scenario 3 displays exponential growth dynamics, illustrating how strategic synergies between participants can create disproportionate value when collaboration mechanisms are optimally structured.
These comprehensive evaluations and illustrative examples explicitly demonstrate that our blockchain-enabled cooperative value capture mechanism is both robust and fair, reinforcing its practical suitability and adding significant rigor expected from high-quality journal publications.

VI. Discussion

Effective cooperation requires participants to share a common framework for evaluating utility, one that accounts for both value creation and equitable distribution. This alignment enables collective efforts to yield measurable, mutually beneficial outcomes, whether financial (e.g., profit sharing), strategic (e.g., market expansion), or reputational (e.g., brand enhancement).

Our research makes a seminal theoretical contribution by bridging blockchain technology and cooperative game theory through the Shapley value framework. This novel integration establishes a mathematically grounded approach to fairness in peer-to-peer value distribution, a critical gap in prior work, which has insufficiently addressed equitable mechanisms for blockchain-based cooperative systems.

The proposed blockchain-enabled Shapley value mechanism offers a decentralized, automated solution to pervasive challenges in cooperative environments: trust deficits, transparency limitations, and distributed inequities. By encoding fairness principles into smart contracts, organizations can achieve three key advantages: (*i*) dispute mitigation: transparent, algorithmically enforced value distribution reduces conflicts; (*ii*) operational efficiency: automation minimizes administrative overhead in profit-sharing; and (*iii*) cooperative resilience: equitable outcomes strengthen long-term participation incentives.

For industries adopting blockchain, these advances translate to tangible benefits: streamlined cooperation, enhanced stakeholder trust, and sustainable network growth. The framework's adaptability makes it particularly relevant for ecosystems where value creation is collective, but distribution remains contentious, from supply chain alliances to Decentralized Autonomous Organizations (DAOs).

A. *Implications*

The cooperative value capture framework ensures participants receive verifiable proof of their contributions in exchange for collaboration. This mechanism aligns with core blockchain value propositions , leveraging three fundamental components:

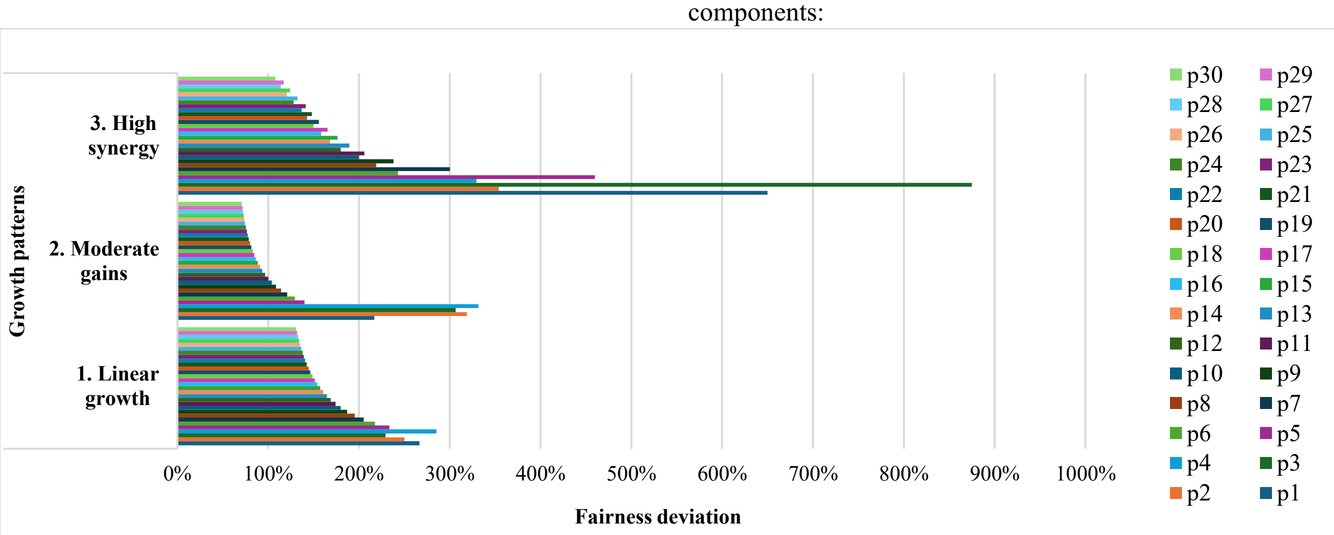

Fig. 6. Fairness deviation across the three scenarios of the thirty-player game

- Network infrastructure that utilizes peer-to-peer architecture to decentralize and secure participant tamper-proof admission and engagement.
- Transaction mechanism which implements a Shapley value-based solution concept to guarantee fairness in value distribution, stabilizing the cooperative core.
- Tokenization system that facilitates quantifiable value capture and dynamic incentivization through tokenized rewards, aligning collective interests.

A participant's claimable benefit is proportional to their marginal contribution [37]. Blockchain smart contracts automate and enforce this principle, offering manifold advantages:

- Decentralized trust that eliminates reliance on intermediaries by codifying rules into immutable contracts, removing single points of failure.
- Transparent value attribution with blockchain's inherent transparency and auditability that foster consensus on contribution metrics, reducing disputes over fairness.
- Cooperative viability assessment where participants can objectively evaluate cooperation benefits, both individually and collectively, based on real-time, contribution-weighted data.

This integration of game-theoretic fairness with blockchain's operational strengths not only optimizes value distribution but also sustains cooperation incentives.

B. *Limitations*

The application of cooperative game theory hinges on three core constraints. First, participants must share a measurable and mutually understood utility metric. Second, the analysis is confined to positive value creation, excluding scenarios of value destruction [40]. Third, cooperative surplus is evaluated net of costs, isolating the utility of cooperation from its associated expenditures.

Deploying peer-to-peer value capture mechanisms on blockchain systems encounters scalability limitations. Such systems challenge the blockchain quadrilemma, balancing scalability, decentralization, security, and trust [41], frequently prioritizing scalability and security at the expense of decentralization. Moreover, the legal implications of smart contracts remain underexplored, particularly their impact on participants. This gap highlights the need for interdisciplinary research integrating legal frameworks to address governance and compliance challenges.

VII. Conclusion

In this paper we analyzed value capture through cooperative games with transferable utility, and we developed a framework aligned with permissioned, account-based blockchains. The model's incorporation of decentralized utility consensus, alongside fair value capture and distribution, proves crucial for sustaining cooperation in networked environments. Blockchain augmented by smart contracts provides a trustless foundation for efficient peer-to-peer interactions and dynamic value exchange. Our findings establish a theoretical basis for future research, particularly in simulating peer-to-peer transaction systems and assessing blockchain-enabled value propositions.

Appendix A

The smart contract model's core data structures are defined using JavaScript Object Notation (JSON), enabling structured and interoperable representation of cooperative logic.

Main class

```
{
 "$class": "TU-CG.project.A-VC",
 "groupName": "Smart Value Capture",
 "cooperationDescription":"Smart Value capture",
 "cooperationPreferences":"Group-wise",
 "memberName": "Lloyd Stowell",
 "memberId": " p_i",
 "memberSingleInitialContribution": 600,
 "contractId": "e12345ma-...-1......sample",
 "$identifier": "e12345ma-...-1......sample"
}
```

Request type

TU-CG.project.A-VC.ValueCaptureEvent

```
{
"$class": "TU-CG.project.A-VC.ValueCaptureEvent",
"cause": "Newcomer Event, recalculate Shapley values! ",
"$timestamp": "2024-04-27T14:12:22.001-04:00"
} Member joining Event
```

Response types

TU-CG.project.A-VC.Payoff

```
{
"$class": "TU-CG.project.A-VC.Payoff",
"amount": 750,
"$timestamp": "2024-04-27T14:12:22.001-04:00"
}
```

TU-CG.project.A-VC.TokenShare

```
{
"$class": "TU-CG.project.A-VC.TokenShare",
"tokenAmount": 75,
"$timestamp": "2024-04-27T14:12:22.001-04:00"
}
```

APPENDIX B

TABLE IV
SIX-PLAYER GAME DATASET WITH THREE SCENARIOS

The dataset has been derived from empirical observations of compensation structures within the French information technology sector.

Group evolution from G2 to G6	Coalitions	Cooperation Value		
		S1	S2	S3
G2	∅	0	0	0
	{p1}	600	600	600
	{p2}	600	400	1200
	{p1, p2}	1450	1160	2030
G3	{p3}	600	400	400
	{p3, p1}	1350	1080	1890
	{p3, p2}	1300	1040	1820
	{p3, p2, p1}	2000	1600	2800
G4	{p4}	600	400	1200
	{p4, p1}	1750	1400	2450
	{p4, p2}	1400	1120	1960
	{p4, p2, p1}	1900	1520	2660
	{p4, p3}	1450	1160	2030
	{p4, p3, p1}	2000	1600	2800
	{p4, p3, p2}	2050	1640	2870
	{p4, p3, p2, p1}	2600	2080	3640
G5	{p5}	750	750	750
	{p5, p1}	1800	1440	2520
	{p5, p2}	1300	1040	1820
	{p5, p2, p1}	1900	1520	2660
	{p5, p3}	1450	1160	2030
	{p5, p3, p1}	1450	1160	2030
	{p5, p3, p2}	2050	1640	2870
	{p5, p3, p2, p1}	2600	2080	3640
	{p5, p4}	1500	1200	2100
	{p5, p4, p1}	2000	1600	2800
	{p5, p4, p2}	1950	1560	2730
	{p5, p4, p2, p1}	2600	2080	3640
	{p5, p4, p3}	2050	1640	2870
	{p5, p4, p3, p1}	2650	2120	3710
	{p5, p4, p3, p2}	2650	2120	3710
	{p5, p4, p3, p2, p1}	3250	2600	4550
G6	{p6}	850	850	1400
	{p6, p1}	1550	1240	2170
	{p6, p2}	1600	1280	2240
	{p6, p2, p1}	2000	1600	2800
	{p6, p3}	1700	1360	2380
	{p6, p3, p1}	2050	1640	2870
	{p6, p3, p2}	2100	1680	2940
	{p6, p3, p2, p1}	2550	2040	3570
	{p6, p4}	1450	1160	2030
	{p6, p4, p1}	1850	1480	2590
	{p6, p4, p2}	1800	1440	2520
	{p6, p4, p2, p1}	1950	1560	2730
	{p6, p4, p3}	1900	1520	2660
	{p6, p4, p3, p1}	2200	1760	3080
	{p6, p4, p3, p2}	2300	1840	3220
	{p6, p4, p3, p2, p1}	2550	2040	3570
	{p6, p5}	1850	1480	2590
	{p6, p5, p1}	1700	1360	2380
	{p6, p5, p2}	1900	1520	2660
	{p6, p5, p2, p1}	2350	1880	3290
	{p6, p5, p3}	1800	1440	2520
	{p6, p5, p3, p1}	2300	1840	3220
	{p6, p5, p3, p2}	2050	1640	2870
	{p6, p5, p3, p2, p1}	2600	2080	3640
	{p6, p5, p4}	1600	1280	2240
	{p6, p5, p4, p1}	1850	1480	2590
	{p6, p5, p4, p2}	2350	1880	3290
	{p6, p5, p4, p2, p1}	2650	2120	3710
	{p6, p5, p4, p3}	2000	1600	2800
	{p6, p5, p4, p3, p1}	2600	2080	3640
	{p6, p5, p4, p3, p2}	2600	2080	3640
	{p6, p5, p4, p3, p2, p1}	3800	3040	5320

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Kamal Bouhassoune holds a Master of Engineering in Computer Science and Statistics from the Polytechnic School of Engineering in Lille (2006), and a Master of Science in Business Development from EDHEC Business School, Lille (2013), both obtained in France.
He earned his doctoral degree in 2024 from Hassan First University, at the Faculty of Sciences and Techniques of Settat, Morocco, within the Department of Mathematics, Computer Science and Applications, and the Computer, Networks, Mobility and Modeling Laboratory.

His research interests include game theory, distributed ledger technologies, machine intelligence, and cooperative enterprise information systems.

Dr. Bouhassoune currently serves on the editorial board and as a reviewer for the International Journal of Blockchains and Cryptocurrencies (IJBC).

Sam Goundar is an international academic having taught at twelve different universities in ten different countries. He is also an Adjunct Professor of Computer Science at The University of Fiji and a former Senior Lecturer of Computer Science (Cyber Security) at the British University of Vietnam.

He is a professor at the RMIT University, School of Computing, Handi Resco Building, 521 Kim Ma, Ba Dinh District, Hanoi, Vietnam.
As a researcher, apart from Blockchains, Cryptocurrencies, Fog Computing, Mobile Cloud Computing, and Cloud Computing, Dr. Sam Goundar also researches in Educational Technology, Artificial Intelligence, ICT in Climate Change, ICT Devices in the Classroom, Using Mobile Devices in Education, and e-Government. He is the author and co-author of more than 200 contributions. He was a Research Fellow at the United Nations University. He is a Senior Lecturer in Computer Science at the British University of Vietnam, Adjunct Senior Lecturer at The University of the South Pacific, Affiliate Professor of Information Technology at Pontificia Universidad Católica del Perú.

Prof. Sam Goundar is the Editor-in-Chief of the International Journal of Blockchains and Cryptocurrencies (IJBC), Editor-in-Chief of the International Journal of Fog Computing (IJFC), Section Editor of the Journal of Education and Information Technologies (EAIT) and Editor-in-Chief (Emeritus) of the International Journal of Cloud Applications and Computing (IJCAC).

Abdelkrim Haqiq has a High Study Degree and a PhD degree (Doctorat d’Etat), both in the field of modeling and performance evaluation of computer communication networks, from the Faculty of Sciences, Rabat, Morocco. He is a full professor in the Department of Mathematics, Computer Science and Applications at the Faculty of Sciences and Techniques, Settat, Morocco, and the Director of the Computer, Networks, Mobility and Modeling Laboratory.

He is an IEEE senior member. He is also a member of Machine Intelligence Research Labs, Washington, USA and a member of the International Association of Engineers (IAENG).

He was a codirector of a NATO Multi-Year project entitled "Cyber Security Analysis and Assurance using Cloud-Based Security Measurement system", having the code: SPS-984425.

Prof. Abdelkrim Haqiq’s interests lie in the areas of modeling and performance evaluation of communication networks, mobile communications networks, cloud computing and security, emergent technologies, Markov Chains and queueing theory, Markov decision processes theory, and game theory. He is the author and co-author of more than 230 papers (international journals and conferences/workshops).

He is an associate editor of the International Journal of Computer International Systems and Industrial Management Applications (IJCISM), an editorial board member of the International Journal of Intelligent Engineering Informatics (IJIEI) and of the International Journal of Blockchains and Cryptocurrencies (IJBC), an international advisory board member of the International Journal of Smart Security Technologies (IJSST) and of the International Journal of Applied Research on Smart Surveillance Technologies and Society (IJARSSTS). He is also an editorial review board of the International Journal of Fog Computing (IJFC) and of the International Journal of Digital Crime and Forensics (IJDCF).
Prof. Abdelkrim Haqiq was a chair and a technical program committee chair/member of many international conferences and scientific events. He was also a Guest Editor and Co-Editor of special issues of journals, books, and international conference proceedings.