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HYBRID VOTING MODEL FOR DECENTRALIZED AUTONOMOUS ORGANIZATIONS WITH DYNAMIC QUORUM

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The article examines the problem of balancing security and flexibility in decision-making mechanisms within decentralized autonomous organizations (DAOs), which operate without centralized control through the use of smart contracts. To this end, two main voting models employed in DAOs are analyzed: the conjunctive model, which requires unanimous approval of a proposal by all participant groups, and the disjunctive model, where approval from a single group is sufficient. Both models have significant advantages and drawbacks: the former ensures a high level of security and protection of all parties' interests but considerably slows down the decision-making process, while the latter provides speed and scalability but introduces risks of centralized influence.

In response to these challenges, a hybrid voting model is proposed, in which the type of logic is determined by the nature of the proposal. Specifically, critical changes, such as updates to governance rules or quorum parameters, must involve all groups, whereas routine operational matters can be decided through a simplified disjunctive procedure. The implemented smart contract architecture supports both mechanisms and enables DAOs to dynamically adjust quorum thresholds through separate governance proposals.

To evaluate the effectiveness of the model, a simulation of 1,000 voting processes was conducted under four different scenarios of participant activity: balanced, one-sided, and low overall participation. The results showed a reduction in the probability of deadlock situations and an increase in the share of successful votes when hybrid logic was applied, particularly under conditions of low or asymmetric participation. In addition, special attention was given to gas cost optimization: the disjunctive approach allows vote counting to be stopped once a quorum is reached by one group, thus reducing overall computational expenses.

Therefore, the proposed solution appears promising for both financial DAOs and decentralized infrastructures, particularly the Internet of Things, where speed, scalability, and secure coordination are especially important.

Keywords: DAO, voting mechanism, smart contracts, blockchain, dynamic governance.

1. Introduction

Decentralized Autonomous Organizations (DAOs) are one of the key innovations in blockchain, providing mechanisms for collective governance without a centralized authority [1]. In a DAO, decision-making rules are embedded as smart contracts at the system launch stage, and changes can only be implemented after a corresponding voting. Thus, the voting mechanism is a fundamental element of a DAO, directly affecting its effectiveness, security, and ability to develop further.

Most DAO implementations use a conjunctive approach to voting, whereby decisions are only made with the simultaneous agreement of all key participant groups – for example, both validators and token holders [2]. This approach guarantees a high level of protection against centralization and fraud, since none of the groups can make decisions on their own. At the same time, it limits the speed of decision-making, reduces the flexibility of the system, and complicates scaling, especially in large or dynamic projects.

These limitations become particularly critical in the Internet of Things (IoT), where decisions must be made quickly, often automatically, and in complex distributed infrastructures [3]. DAOs in such systems can serve as a decentralized mechanism for managing access to devices, updating firmware and configuration parameters. However, traditional conjunctive models in such conditions can cause significant delays or decision blockages, leading to downtime of critical network components.

In the context of the growing complexity of blockchain systems and the need for quick responses, there's a need for more flexible management models that can balance between security and efficiency [4]. In particular, it is worth considering alternative approaches to voting that allow decisions to be made with the support of only one group. For example, it can be either validators or token holders, provided that a set quorum is reached. Such disjunctive models can significantly improve the speed of decision-making without losing decentralization.

The purpose of the article is to create a decision-making mechanism in DAO that combines the security of conjunctive and flexibility of disjunctive voting with the ability to dynamically adjust quorum thresholds to maintain a balance of control. The proposed solution is implemented as a smart contract architecture that supports joint and separate voting for each group, as well as dynamic changes to voting parameters within the same DAO system.

2. Literature review and problem statement

Decentralized Autonomous Organizations have emerged as an innovative form of organizational structure that rethinks classic models of corporate governance. They are based on the use of blockchain technologies and smart contracts, which guarantee transparency, automation, and irreversibility of the decision-making process in the digital community. The first large-scale implementation of DAO took place in 2016 as part of The DAO project. Despite a vulnerability in the code that led to significant losses, this case became a starting point in the development of decentralized governance [5].

Unlike traditional corporations, where management is carried out through hierarchies of directors, managers, and shareholders, DAOs function as self-organized structures where decisions are made by voting by token holders or other designated groups. Smart contracts act as a digital “constitution” — they define rules that are automatically applied without the involvement of a central authority. This has made DAOs attractive to projects seeking decentralization, transparency, and open participation.

Today, DAOs are one of the key elements of blockchain ecosystems and are widely used to manage Decentralized Financial Platforms (DeFi), NFT services, mutual investment funds, infrastructure projects, and even new-generation social networks. DAOs enable democratic management of funds, protocol updates, community moderation, and changes to key system parameters. Thanks to DAOs, participants have the opportunity to make collective decisions through predefined voting mechanisms, which are usually embedded in smart contracts [6].

DAOs gained significant popularity after 2020, when, amid the DeFi boom, many projects began to transfer control from centralized teams to digital communities. Examples such as Uniswap, Lido, Arbitrum DAO, and Optimism Collective demonstrate the potential of DAOs as full-fledged governance models. For example, in Lido DAO, most decisions are made by LDO holders voting, but critical changes require additional approval from technical subgroups, creating a multi-level model. Optimism has a bicameral structure reminiscent of the classic parliamentary model: key decisions require consensus from both chambers. In Uniswap DAO, although formally a “one token, one vote” model is in place, decisions often require the support of both large investors and an active community – which also brings it closer to the practice of conjunctive consensus.

The widespread use of DAOs is associated with a number of advantages [7]:

1. Transparency: all transactions and votes are recorded in the blockchain.
2. No intermediaries: management is carried out without centralized structures.
3. Feedback: each participant has the opportunity to influence decisions, which increases the community's interest in the development of the system.
4. Protection against manipulation: voting rules are fixed in the code and can only be changed by a community decision.

Besides finance and tech, DAOs are getting more attention as an architectural model for distributed systems, especially in the Internet of Things (IoT). In environments where thousands of devices coordinate joint actions, such as in energy, logistics, and urban management, DAOs can provide secure protocol updates, distributed voting, and resilience to centralized failures.

The most common approach to collective decision-making in DAOs is the conjunctive voting model, where a decision is considered approved only when all specified groups of participants have reached a quorum and given their consent [8]. For example, if there are two groups in a DAO – validators and token holders – a positive decision requires the simultaneous support of both groups.

This model is widely used because it significantly improves system security by preventing one group from gaining control, but it creates the risk that decisions will take a long time to be made, or may not be made at all.

Among the advantages of the conjunctive model, the following can be highlighted:

1. Increased security. The need for approval from several groups significantly reduces the risk of one interested party taking control. For example, even if a participant has accumulated a significant number of tokens, they will not be able to implement changes without the consent of other groups.

2. Multi-level control. Each group performs a control function, checking the decisions of other parties, which contributes to the adoption of balanced and informed decisions.

3. Protection against manipulation. The requirement to achieve consensus among several groups makes it difficult for individual participants with a large number of tokens to manipulate voting results, which increases participants' trust in the community.

4. High level of trust. Decisions are made only when the interests of all groups are taken into account, which promotes transparency and fairness in the process.

However, this model also has its drawbacks [9]:

1. Slow decision-making. The need to reach consensus among several groups can significantly slow down the decision-making process, especially when there is a conflict of interest between groups or low participant involvement, which can be critical when an issue needs to be resolved urgently.

2. Risk of deadlock. If one of the groups does not agree with a proposal, this can lead to a complete blockage of the decision-making process, even if all other groups support the decision.

3. High participation requirements. Achieving a quorum and approving decisions requires the active participation of a large number of participants from different groups, which can be difficult to ensure in practice.

Despite the obvious advantages of security and transparency, the traditional conjunctive model has limitations in terms of scalability and adaptability. That is why, in today's dynamic environment of blockchain infrastructures, there is a growing demand for more flexible governance mechanisms that allow quick decision-making without compromising key principles of decentralization and security. This creates a need to study alternative or combined models, such as disjunctive voting or hybrid approaches with dynamic quorum parameters.

3. The aim and objectives of the study

The purpose of this study is to overcome the limitations of traditional conjunctive voting mechanisms in decentralized autonomous organizations, particularly those related to decision-making efficiency, scalability, and adaptability.

To achieve this, the study sets out the following objectives:

– to analyze the drawbacks of conjunctive and disjunctive voting models in DAO governance, to propose a hybrid model that combines their strengths;

– to design a smart contract-based architecture capable of dynamically selecting voting logic based on the type of proposal, and to implement dynamic quorum parameters as part of the governance mechanism.

Additionally, the study aims to validate the proposed solution through simulation, demonstrating its potential to improve resilience and operational effectiveness in both financial and infrastructure-focused DAO systems.

4. The study materials and methods for hybrid voting implementation in DAO

4.1. Description of the hybrid voting model

An alternative to the traditional conjunctive model is disjunctive voting, which allows decisions to be made in a DAO if at least one of the specified groups of participants reaches the established quorum. This approach increases flexibility, speeds up decision-making, and improves scalability while preserving the basic principles of decentralization.

The proposed architecture considers the most common model, which includes two groups:

1. *Validators* – a small circle of technically trained or designated participants who are trusted and perform the function of expert control. Their participation ensures quality control over critical changes.

2. *Token holders* – a broad circle of community members whose voting weight is determined by the proportion of tokens they hold. This group provides decentralized representation of the community's interests.

Within the disjunctive model, a proposal is considered adopted if the established quorum is reached in at least one group.

4.2. Architecture for implementing the hybrid voting model

The proposed voting model is implemented through a modular smart contract architecture that enables both conjunctive and disjunctive logic. The following architecture illustrates how the conceptual model is realized in a decentralized system.

A key component of the proposed system is the *JudgeContract* smart contract, which processes votes, verifies signatures, and determines the results of the vote. For each group, it has separate voting methods:

1. *addValidatorVote*() – accepts a signed message from the validator, verifies its membership in the group, and saves the vote.

2. *addHolderVote*() – processes the holder's vote, calculating the weight according to the number of tokens held.

All votes are transmitted as off-chain signed messages, which significantly reduces gas costs, while signature verification is performed using the ecrecover function. The vote counting process is implemented as a sequential quorum check for each group (Fig. 1):

1. *JudgeContract* calculates the proportion of “YES” votes among validators. If this share exceeds the set threshold *REQUIRED_VALIDATORS_PERCENT*, the decision is considered adopted, and the holders' votes are not checked. The implementation of the validators' vote counting function is shown below:

```
function countValidatorsVotes(
    address[] memory validators,
    BaseProposal baseProposal,
    uint requiredValidatorsPercent
) internal view returns (bool) {
    uint validatorsNum = routerContract.validatorsCounter();
    require(validatorsNum > 0, "Validators not found");

    uint yesVotes = 0;

    for (uint i = 0; i < validators.length; i++) {
        BaseProposal.Vote memory vote =
            baseProposal.getVote(validators[i]);

        if (vote.option == ProposalLibrary.VoteOptions.YES) {
            yesVotes++;
        }
    }

    return yesVotes * 100 >= requiredValidatorsPercent *
validatorsNum;
}
```

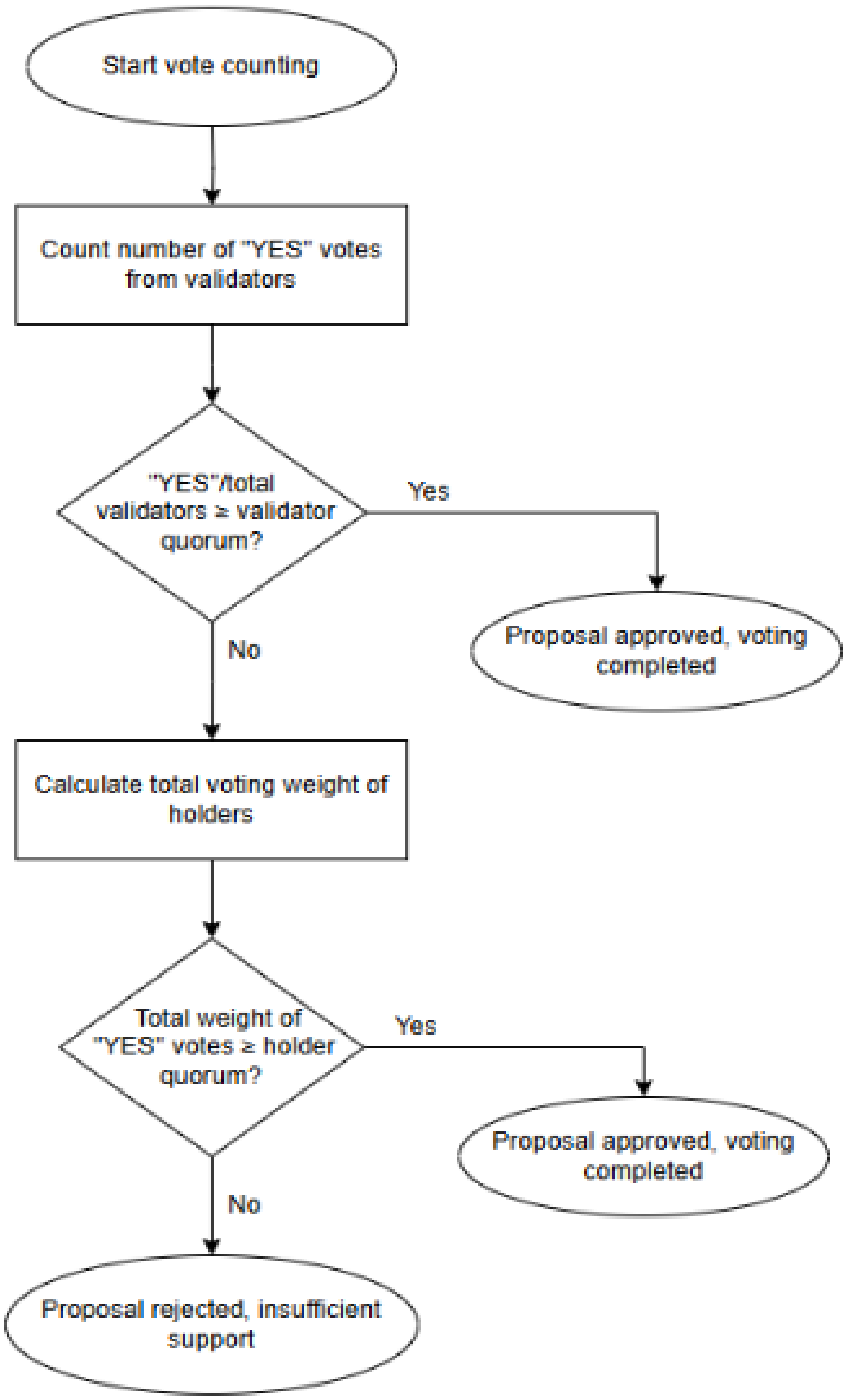

Fig. 1. *JudgeContract* voting process

2. If the validators do not reach a quorum, the system proceeds to analyze the votes of the holders. Each vote is assigned a weight proportional to the share of tokens held by the participant. “YES” votes increase the total weight, while “NO” votes decrease it. “CANCEL” votes are not counted in the final result, but are still recorded. If the total weight exceeds *REQUIRED_HOLDERS_PERCENT*, the proposal is also considered approved. The implementation of the holder vote counting function is shown below:

```
function countHoldersVotes(
    address[] memory holders,
    BaseProposal baseProposal,
    uint requiredHoldersPercent
) internal view returns (uint) {
    uint totalWeight = 0;
    uint totalSupply = routerContract.totalSupply();

    for (uint i = 0; i < holders.length; i++) {
        BaseProposal.Vote memory vote =
            baseProposal.getVote(holders[i]);

        uint balance =
            routerContract.openCommunity()
            .balanceOf(holders[i]);

        uint weight =
            (balance * 100 * FIXED_POINT_MULTIPLIER)
            / totalSupply;

        if (vote.option == ProposalLibrary.VoteOptions.YES) {
            totalWeight += weight;
        } else if (vote.option == ProposalLibrary.VoteOptions.NO) {
            totalWeight -= weight;
        }
    }

    return totalWeight >= requiredHoldersPercent;
}
```

3. If no group reaches the quorum, the vote is considered failed at this point, but the vote counting process can be restarted after new votes from participants appear.

The system supports a re-voting mechanism. Users can change or withdraw their votes, while the system keeps a full history of changes, selecting only the last valid decision for counting. This approach ensures technical transparency, verifiability, and openness of voting process.

A distinctive feature of the proposed architecture is that all quorum threshold values – both for validators and holders – are stored in a single configuration smart contract called *RouterContract*. *JudgeContract* obtains the current parameter values from it using the *getConstant*() function, which allows the system to be flexible, adaptive, and updatable without the need to change the logic of the main contract.

A key element of decentralization in this model is that all quorum values can also be changed by voting in the DAO. To do this, the community initiates a separate CONSTANT_PROPOSAL type proposal, which, once approved, changes the corresponding constant in *RouterContract*. In this way, the DAO retains full control over the decision-making mechanism, including the voting rules themselves.

On the one hand, this approach provides flexibility and allows quorums to be adapted to the needs of the community in conditions of changing participant activity or ownership structure. On the other hand, there is a risk of abuse when one group can lower the quorum threshold for their own group or raise for another. This opens up potential attack vectors and undermines the balance of influence in the DAO.

To prevent manipulation when changing critical parameters, such as the threshold values required for accepting a proposal, it is advisable to introduce stricter requirements for voting on such changes. This creates a need to develop a hybrid voting model that uses conjunction, i.e., unanimous decision-making by all groups to approve critical decisions in the system, such as changes to quorum thresholds, and flexible disjunction for other decisions in the system.

Thus, the system implements a hybrid approach that allows balancing security and flexibility. DAO gains the ability to make effective operational decisions while protecting critical management logic from potential abuse. This model not only increases adaptability but also ensures the stability of management processes in scalable decentralized systems.

5. Experimental validation of the hybrid voting model

5.1. Simulation setup and methodology

Undoubtedly, the disjunctive model sacrifices some security guarantees in order to achieve greater flexibility and speed in decision-making. To determine how significant this difference is in real-life scenarios, a simulation experiment was conducted to model the voting process in a DAO with two independent groups: validators and token holders.

For the purposes of the simulation, it is assumed that the system includes 10 validators and 100 token holders, with a total of 1 million tokens randomly distributed among the latter. To make a decision, a quorum of 60% of validators and 30% of the total number of tokens held by holders is required. This distribution is justified by the expectation of stable activity of validators and less interest of holders in current voting.

Four scenarios were modeled with different levels of activity for both groups. In the balanced scenario, both groups were active – 80% of validators and 60% of holders participated in the vote. The other two scenarios had only one group active. The fourth scenario was based on low voter participation, with each group member participating with a 50% probability.

In each scenario, 1,000 votes were simulated, where for each participant, it was determined with a certain probability whether they would participate in the vote and, if so, whether they would support the proposal. It was assumed that approximately two-thirds of the participants would support the proposed proposals, while the rest would reject them. Deadlock situations were also calculated, when conjunctive voting reaches a dead end due to low participation of one side or the other.

5.2. Results and analysis

Based on the specified parameters, the results shown in Table 1 were obtained.

Table 1. Simulation results

Scenario	Successful voting of the conjunctive model	Successful voting of the disjunctive model	Deadlock when using the conjunctive model
Balanced	42.3%	99.2%	56.9%
Passive validators	0.6%	71.3%	99.4%
Passive holders	0.5%	64.7%	99.3%
Low participation	6.2%	31.0%	70.2%

The simulation results demonstrate that the disjunctive model significantly increases the probability of successful voting in all scenarios, especially when one of the groups is less active. The conjunctive model, despite its high level of security, proved to be extremely sensitive to participant absence and regularly entered into a deadlock, making it impossible to reach any decision. Thus, the operational effectiveness of the disjunctive model is empirically confirmed, especially in conditions of low participation or asymmetry between groups.

Following the evaluation of voting success through simulation, a comparative table (Table 2) is presented to highlight the key advantages and disadvantages of each of the two considered models:

Table 2. Comparison of voting models in DAO

Criteria	Conjunctive model	Disjunctive model
Condition for approval	Mandatory consent of all existing groups	Agreement of any of the groups
Security	High: multi-level verification and mutual control	Average: voting depends on the activity of only one group
Decision-making speed	Low: consensus must be reached among several groups	High: achieving a quorum in any group is enough
Possibility of deadlocks	High: significant chance of deadlock situations with low participation from one of the parties	Low: one active group can push through a decision while another skips the vote
The risk of one group taking control	Minimum: the consent of all groups is always required	High: one group can make decisions without considering the opinions of others
Fit for critical change	High: ensures thorough verification of decisions	Low: may allow critical changes with the support of only one group
Use in DAO	Widely used in large DAOs (e.g., Lido, Compound, Optimism)	Limited, although used in some specific solutions
Gas consumption	High: the votes of all groups are always counted	Low: vote count may stop if one of the groups reaches quorum.

The analysis shows that none of the models is universal. Conjunctive voting guarantees a high level of security and balance of interests, but slows down the decision-making process and is prone to deadlocks when participants are not very active. On the other hand, the disjunctive model provides significant speed and adaptability, but creates the risk of one-sided influence by the more active group.

5.3. Summary of findings

That is why it is advisable to use a hybrid approach, in which the type of voting is chosen depending on the type of proposal. Thus, for changes that affect management rules, such as setting a quorum for a particular group, conjunctive logic should be applied as a safeguard against potential manipulation. On the other hand, for less critical or operational changes, such as regular updates to logic or UI/UX, a disjunctive model is enough to make sure things run smoothly and quickly, especially in big communities where people aren't very active.

All this forms an adaptive voting architecture in which the logic is determined automatically and the threshold values are stored in a configuration contract managed by the DAO.

This approach allows DAOs to be scalable, secure, and flexible, and also opens up opportunities for applying similar models outside of financial systems – in particular, in distributed IoT networks, where rapid response and secure coordination are important.

Special attention should be paid to gas consumption. In the disjunctive model, the quorum is checked sequentially for each group, and the process can end immediately after one of them reaches the quorum. This reduces the average gas consumption during vote counting. In contrast, the conjunctive model is required to process votes from all groups, regardless of whether a quorum has already been reached in any segment, resulting in predictably higher costs. In large-scale DAOs, this difference can have a significant impact on the overall efficiency of the system, especially in scenarios with a large number of participants. This is critical for DAOs or IoT systems where optimization of computing resources and minimization of costs are required.

As a result of this study, all declared objectives were fulfilled. The drawbacks of conjunctive and disjunctive voting models were analyzed, leading to the development of a hybrid architecture that combines their advantages. Smart contracts were designed to automatically select the voting logic based on the type of proposal and to support dynamically adjustable quorum thresholds.

Simulation across four scenarios confirmed that the proposed model reduces the possibility of deadlocks and improves decision-making efficiency under conditions of uneven voter activity.

The scientific novelty lies in the introduction of adaptive voting logic that adjusts dynamically, as well as in combining off-chain vote submission with secure on-chain processing. This allows DAOs to remain scalable, resilient, and flexible even in unstable participation environments.

6. Discussion of results and implications of the hybrid voting model

Traditionally, voting mechanisms in DAOs rely on conjunctive logic, where a decision requires the approval of all parties. This approach ensures a high level of security by preventing any one group from dominating, but it significantly reduces efficiency, especially when there is asymmetry in the size or activity of the groups. If at least one group has low participation, there is a real risk of deadlock, i.e., a situation where no decision can be made. In large DAO systems, this situation can lead to management paralysis – for example, the inability to perform routine updates or change system parameters.

Given the increasing complexity of decentralized systems, the adaptability of decision-making mechanisms becomes a key factor in their viability. DAOs striving for sustainable development must balance flexibility and security in decision-making [10].

In this context, disjunctive voting, which allows decisions to be made with sufficient support from at least one group, is an alternative solution that significantly improves the dynamics of decision-making. However, at the same time, it creates the risk of domination by the more active group. To avoid such cases, a hybrid model is proposed, where the type of voting is determined based on the subject matter of the proposal. That is, critically important updates, such as changes to voting rules or the structure of the DAO, must be adopted unanimously, taking into account the interests of all groups. But operational and technical changes can be adopted using the disjunctive model.

To confirm the feasibility of this approach, 1,000 votes were simulated in four scenarios of activity and support by participants, the results of which showed a significant advantage of the disjunctive model in terms of the proportion of successful votes and minimization of deadlocks. This indicates that in conditions of low or asymmetric activity, hybrid logic provides both stability and efficiency.

An additional aspect of adaptability is the ability to dynamically set quorum thresholds for each group, which is particularly relevant when the number of DAO participants changes. To prevent manipulation, it is proposed that changes to these parameters be fixed only by a conjunctive voting scheme.

In general, combining disjunctive efficiency with conjunctive reliability in a hybrid model creates a universal mechanism suitable for scalable and stable DAO systems, including applications outside of finance, such as decentralized coordination of the Internet of Things or shared resource management.

Conclusion

This paper proposes a hybrid voting model for DAOs that combines conjunctive and disjunctive logic depending on the type of proposal. To implement it, a smart contract architecture has been developed with support for a dynamic quorum controlled by the DAO itself through a special type of voting. The simulation confirmed the effectiveness of the approach: the hybrid model reduces the possibility of deadlock and increases the effectiveness of decisions in scenarios with uneven or low participant activity. The proposed solution is suitable for both financial DAOs and decentralized infrastructures such as IoT, where response speed and stability are critical.

The key findings and contributions of this study are as follows:

1. Proposed a hybrid voting model that combines conjunctive logic for critical decisions and disjunctive logic for operational matters, depending on the type of proposal.

2. Developed a modular smart contract architecture that supports dynamic quorum thresholds and automatic selection of voting logic, ensuring technical adaptability and ease of governance updates.

3. Introduced off-chain vote submission with on-chain validation, significantly reducing gas costs while maintaining transparency and verifiability.

4. Conducted simulation experiments across four activity scenarios, confirming that the hybrid model improves decision-making efficiency and minimizes deadlocks under low or asymmetric participation.

5. Demonstrated scalability and flexibility, making the model suitable not only for DAO governance but also for broader applications such as distributed IoT systems that require secure, efficient coordination.

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ГІБРИДНА МОДЕЛЬ ГОЛОСУВАННЯ ДЛЯ ДЕЦЕНТРАЛІЗОВАНИХ АВТОНОМНИХ ОРГАНІЗАЦІЙ З ДИНАМІЧНИМ КВОРУМОМ

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У статті розглядається проблема досягнення балансу між безпекою та гнучкістю у механізмах прийняття рішень у децентралізованих автономних організаціях (*DAO*, *Decentralized Autonomous Organizations*), що функціонують без централізованого контролю завдяки використанню смарт-контрактів. Для цього проаналізовано дві основні моделі голосування, що використовуються в *DAO*: кон'юнктивну, яка передбачає обов'язкову підтримку пропозиції всіма групами учасників, та диз'юнктивну, де достатньо схвалення однією з груп. Обидві моделі мають суттєві переваги та недоліки: перша гарантує високий рівень безпеки та дотримання інтересів усіх сторін, але значно уповільнює процес ухвалення рішень, тоді як друга забезпечує швидкість і масштабованість, але створює ризики централізації впливу.

Як відповідь на ці виклики запропоновано гібридну модель голосування, у якій тип логіки, а саме кон'юнктивна або диз'юнктивна, визначається залежно від характеру пропозиції. Зокрема, критичні зміни, такі як оновлення правил управління чи параметрів кворуму, мають прийматись за участі всіх груп, тоді як рутинні операційні питання – за спрощеною диз'юнктивною процедурою. Реалізована архітектура смарт-контрактів підтримує обидва механізми та дозволяє *DAO* динамічно змінювати порогові значення кворумів через окремі управлінські пропозиції.

Для перевірки ефективності моделі проведено симуляцію 1000 голосувань у чотирьох різних сценаріях активності учасників, а саме збалансованому, односторонньому та сценарії з низькою загальною участю. Результати показали зниження ймовірності тупикових ситуацій і підвищення частки успішних голосувань при застосуванні гібридної логіки, особливо в умовах низької або асиметричної участі. Крім того, окрему увагу приділено оптимізації витрат газу: диз'юнктивний підхід дозволяє припинити підрахунок голосів після досягнення кворуму однією групою, що знижує загальні обчислювальні витрати.

Таким чином, запропоноване рішення є перспективним як для фінансових *DAO*, так і для сфери децентралізованих інфраструктур, зокрема Інтернету речей, де особливо важливі швидкість, масштабованість та безпечна координація.

Ключові слова: *DAO*, механізм голосування, смарт-контракти, блокчейн, динамічне управління