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Research Article

Towards a systematic understanding of blockchain governance in proposal voting: A dash case study

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ABSTRACT

The transparent and immutable nature of blockchain provides incentives for organizations wishing to create and implement an open, decentralized governance structure. As members exercise their voting rights, a fault-tolerant record accumulates on the blockchain that can be analyzed to diagnose and intercept potential threats to the governing body. To date, there has not been a systematic study of on-chain governance with respect to voting. In this paper, we provide an analysis of blockchain governance through a case study of the first cryptocurrency to adopt on-chain voting, Dash. Our analysis introduces the key characteristics of blockchain governance, steps through a data-driven exploration of Dash's on-chain voting system, and highlights exploitable attack vectors and vulnerabilities for the subversion of Dash's on-chain voting system via a novel network analysis methodology. We then conclude with guidelines for other organizations looking to implement similar blockchain governance solutions while maintaining integrity in their operations.

1. Introduction

Faced with an ever-increasingly competitive landscape, organizations are being pushed to innovate across every aspect of their business. This includes even core procedures that govern internal decision making, an area traditionally resistant to change. As the understanding and proliferation of blockchain technologies has expanded, its use cases have grown beyond payment processing and money transmission into the areas of data sharing, item tracking, supply chain monitoring, power systems, and even digital voting [1–4].

The last of these, internet-based digitized voting as enabled by the blockchain, created a new class of governance systems with inherent transparency and immutable properties. These properties are intrinsic traits of the underlying blockchain, a public ledger of transactions made from cryptographically hashed blocks [5,6]. This historical ledger is shared among many users, where each block contains a cryptographic hash of the prior block, a timestamp, and transactional information. The benefits of such a system are security and transparency since blocks are added sequentially. By building on the previous block, the chain cannot be easily removed or altered because the blocks that immediately succeed in the current block will be affected by the hash and reject the attempted modification [7].

Although the application of blockchain technology is still maturing, industries have begun to realize its potential and have already started incorporating certain aspects of on-chain governance into their businesses [8–10]. One such entity is Dash, the first cryptocurrency to establish on-chain governance through the establishment of a decentralized autonomous organization (DAO) and masternode protocol. This paper intends to analyze Dash's governing system to build on the existing body of knowledge of governance structure by introducing key concepts central to blockchain governance, analyzing their on-chain governance ecosystem, identifying potential voting system subversion, and concluding with guidelines for other organizations looking to implement similar digitized voting solutions. By doing this unique analysis, we hope to draw attention to implementation, security, and integrity challenges facing blockchain technologies with respect to their governance structure in proposal voting and showcase analytical techniques that can be used to analyze on-chain voting systems.

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1.1. Governance and proposal voting systems

Succinctly, governance is the process for which members of an organization establish a set of underlying rules for the execution of executive decisions [11]. Historically relegated to large corporate institutions with centralized decision making hubs, governance procedures have grown to be more inclusive of decentralized, distributed organizations through the use of modern blockchain-based implementations. Currently, blockchain technologies for electronic voting are being employed in non-profit organizations, cryptocurrency communities, and local politics as a means of governance for on-chain voting recording keeping and storage [12–14]. In fact, in 2018, Broadridge Financial Solutions successfully conducted the first proof of concept by adopting blockchain proxy voting to allow investors to vote remotely during their annual meeting [15]. While Broadridge Financial Solutions' innovation displays the potential of large industry adoption of blockchain governance, the cryptocurrency sector has been most keen to adopt this form of on-chain governance. The idea of governance within the cryptocurrency sector takes its history from the concept of gaining consensus or multi-party validation of mined blocks. A natural extension takes the idea beyond validating only transactions stored in a block to validating blocks containing voting records. For the cryptocurrencies that leverage this digitized voting ledger, the motivation is to coordinate decision making across multiple entities, ensuring all aspects of network sustainability are being addressed. Like traditional corporations, the health of a network involves marketing, branding, community engagement, and technological developments.

To facilitate the advancement of the network along the aforementioned dimensions, governance-enabled cryptocurrencies will solicit proposals from the greater public and then leverage their decentralized voting structure to approve those that are deemed most beneficial to the overall mission by a majority vote. Through this procedure, many established cryptocurrencies leverage improvement proposals as a means of guiding their development. Bitcoin through Bitcoin Improvement Proposals and Ethereum through Ethereum Improvement Proposals both solicit proposals for changes to the network protocol, design, issues, and processes [16,17]. Although both proposal systems are sophisticated in their own right, that is not to say they are without fault. In any governance model, when large groups of unregulated individuals are allowed to freely propose ideas and vote, some fraud is likely to happen [18,19]. Despite being the two largest cryptocurrencies by market capitalization, neither has a fully formed governance structure that tracks proposals and their votes on an immutable blockchain [20].

Due to the lack of a fully functioning governance structure, performing analysis on the vulnerability and integrity of blockchain voting on a large scale is not possible for Bitcoin or Ethereum. That distinction belongs to Dash, a 2014 Bitcoin fork, with a modified network protocol that leverages static Internet Protocol (IP), a protocol for routing and addressing packets of data to the correct destination, nodes to perform additional on-chain functions, one of which includes proposal voting [21]. Because Dash governance utilizes a transparent and immutable blockchain to record proposals and voting records, analysis can now be performed on the characteristics and trustworthiness of on-chain voting. The intent of this paper is two-fold.

- The first goal is to use Dash's governance system to shed light on the management of blockchain voting systems through a data mining approach to inform decision makers of potential benefits, vulnerabilities, and integrity considerations that must be determined before any large-scale organizational implementation.
- The second is to propose a systematic network methodology to analyze the integrity of on-chain voting records to understand the vulnerabilities of decentralized voting. We hope the generality of our approach can be applied to analyze any on-chain governance voting system.

To achieve this goal, in Section 2, we provide background information first through related works in this area and then through an overview of Dash's governance proposal system and insights that describe their ecosystem. We then showcase analytical techniques that can be performed to investigate on-chain governance systems in Section 3. Namely, data mining is performed on submitted proposals to provide insights into Dash's strategic vision for the future and the significance of soliciting proposals. Next, Section 4 contains a unique exploration using network analysis on voting patterns that allows us to provide a novel investigation of behavioral patterns and identify potential vulnerabilities in on-chain voting systems before we end with our discussions and final conclusions in Sections 5 and 6, respectively.

2. Background

In this section, related work in the area of traditional and decentralized blockchain governance is summarized. We then follow up with a detailed overview of Dash's governance protocol and provide insights into the voting process.

2.1. Related work

Blockchain governance has recently interested the research community. Active research is conducted to understand the governance structure of a blockchain through systematic analysis of its technology [22,23]. These works explain the role governance has in enforcing agreements and achieving cooperation that is distinct from traditional governance and other information technology mechanisms. Building on this, Lumineau et al. [24] researched the effectiveness of a blockchain governance mechanism and highlighted the key ways blockchain governance can change the way organizations collaborate for optimized efficiency.

Indeed, these works highlight the piqued interest in blockchain governance. In parallel to studying standard blockchain governance, research has also been performed on decentralized governance enabled through DAOs. These groups are essentially member-owned communities without a central leader. These DAOs place their trust in blockchain technologies through smart contracts they build together on the blockchain, and these contracts become the governing body. The enablement of smart contracts allows for the automatic execution of code when a set of criteria is met, therefore not needing human intervention [25]. Bitcoin is a representation of the first practical implementation of a DAO and has offered a novel model for behavioral and organizational collaboration. Using the prototype built by Bitcoin, other blockchain-based organizations are built upon a decentralized governing body such as Dash, Aave, and Uniswap [26,27]. This particular type of governance is the focus of our paper.

The literature in this area focuses on comparing and contrasting the decentralized governance for blockchain with traditional governance through qualitative analysis [28,29]. However, there has not been an analytical approach to systematically investigating the mechanisms of a DAO from a governance perspective. Most works in this area accept the usefulness of decentralized governance on blockchain and only suggest tools and future improvements through advancing technology [30–32]. The combination of advanced data analytics techniques and blockchain governance has not been explored. Given this literature gap, we aim to provide a systematic understanding of blockchain governance through the use of modern analytical tools. We hope that, by applying methodologies from network analysis and traditional data mining, others can use similar approaches to understand the interactions of a blockchain-based DAO.

2.2. Dash governance as a DAO

The Dash network's vision openly states that it seeks to increase financial freedom and opportunity by providing the easiest-to-use payments-focused blockchain network. To coordinate actions and facilitate planning, core members of the Dash community incorporated a formal non-profit entity and established themselves as a fully functional DAO. With all the rights and privileges provided to a corporate organization, the DAO is able to solicit proposals publicly to further its mission. Dash's DAO network utilizes an Application Programming Interface (API), a programming application to connect between computers, to enable user engagement through the proposal. Monthly, a request for proposal process is initiated where potential projects are submitted to the network via API commands sent directly to the blockchain from a wallet address containing at least 5 Dash (as of 2022-03-18, 1 Dash=94.59 USD). This 5 Dash acts to thwart network abuse by those who wish to spam or perform grieving actions against the community. The following information is required to create a proposal:

- proposal-name: a proposal label
- URL: a link containing the proposal details
- payment-count: the length of payment
- block-start: the requested start of proposal payments
- dash-address: the wallet address to receive payments
- monthly-payment-dash: the requested payment amount

Upon submission, the 5 Dash fee is collected, then destroyed, and the proposal is included in the next available voting block to be mined. Moreover, the 5 Dash fee is non-refundable, meaning that if a proposal is not approved for funding, the creator does not receive their 5 Dash back. This steep penalty aims to ensure that only serious proposals are submitted for the health and well-being of the community. In practice, before a (legitimate) proposal is submitted, the creator will suggest the idea to the Dash community through popular communication mechanisms such as Discord. The creator will then only submit the proposal when enough feedback is given to ensure a positive outcome. Currently, Dash's Discord community has approximately 4000 members. Although this is small in relation to the entire space of Dash owners, it is assumed that those who are heavily invested (both monetary and ideologically) in the future of Dash are active members of the community and, thus, actively participate in this communication channel.

Dash's DAO distributes voting responsibilities across multiple entities via its masternode protocol. Masternodes are special nodes that facilitate additional features on the network. To receive this distinction, a potential masternode operator must configure a remote cloud server with a standardized IP address to connect with the Dash blockchain using the most recent version of the Dash Core wallet software. Through a series of synchronization commands, the remote server downloads the Dash blockchain and forms a link with the other full nodes on the network. A wallet address is then created on the full node, funded with 1000 Dash by the potential masternode operator, and the final authentication commands are sent to the blockchain [33]. Once completed, the masternode operator is now able to participate in the governing activities within the Dash ecosystem. The governance of Dash can be seen as a departure from Bitcoin since users can only vote if they own at least 1000 Dash. In principle, the threshold of owning 1000 Dash ensures only members who are committed to the future direction of Dash have a voice. A situation such as this can be seen as analogous to an organization requiring a certain number of shares before allowing voting, such as with Broadridge Financial Solutions, where the proposal is equivalent to decisions that have to be made about the future of the organization.

In Fig. 1, we provide a sample instance of proposals on Dash Central, a website for Dash masternode monitoring and budget voting. As one can see, there is a progress bar on the left which indicates the progression towards the yes votes that need to be approved, and indicators on the right are up/down votes that gauge the popularity of the proposal. We reiterate at this point that only 5 Dash are needed to submit a proposal, but 1000 Dash are needed to be able to vote.

For proposal voting, the only options given are “Yes”, “No”, or “Abstain”, meaning the masternodes can approve the proposal, reject the proposal, or cast a non-vote. Once a proposal is formally submitted and its record is etched as a governance object on Dash's blockchain, the voting procedure requires the net total of yes votes to be greater than 10% of the total masternode population at the time votes are counted. Although counterintuitive, Dash's governance document only requires greater than 10% of active masternodes' approval instead of the common 50%. To date, there has not been a proposal submitted to change from the 10% threshold. Therefore, we interpret this to mean that the Dash community is content with this threshold. Fig. 2 provides an illustration of the details for a specific proposal “Dash: Alt Thirty Six Proposal”. This sample proposal is pending and needs an additional 215 votes to be approved. If this proposal is granted, the owner will be paid 5 Dash, as requested, to fund their initiative. Given the ratio of “Yes” to “No” and “Abstain” votes, it appears that this is a popular proposal and may indeed be funded.

The funds allocated to projects are derived from a portion of the block

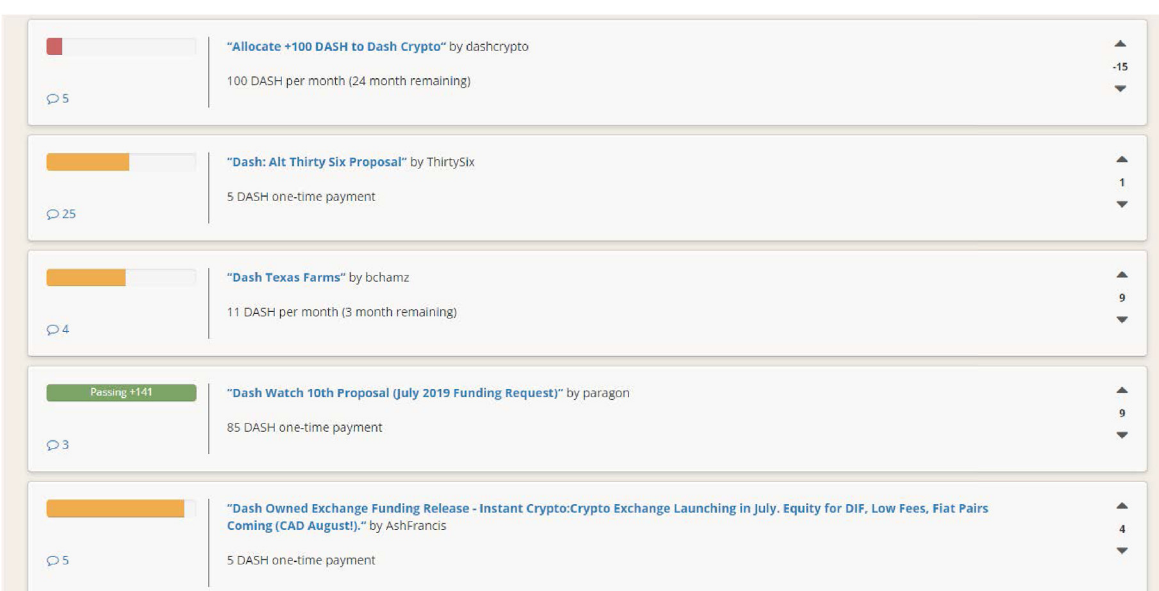

Fig. 1. An illustration of proposal discussion and voting progress on Dash Central.

Fig. 2. Proposal details and voting buttons for Dash Central.

reward that is mined in between proposal periods. The DAO controls a special wallet address that stores 10% of the block reward mined for every block included in the blockchain. Each voting period extends precisely 16616 blocks (approximately one month). This number is intentional and deemed to be the time a so-called superblock is created, as illustrated in the diagram below.

$$\underbrace{\text{Block} \leftarrow \text{Block} \leftarrow \ldots \leftarrow \text{Superblock}}_{\text{16616 Blocks}} \leftarrow \underbrace{\text{Block} \leftarrow \text{Block} \leftarrow \ldots \leftarrow \text{Superblock}}_{\text{16616 Blocks}}$$

This special block is simply a designated term for a blockchain block that distributes both mining rewards and proposal funding. At the conclusion of voting, proposals that successfully pass have their funds dispersed according to the terms defined in the project [34].

For specific months where the budget request of proposals is greater than that of the allocated funds, the proposals with the highest yes votes (beyond the threshold) receive the highest priority in funding. In the scenario where a proposal acquires the necessary votes but insufficient funds remain to pay the full proposal amount, the project will not be funded. Instead, lower cost proposals that have passed the voting threshold and fit within the budget will be funded. The unfunded proposal will then have priority funding in the next funding cycle. If there are unallocated funds at the end of the funding cycle, then those funds are never distributed.

In contrast to traditional governance systems where voting must occur in person, with the implementation of blockchain technology, the need to vote in person is no longer necessary. Dash's DAO is a fully-functional example that successfully showcases remote decentralized governance and is fully transparent and secure by placing the votes on an immutable blockchain. Traditional brick-and-mortar corporations face numerous governance issues, such as conflicts of interest, accountability, investor resources, and transparency [35,36]. By having the transparent and fixed ecosystem that a blockchain provides, there will be an open framework for accountability in stakeholder voting and how investor resources are spent. The benefits this system provides are in its honest behavior so that any conflicts of interest are addressed and can be mitigated.

3. Exploratory data analysis of dash governance

In this section, we perform a detailed exploratory analysis of proposals submitted to Dash's DAO. The section intends to highlight user activity, highlight the significance of submitted proposals from both a future-vision and monetary perspective, and identify engagement issues in blockchain voting.

Since its inception, Dash's DAO has considered over 550 proposals, each of which is accessible via the Dash Central API. For our analysis, we downloaded all proposals submitted from 2015-08-27 to 2020-05-22, allowing the API to return fields with information on the budget requested, proposal description, and unique identifiers of submitters. These details are relevant for tracking the types of proposals being submitted to the network and provide insight into the pool of project principal investigators. To track votes that were cast, voting information was downloaded from the Deterministic Masternodes Monitoring website [37]. Through this site, masternode voting history can be accessed in conjunction with IP identifiers, software versions, and wallet addresses. With this data source, we are able to directly collect information and analyze the voting patterns of the 4987 masternodes who participated in voting across 577 proposals. It should be noted that the number of masternodes changes over time. However, given the requirement of providing 1000 Dash to become a masternode, we can bound the total number of masternodes above by $|\text{masternodes}| \leq \text{TotalCirculatingSupply}/1000 \approx 10628$. On Dash's official website, they state that the month of November 2018 had over 5000 masternodes in over 45 countries. Therefore, we believe that at any given time, there are estimated to be approximately these many masternodes. Although we cannot identify the exact proportion of these masternodes, it is well-known that they are a combination of individuals and groups. This is observed through investigating the information publicly available on Dash Central and performing a detailed internet search of the proposal creators, in addition to their activity on Dash's Discord community. Since the inception of the DAO masternode protocol, a total of approximately 90 million USD has been requested for funding, with nearly 40 million USD being paid out to approved proposals. With this large amount of money being requested and awarded, one would hope that Dash's fully functional governance systems of on-chain voting are well constructed and immune to any subversive attacks.

Conceptually, it is worth noting that the transparent nature of the blockchain is what allows for the unrestricted collection of voting records, whereas in a more traditional governance scheme, historical votes would have to be recorded by a trusted third party. Voting records would then be held by this central authority, where access may be restricted through means both unintentional and deliberate. In traditional governing scenarios, access to these records could also be lost as the result of only one key failure in the custodial party's storage protocol. A lack of secure storage procedures and a subsequent breach would not only compromise access to the records but also call into question the validity of the records kept since no previously recorded, publicly accepted consensus of all prior voting outcomes would exist. The immutable properties of the blockchain bypass this, creating a publicly agreed-upon record of each vote. The blockchain process of record-keeping is particularly relevant to establishing and maintaining the trust of the individual voting members since their votes are not handled by any intermediary but are etched directly on the blockchain as cast.

3.1. Analysis of dash community and Masternode engagement

In light of the previous points around blockchain transparency, with Dash's publicly available voting records, it is possible to download and restructure the data into a format that allows for queries into the behaviors of voting members, behaviors that can also proxy as indicators of organizational health. Beginning with Fig. 3, we visualize the number of proposal submissions and subsequent votes cast over time. These initial metrics characterize governance engagement simultaneously from the perspective of community contributors and masternode voters. Over time, although the number of proposals submitted has increased, the engagement of the masternodes in terms of the number of votes has decreased over the same time period. This leads to the most active users having more representation in the voting of proposals and possibly further leads to a biased direction towards the future of Dash should a discrepancy in voter representation be found to exist.

Moreover, Fig. 4 further elucidates the trend in voting by highlighting a decrease in the average number of votes while also noting that there is a slightly increasing trend in "No" and "Abstain" votes. This suggests that some masternodes are not only abstaining from voting but also completely disengaged from the voting process. This realization motivates the concern that without sufficient engagement in the democratic process, it becomes possible to exercise undue influence over the network through the manipulation of project acceptance or rejection rates.

Historically, the Dash masternode network has been very supportive of proposals submitted to their DAO, approving nearly 79% of all project proposals. However, as one can observe from Fig. 5, the monthly project approval rates have shown some degree of variability. This may be associated with the overall trend of the value of Dash, thus illustrating how utilizing a blockchain-based DAO can still lead to decisions backed by the value of a currency. Nevertheless, as this form of governance is completely decentralized, the masternodes are still rejecting a healthy number of proposals, therefore demonstrating the success of decentralized governance where members are left to govern themselves.

3.2. Topic analysis of dash proposals

In this section, we perform topic analysis on the titles and descriptions of Dash governance proposals by utilizing Latent Dirichlet Allocation (LDA). In our previous data mining exploration, we have brought to light user activity for an implemented on-chain governance system, but we have not examined if the proposals and topics submitted to Dash's DAO are serious in nature or simply grievance attacks. By analyzing the topics and descriptions of submitted proposals, we hope to answer the following on-chain governance implementation questions.

- What kinds of proposals are being submitted each month by self-governed individuals?
- How earnest and significant are the nature of the proposals submitted?
- Can a DAO have a clear future vision?
- Are there certain types of proposals the governance system is biased towards?

As mentioned previously, community contributions in the form of submitted proposals have been increasing over time. Using the proposal descriptions, it is possible, with minimal text cleaning, to fit an unsupervised machine learning algorithm called LDA to identify groupings of common words across the submissions [38]. This form of modeling is analogous to multi-dimensional clustering, where instead of groupings similar numerical observations, the output consists of groupings of words with high co-occurrence rates that form topics. That is, the results of this analysis contain topics that group together commonly related words.

Fig. 6 gives the top terms in each of the six topics derived from the LDA algorithm. We have removed common or irrelevant words from these proposals, such as "Dash" and the word "proposal" itself. We can immediately see that certain topics group together commonly related words—"event" and "conference" appear together in a topic, as do "payment" and "users". These groupings, together with domain insights, can help to name each topic category.

Using domain expertise and intuition, names can be assigned to these groupings. Our topic labeling is as follows:

1. Words: time, transaction, team, business **(Marketing)**
2. Words: conference, event, community, events **(Conferences and Events)**
3. Words: funding, budget, proposals, compensation **(Development and Budget)**

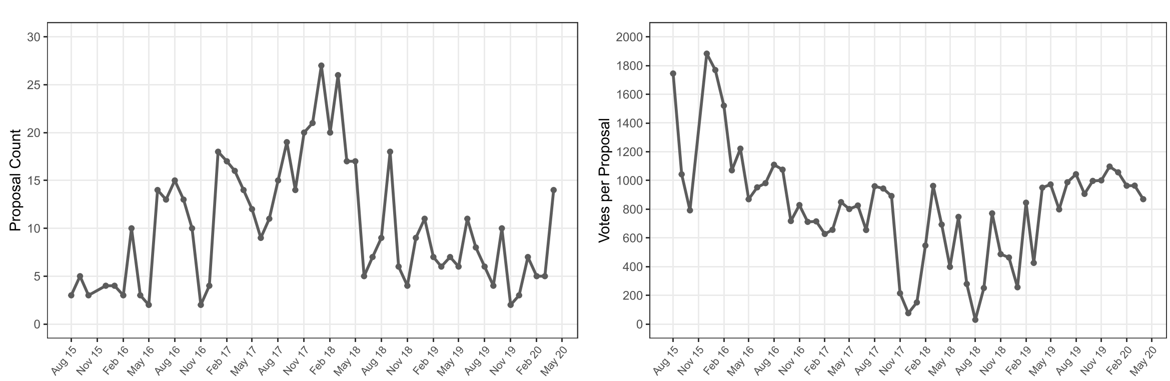

Fig. 3. The number of proposals submitted and the number of votes received over time.

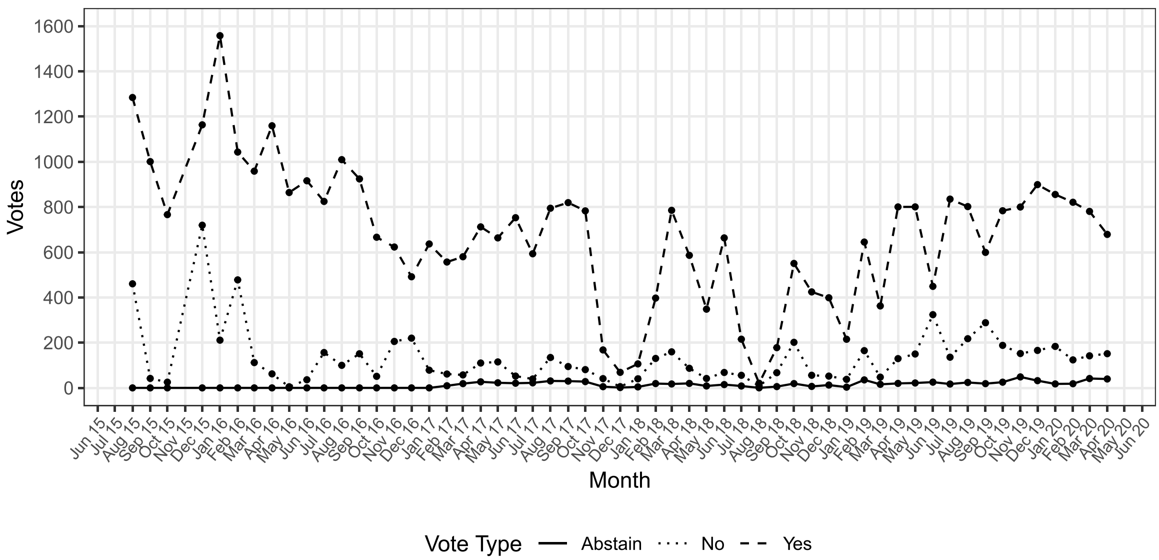

Fig. 4. The number of "Yes", "No", and "Abstain" votes over time.

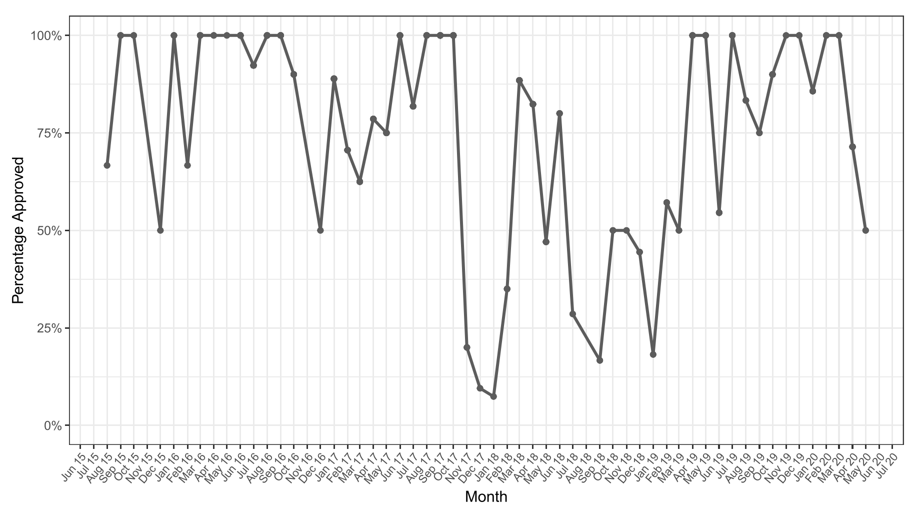

Fig. 5. Percentage of approved proposals as a function of time.

4. Words: payment, integration, support, team **(Projects)**
5. Words: support, users, merchants, media **(Third world Adoption)**
6. Words: video, media, youtube, news **(Cryptocommunity Outreach)**

After labeling the topics, we were able to assign each proposal to the topic based on its algorithmic classification. The following Table 1 shows a random subset of proposals under each topic to provide a reference for the project types contained within. This illustrates the ambiguity of certain proposals and their classification, as the LDA algorithm may not correctly classify each proposal, particularly ones that reside on the boundary of multiple topics.

Notwithstanding, when combined with information on past voting, the strategic vision becomes apparent. Fig. 7 displays this distribution of topics over time. We can see that, interestingly, Conferences and Events were relatively popular during 2017, but since 2018 they have been much less frequent. Conversely, both Projects and Cryptocommunity Outreach have increased their relative share of proposals in the 2018 time frame. This change in the organization's philosophy and priorities during that period may imply that the DAO can function properly without a centralized governing body in regard to organizational strategy.

From this analysis, we can thus answer the previously posed questions. Namely, submitted proposals do possess a natural category in which they belong and are not simply users submitting bogus proposals but ideas that can have a significant impact on the future success of Dash. On that same token, this illustrates that a DAO can indeed unify and have a clear vision and support for the future direction of an organization. The open transparency of the on-chain governance of the Dash proposal provides direct access to the prevailing ethos of the Dash ecosystem from both the perspective of project proposers and voting members. Behavioral characteristics behind engagement and strategic focus can be directly measured and quantified entirely from the blockchain. When compared to more traditional voting systems, this level of transparency, when combined with analysis, can help monitor against disengaged members as well as continuously track the strategic direction of the community.

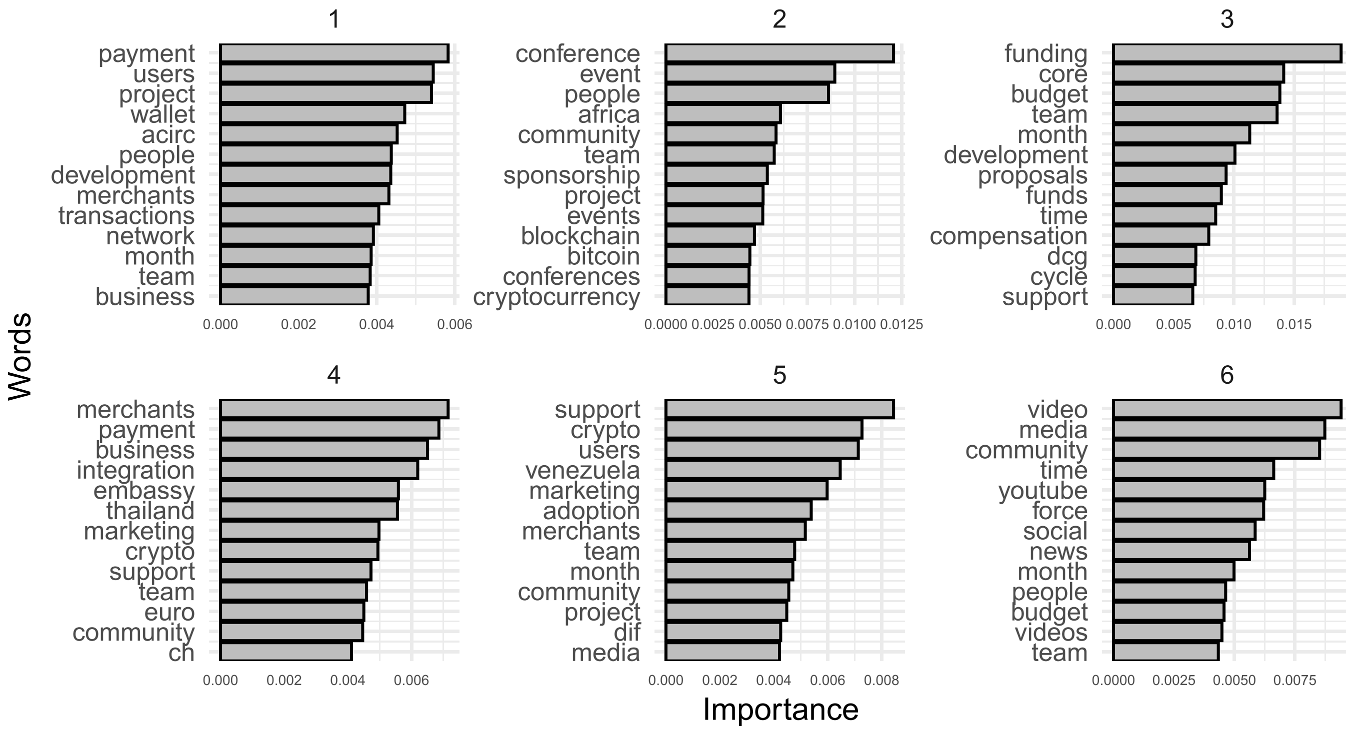

Fig. 6. The top terms in each of the six topics are derived from the Latent Dirichlet Allocation (LDA) algorithm.

Table 1
Randomly selected Dash proposals within each Latent Dirichlet Allocation (LDA) topic.

Topic	Title	Monthly (USD)
Third world AdoptionThird world Adoption	Dash Embassy Thailand Q proposal	15,751.26
	AnyPay Dash Merchant Acceleration Verified New Das …	3116.00
Conferences and EventsConferences and Events	Anypay Dash June August	68,474.73
	PorcFest Sponsorship Proposal Keynote by Ben Swann	23,937.76
ProjectsProjects	Dash Watch Fourth Proposal Jan	14,844.05
	Dash Masternode Tool Sept Dec support for Determin …	11,214.56
Development and BudgetDevelopment and Budget	Core Team Compensation February	216,659.00
	Anarchapulco Mexico Campus Party Brasil	5090.82
Cryptocommunity OutreachCryptocommunity Outreach	Dash BUSINESS MASSIVE ADOPTION IN GHANA WEST AFRIC …	11,671.52
	Dash India Workshops Community Building Educationa …	7428.96
MarketingMarketing	Dash Latam Mass Adoption Marathon Expansion into U …	16,008.87
	FanDuel and Dash Partnership Continued	22,784.14

4. Network analysis methodology

In this section, we leverage network analysis to analyze the voting records of masternodes to further gain an understanding of masternode behavior. In particular, we focus our attention on analyzing how individuals can impact the ecosystem and manipulate the acceptance of proposals. This investigation allows us to objectively and quantitatively assess the level of decentralization and vulnerabilities within Dash's on-chain governance system.

Working within the previously established diagnostic monitoring context, it is possible to analyze the blockchain preemptively to identify potential security and integrity threats to the governance system itself. One such scenario, particularly relevant to structures similar to Dash, involves proposal vote subversion through potential masternode collusion. As discussed previously, masternodes are specialized nodes synced to the Dash blockchain, but they are only uniquely identifiable to the network at the wallet or IP level. Should a single entity with control over multiple masternodes or a small group of multiple masternode owners decide to collude, the Dash governance system would be forced to contend with an existential threat to its proposal process. In Table 2 we show an illustration of the data as collected from the masternode monitoring API. From Table 2, we notice the introduction of an "NA" vote. This occurs in the event where a masternode did not cast a vote. Although, intuitively, this may seem equivalent to an "Abstain" vote, we treat this independently for our analysis. From a data mining perspective, we cannot impute NA with "Abstain" since the data are missing not at random and imputation may provide misleading results. Our analysis will take a network theory approach since this allows us to directly visualize the voting patterns of masternodes and their relationships to one another. Other ways of performing similar analysis would be biclustering or collaborative filtering [39,40].

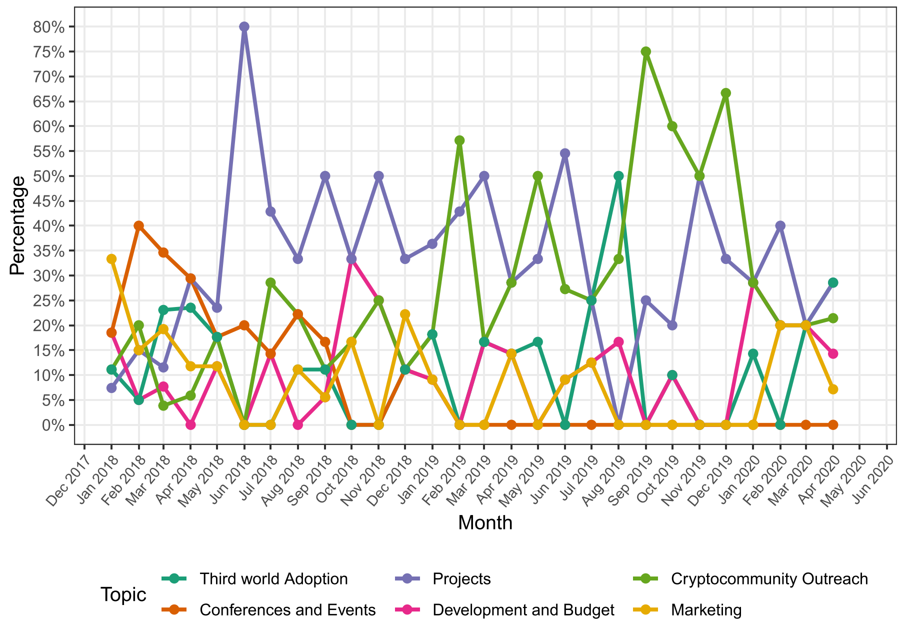

Fig. 7. Percentage distribution of Latent Dirichlet Allocation (LDA) topics as a function of time.

Table 2
Illustration of masternode voting data for three proposals.

Pubkey	IP: Port	ForceTech Dash Pay Plan	Dash Nation DFO 2018–2019	Coreteamcomp1118
XywELwcWFjS1m …	45.32.176.120:9999	NA	Abstain	Yes
XstekpNQm5ua1F …	45.32.193.246:9999	NA	NA	NA
XnhM7gomoHnYC54 …	45.63.48.22:9999	No	Yes	Yes

4.1. Data processing and methodology

For our network analysis, we consider 4987 masternodes and their voting across 577 proposals. Before beginning our analysis, we first remove all masternodes that have never voted. These completely disengaged masternodes consist of approximately 43.0% of the total active masternodes. As a data preprocessing step, we map the categorical strings {"Yes", "No", "Abstain"} to {-1, 0, 1}, respectively. We then constructed a similarity metric for comparing masternode relatedness before deriving the network while ignoring the "NA" values.

In detail, this process involved first creating a symmetric co-occurrence matrix containing the proportion of times each masternode voted in tandem with one another, ignoring the missing votes. Then, utilizing asymmetric binary distance and taking the reciprocal, we converted all values into an intuitive similarity metric bounded between 0 and 1. We then searched across the matrix for identical values shared between masternodes. This provides us with a similarity score where users with the same similarity rating voted the same. The construction of the final network of voting patterns is given in Algorithm 1 below.

Algorithm 1: Masternode Voting Network

Input δ - Masternode voting data set
Output Similarity value of masternodes

Update votes $\{v_{i_k}\}$ of δ by {"Yes", "No", "Abstain"} $\longmapsto$ {-1 , 0 , 1}, respectively for each masternode i
for each pair of masternodes $i, j \in \delta$ **do**
    Compute Euclidean distance for all non-missing entries, $d_{ij} = \sqrt{\sum_k (v_{i_k} - v_{j_k})^2}$, between voting records of masternode i and j
end for
Construct distance matrix, M, where $M_{ij} = d_{ij}$
Construct similarity matrix, S, where $S_{ij} = 1 - \dfrac{M_{ij}}{\max(M)}$
return Vector of row sums of S

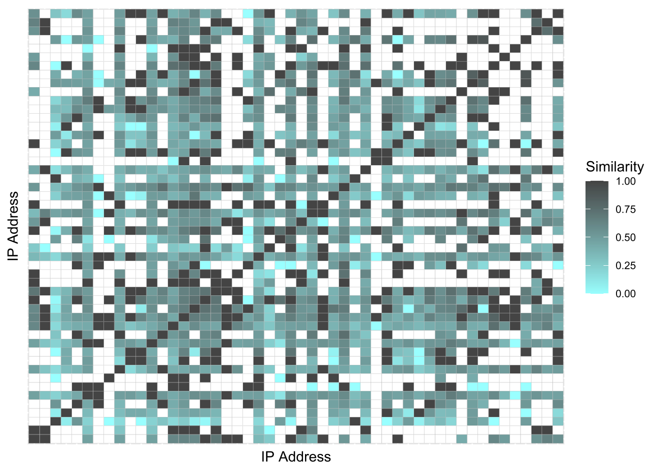

Fig. 8. Illustration of the similarity matrix for 50 masternodes.

During the construction of the similarity matrix, 43.03% of the distances were undefined. This can be attributed to the fact that some masternodes pairings did not vote on any of the same proposals. The similarity matrix S shown in Fig. 8 illustrates the similarity of a random subset of 50 masternodes analyzed. (Due to the large nature of this visualization, we were not able to create an appealing graphic by displaying all masternodes.) A similarity score of 1 indicates that between masternode i and j, their voting records were identical. Whereas a similarity score of 0 indicates completely disjoint voting behavior. As expected, along the diagonal, we have the same color due to our similarity matrix being symmetric by construction. The light blue cells represent dissimilar users, and black indicates similar users. Though only a sample, it is immediately noticeable from a large amount of black within our illustration that there are pairwise relationships where two masternodes share equivalent voting patterns. We reiterate that in our analysis we considered voting records across 577 proposals. Therefore, in the worst case, there is a pair of distinct masternodes who voted completely in tandem 577 times. In the United States Congress, it is estimated that approximately 90% of members vote along party lines [41]. Being political in nature, that may not be surprising, but in the case of a Dash's DAO, where proposals are not political in nature, it is peculiar that two independent masternodes that potentially live in two different locations across the world, vote completely in tandem.

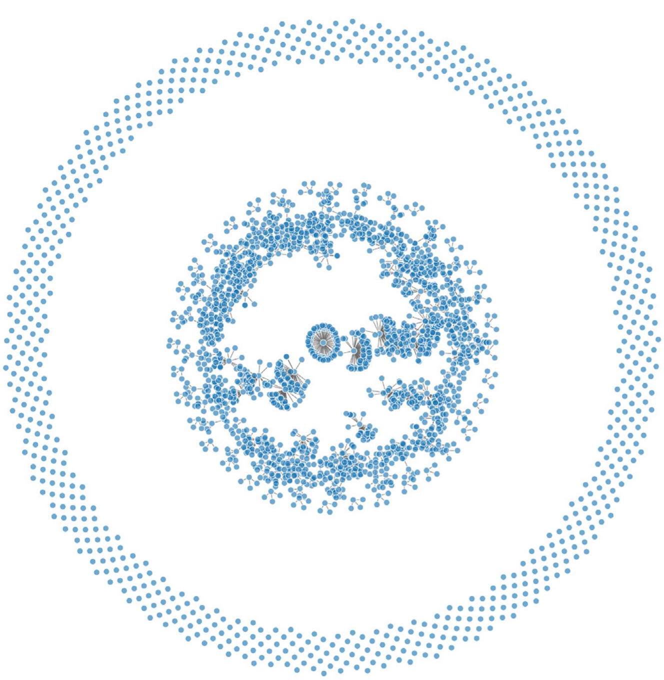

Fig. 9. Network plot of the masternodes connected by voting pattern.

Additionally, when aggregating across the full network, Fig. 9 provides a full network graph illustration of the masternodes with identical voting patterns. In total, our algorithm was able to identify 1501 network nodes with unique voting patterns. These network nodes are represented by the isolated bubbles in the outer rim. All others, 3486 nodes in total, had at least one other masternode sharing the same voting pattern. These nodes are shown attached in the middle of the network plot, where the larger groups with identical patterns crowd the middle. The largest cluster contained 144 masternodes with identical voting records dating back nearly to the beginning of the proposal process, and the second-largest cluster contained 97 nodes. Moreover, there exist multiple instances of masternodes with eerily similar IP Ports (e.g., 10.32.54.76, 10.32.54.77, and 10.32.54.78), which may imply masternodes are creating multiple accounts to gain additional voting power.

An interesting fact is that, in the middle of Fig. 9, 20 very dense groups are visible that account for more than 1000 nodes. The group sizes within this region can contain as many as 144 nodes or have as few as 27, but should these dense groups decide to collude, they would have more votes than the entire decentralized majority. The potential collusion would defeat the entire principle of decentralization of the blockchain, essentially making the voting centralized by a few masternodes who own large percentages of votes. With this realization, certain questions immediately arise:

- Can certain groups unilaterally control Dash proposals?
- How concentrated is masternode ownership?
- Is there any collusion between masternodes?

A decision maker seeking to decide if blockchain governance is the correct fit for their organization must assure that these concerns are being adequately addressed. As stated earlier, Dash is the oldest cryptocurrency voting on a blockchain, and each masternode should be invested in its future, as evident by the 1000 Dash threshold. However, this is not always the case, since voting records point to multiple disengaged masternode owners, who presumably want to benefit from the appreciation of the Dash cryptocurrency but not directly participate in the decision making. A direct parallel can be drawn between masternode participation and shareholder meeting voting. Although each person is financially invested, not everyone will be interested in placing votes or submitting proposals to vote on. Over time, this could lead to groups of the most active voters colluding to push their agenda. From our analysis, there is a suggestion that collusion among masternodes is occurring, which is largely seen by dense pockets within our network structure. For an organization implementing blockchain technology, there should be a protocol in place that dictates activity rates as a benchmark for passing proposals.

Large-scale blockchain voting is on the horizon, and steps must be addressed to ensure the integrity of voting. Although the benefits of blockchain immutability and transparency do shine through, they, in and of themselves, cannot stop coordinated attacks. If any organization adopts a blockchain voting structure as a part of business model, there is currently no way to prevent such manipulations from defeating the integrity of the voting process. From our analysis, we have brought to light possible issues with regard to blockchain voting. To combat certain issues, we recommend a system to be put in place to detect groups of individuals who have the same voting patterns across multiple proposals, and in the case of a pay-to-play scenario, we perform IP checks to determine the true "uniqueness" of a user. Additionally, if voting occurs on a blockchain, some minimal threshold should be placed on the minimum number of total active voters needed to enact a proposal. A requirement like this would require all shareholders to be actively participating in voting.

5. Discussion

Faced with the need to innovate, corporations adopting blockchain governance is a real scenario. Although its history began with payment processing and money transmissions, the governance structure that cryptocurrencies are using to further their development can be easily modified for corporate entities. However, certain barriers need to be overcome to successfully implement this technology.

From an implementation perspective, blockchain governance may not be suitable in situations where maximum participation is required. As shown from our analysis, when members are left to govern themselves, there is the possibility that a large number of members will disengage from participation. Depending on the scenario that occurs, this may cause more harm than good should the set of the most active voters decide to collude into voting. Additionally, for organizations that have a central body that dictates the strategic vision, soliciting proposals from the general public may not be necessary. The prioritization of these proposals would be handled by a senior decision maker who would dictate the future of the organization or team in a centralized manner.

Another area of concern to consider is identity management. From our network analysis, there is also strong evidence that multiple single-user entities own multiple masternodes, which they leverage into more voting power. In our dataset, there are several sequential IP Ports (e.g., 10.32.54.76, 10.32.54.77, and 10.32.54.78) that host nodes that have the same voting pattern. This is especially critical due to the possibility of concentrated ownership defeating the purpose of decentralized governance. Because no public analysis of this type has been performed, it is unknown to the authors whether the Dash masternode community is aware of such issues or if anything is being done to combat this vulnerability in the DAO ecosystem. Nevertheless, to preserve the integrity of implementing and utilizing an on-chain voting system, some systems should be in place to restrict IP spoofing to honor one vote per masternode.

There is no clear best solution. Suppose that indeed one entity is creating multiple addresses for multiple votes; for the health of the governing body, this should be eliminated as soon as possible. The entity should be punished, and a new policy should be implemented. One can provide the argument that the organization can provide an address for the entity to vote after vetting the entity, such as through a "know your customer" protocol. This type of policy has been enacted by organizations such as investment banks and cryptocurrency exchanges to eliminate transaction fraud [42]. The contradiction of implementing this policy for a decentralized organization would defeat its purpose. If individual users must register with a central entity before casting a vote, this is fundamentally centralized governance.

To preserve the integrity of a decentralized system, one may need to make concessions. Through network analysis, a corporation can identify and analyze similar voting patterns between entities. If it is deemed that votes are too similar between different IP addresses, then a "know your customer" protocol can be implemented simply for those users. This is perhaps a fair trade-off between preserving the governing body and ensuring honest voting. In the unlikely scenario where two distinct entities happen to have similar IP addresses due to sharing network resources (such as residing at the same location or through the use of virtual pirate networks), this proposed solution would also be successful.

However, this is not to say that there are no benefits to adopting blockchain governance. To some organizations, the reward may outweight the risk. One benefit is that digitized voting is censorship resistant, implying that each person will have their voice heard and not have their voice erased. This is particularly important in environments where individuals in positions of power may want to quell opposing voices. Additionally, this technology allows for a geographically diverse group of individuals to vote as opposed to having to meet in one centralized location. From a corporate perspective, having members come together to vote on issues is understandable due to concerns about voter fraud happening if votes were cast in other electronic ways besides a blockchain, for example, through email. However, with this technology, members no longer need to be centrally located to vote, and because of the transparency and immutability that blockchain voting provides, members can be sure of the integrity of their votes.

Another advantage of adopting this technology is its efficiency, transparency, and immutability. Dash's governance system displays voting progress in real-time, which enables the general public to see the status of a proposal, how many days remain in voting, and the geographical location of masternodes at the time of voting. By removing the need for a third party to manually receive votes and process them, the votes on the blockchain will be readily computerized for easier and faster vote counting. Moreover, in a traditional governance scheme, historical votes would be recorded by a trusted third party. Voting records would then be held by this central authority, where access may be restricted through means both unintentional and deliberate. If a breach occurs and the voting record is edited or deleted, the integrity of the vote would be called into question if no other voting records are kept. This is where the benefit of voting on a blockchain would pay dividends. From the inherent immutable structure, any breach in the blockchain will unlikely cause any loss or editing of voting records due to the property of sequential blocks.

When discussing the transparency that blockchain governance practices provide, the transparency may not be directed towards the entire general public but rather to a large but closed group of individuals. For instance, a large corporation may elect to have a blockchain governance structure in place to allow voting only within the organization or within certain teams. This would remove the need for another individual to gather votes and restrict the need to hire an outside authority to handle the voting procedure. Moreover, in the case where a regional manager steps aside, the subordinates can elect to govern themselves, making true democratization for decision making.

When considering the adoption of blockchain technologies from a corporate perspective, there are potential issues that may cause alarm, such as voter participation and manipulation. However, there are also benefits for managers who want to adopt blockchain. Succinctly, the benefits can be summarized as transparency, secure recording keeping, and diversity in voting.

6. Conclusion

In this paper, we explained the widespread adoption of blockchain technologies among various types of organizations for multiple purposes. Blockchain governance systems have the potential to be the way of the future for transparency and immutability, but there are subversion, integrity, and manipulation issues to be addressed before large-scale organization adoption. In particular, we highlighted how blockchain voting is gathering attention and being used today as a form of governance. Because of the recent discovery of blockchain technologies, there are still many unanswered questions around the stability and vulnerability of such adoptions. In the case of Dash, blockchain technology is used as an immutable, transparent, and honest way of governance. On that same token, we have also shed light on the advantages of adopting blockchain governance and how they can be used, and possible benefits as opposed to traditional governance systems. Moreover, we have illustrated possible analytical techniques that can be utilized to examine the well-being and health of an on-chain voting ecosystem.

To understand blockchain governance and how this can be adopted for different organizations, we performed an analysis of the Dash governance proposals and used it to highlight trends across multiple aspects. Dash has a tried-and-true governance structure and is an established cryptocurrency that utilizes blockchain technology for voting. We showed how governance works within the Dash proposal systems and made connections to how they can be adapted to organizations. We have demonstrated potential data mining frameworks that individuals can utilize as a means of analyzing on-chain governance systems to understand their ecosystem. Moreover, we have additionally shown that there are possible issues prevalent in blockchain voting, such as interconnected IP addresses, as shown in our network analysis, indicating that there is a possibility for a particular group or even a single user to strongly impact the voting outcomes should collusion between parties occur. To counter this, we have provided recommendations for a system or protocol to implement if blockchain voting is adopted. We hope this analysis has shed light on some aspects of the Dash governance system and, in particular, flaws and issues that are currently within blockchain voting and will pave the way for further work to continue making sure the governance system is enacted.

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