IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received December 14, 2021, accepted March 6, 2022, date of publication March 22, 2022, date of current version March 30, 2022.

Digital Object Identifier 10.1109/ACCESS.2022.3161392

Longevity Foundation: Perspective on Decentralized Autonomous Organization for Special-Purpose Financing

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ABSTRACT Decentralized autonomous organizations (DAO) launched on a blockchain and governed by a smart contract promises to bring self-organization to a new technological level. Crisis management has no standard decentralized solution within DAO yet. A central authority is a natural component due to compliance reasons in certain domains, for example, special-purpose financing, in which the DAO governance model could be reasonably applied. More generally, a centralized DAO representative could streamline implementing DAO decisions that involve interactions with legacy systems. The article presents a perspective of modern technologies for organizing a foundation for special-purpose financing and considers longevity as a model example of the purpose.

INDEX TERMS Blockchain, decentralized autonomous organization, financing, longevity, smart contract.

I. INTRODUCTION

More and more processes go digital. We especially feel it during the last years of the lockdowns caused by the COVID-19 pandemic [1], [2]. Symmetric cryptography [3] allows users to communicate over the public insecure Internet channels [4], public-key cryptography and infrastructure allows to identify users and to authenticate their actions. As a result, nowadays one uses online services even in highly regulated industries like banking and public sector [5]–[7]. Blockchain-based smart contracts [8], [9] enabled agreements in the form of a computer program including a peer-to-peer environment [10] and state level [11]. Smart contracts use blockchain as a tamper-resistant public bulletin board to define rules–contract calls–together with the ordering and processing services for these calls. The elimination of the trusted third party by the means of the decentralized environment and the reduction of the agreement to the computer program execution made it possible to launch decentralized autonomous organizations (DAO) [12]–[14].

DAO incorporates modern information and communications technology enabling simple voting setup and adherence to rules by design [15], [16]. DAO makes a step forward to the liquid democracy [17]–[19] where each user can either directly participate in the decision process or delegate this right to another entity. It brings self-organization to a new technological level including venture capital, social media, and funding allocation. However, DAOs have problems without standard solutions: crisis management (measures to reduce the negative financial and reputational effects of crisis situations) and efficiency (the ability of fast and thoughtful decision-making), to name a few. A DAO's smart contract, like any software program, is prone to bugs. Best programming practices help to reduce the number of bugs [20], but it is impossible to eliminate them. The price of an exploited bug in a smart contract can be hundreds of million United

The associate editor coordinating the review of this manuscript and approving it for publication was Giovanni Merlino.

States dollars [21] which makes the bug exploitation a crisis situation.

The decision-making may be ineffective for large groups [22]–[24] as an intelligent choice may take efforts or specific knowledge from each participant. Centralized issue resolution is a straightforward solution to both decision-making and crisis management. Moreover, a central authority is a natural component in certain domains, in which the DAO governance model could be reasonably applied, e.g. due to compliance reasons. More generally, a centralized DAO representative could streamline implementing DAO decisions that involve interactions with legacy systems. For example, in special-purpose funding, it is easier for acceptors to get money from a single legal entity to follow the know your customer compliance [25], anti-money laundering and countering the financing of terrorism [26]. Let quasi-DAO (qDAO) be a smart-contract-driven organization with decentralized decision-making and a Foundation (legally established organization) that makes governance decisions legally binding. In this paper, we provide a perspective of qDAO for special-purpose funding.

While the academic literature on DAOs is limited, a number of projects have been proposed in white papers and launched, including venture capital funds [13], cryptocurrency governance [27], liquidity pools [28], lending [29]–[31]. Charity and special-purpose funding are not an exception: Moloch DAO [32] is a fund to develop public infrastructure for ETH 2.0, Endaoment [33] is a decentralized finance (DeFi) community foundation and public charity offering Donor-Advised Funds, DAO1 [34] is a platform to provide access to the next generation of DeFi and it declares charity initiative as a part of the project.

We consider longevity as a problem domain for The Foundation operation to be more specific in the examples throughout this paper. At the same time, the main constructions are not specific to the problem domain and can be transferred to other domains. Longevity is an emerging multidisciplinary field driven by the rapid convergence of biotechnology, medicine, engineering, big data, and artificial intelligence aimed at extending a healthy lifespan, preventing age-associated diseases, and improving the performance of humans and animals. It is widely recognized as a field uniting medicine, science, economics, the healthcare system, global health, governance, and education. One should abstain from thinking about longevity as a mechanical life extension. Rather, the longevity field is focused on prolonging a healthy lifespan by adopting, where possible, an individual and precision-driven approach to each patient, which can be repeatable/translatable across a variety of cases. The longevity concerns everyone [35] and recent breakthroughs [36] allows us to expect more innovations soon.

The blockchain community has proposed a number of longevity-related projects: VitaDAO [37], PulseChain Airdrop [38] and Moon Rabbit Longevity DAO [39]. We appreciate their contribution and have a different and complementary perspective on the topic:

- VitaDAO is a DAO for equity financing with the profit for investors in intellectual property or research data asset shares. Some research institutions can not accept such terms. The logic of property does not apply to education proposals. The workflow aims to change from early research to the product and can be ruined at any stage. We consider charity instead of investment to keep the full variety of possible proposals to boost the research area.
- PulseChain raised funding for SENS Research Foundation in an airdrop [38]–an event in which a project decides to distribute free tokens or coins to the community [40]. Airdrops aim to gain attention and new followers, resulting in a larger user base and a wider coin distribution. PulseChain is not governed by a DAO and is hard to scale for multiple funding requests.
- At the time of this writing, we do not have an official description of Moon Rabbit Longevity DAO and looking forward to getting it.

The article presents our view on the possibilities of modern technologies for organizing a foundation for special-purpose financing and considers longevity as a model example of the purpose.

The rest of the paper is organized as follows. Section II introduces participants' types of the Foundation ecosystem and describes the major use cases that it must support. The qDAO governance features are discussed in Section 3. Sections 4 and 5 describe the capabilities of the foundation for innovators and backers. The possible blockchain backend is discussed in Section 6. A high-level description of the proposed system is provided in Section 7. And Section 8 concludes the article.

II. PARTICIPANTS

The **innovators** boost the longevity domain from different sides: fundamental and applied research, technology adaptation. Innovators generally require financing aimed to facilitate and accelerate early-stage longevity research, get our society closer to actionable interventions for life extension and treatments to combat age-related diseases. Additionally, the area needs qualified specialists to deal with existing and ongoing challenges. We define innovators categories that need to be supported within the Foundation ecosystem:

- Research and development by groups and institutions
- Adaptation of the new testing and treatment by medical centers and hospitals
- PhD and post-doctoral research in specialized groups.

The **backers** donate money to support innovators and get voting power for the Foundation governance. The voting power provides an ability to influence the funding decisions directly and opens special features like access to the detailed and vetted map of the longevity industry, recognition, and honors with non-fungible tokens (NFT) [41], access to the latest early-stage longevity tech.

The **Foundation** coordinates participants' interactions. It organizes innovators' proposals preprocessing, accepts backers' donations and provides access to their benefits (or manages backer authentication if the benefit is provided by a third party), donates into the community-supported proposals, and provides media support of the longevity technology. The Foundation is also responsible for designing, implementing, and maintaining the DAO smart contract and underlying blockchain.

The **partners** increase credibility from both longevity–the **vision board**–and decentralization perspectives–**pillars**. The vision board comprises visioners who provide their expert comments on the proposals and candidates to delegate the voting power. Such pre-vetting can help to pay attention to the most interesting ones. The visioner position is elective using qDAO governance process as outlined in Section 7.

Pillars of longevity are a diverse set of research hubs and big companies that help mitigate centralization risks for qDAO and boost its legitimacy. The pillars are identified entities with a significant portion of the voting power within a qDAO; thus, they introduce a known lower bound on the voting power centralization. In private or permissioned blockchain architecture [42], [43], the pillars will additionally be consensus participants, having full system audit permissions, since the Foundation should not maintain the underlying qDAO's blockchain alone in order to avoid network centralization.

III. GOVERNANCE

In the traditional governance model, shareholders–principals–hire managers–agents–and then delegate the company's day-to-day operating decisions to these managers [44]. Both principals and agents maximize their personal utility, and the utilities are misaligned. Stock price and dividends express the principals' utility, while different strategies may guide agents: low-risk projects to maximize the probability of future hiring or short-term earnings to maximize the income before the contract expiration. Effective governance controls the incentives of decision-makers to ensure that their decisions align with the goals of the corporation and its owners [45]. However, the more people are in the company, and among shareholders, the more misaligned interests come into play. The hierarchical structure of agents makes decisions on behalf of shareholders, where each agent and principal has its own incomplete information and utility. These decisions can be far from personal expectations.

A decentralized autonomous organization (DAO) is an alternative governance model. A DAO is a blockchain-based system that enables people to coordinate and govern themselves mediated by a set of self-executing rules deployed on a (public) blockchain [16]. While there is no consensus on the DAO definition both in academia and industry, its most distinctive features are the ability of participants to coordinate and self-govern online, enabled by an open-source smart contract deployed on a blockchain that specifies the DAO governance rules.

The separation of ownership and control characterizes traditional corporate governance. In contrast, each participant of DAO is an agent and principal of the company at the same time. The way DAO leverages smart contracts to form an organization leads to the alienation of trust in governance from the organization to a collective decision-maker and underlying blockchain instance. The spread of trust instead of separation of control makes DAO a new form of governance [46]. The introduction of principals who act as their own agents and the leverage of smart contracts as a corporate governance tool makes DAO the first case of a pure information technology governance model [47]. DAO presents new challenges and potential risks for corporate governance and inherits some from traditional ones that need to be addressed properly.

Blockchain can be modeled as a public bulletin board [42], [43]; thus, in isolation blockchain technology reduces information asymmetry. However, outside the blockchain, DAO participants have different inputs for decision-making caused by varying interests and backgrounds, among other factors. Therefore, the problem of information asymmetry may be more acute in DAO in comparison with traditional methods of corporate management, especially in the case of DAOs with large or diverse participant base. To decrease the impact of the information asymmetry, DAO can include the educational materials/knowledge base for its participants and the ability to delegate decisions to reputable participants. Also, reputable participants can be marked by the other participants of the DAO. For example, the vision board participants are experts to score proposals for special-purpose financing.

Despite best efforts, DAO's smart contracts, as any software, are prone to errors and may not cover all the possible usage scenarios arising in practice. So, the mechanisms for dispute resolution and crisis situations–unspecified cases and unexpected behavior–are needed. A possible solution for dispute resolution is an additional independent structure designed for this particular purpose, which can be activated and engaged by DAO smart contracts. For example, the pillars can be decision-makers in the dispute resolution mechanism in qDAO. The Incident Response Plan with an alternative governance model–a traditional centralized governance system (safety network)–that can be activated in semi-automatic or automatic mode and take control of the situation is a way to handle crisis situations. DAO also should provide a way to switch control back to the DAO after the crisis is over. The crisis or unforeseen events can lead to changes in the DAO governance rules and smart contracts that define them. DAO should provide an official way for its participants to propose and implement necessary changes. In special-purpose financing, the Foundation can design the crisis solution and launch it upon pillars approval.

When decision-making rights are spread too thin throughout a peer-to-peer organization, the efficiency and effectiveness of governance may fail. DAO needs protocols and incentives to motivate its participants to participate directly or indirectly (by delegating their votes). The motivation framework should have both reward and punishment (carrot and stick) components to be efficient. In our case, the vision board, pillars, and Foundation are involved in the DAO activities by design. The backers are the least involved participants category. The possible benefits of active participation for them are discussed in Section 5. Voting power auto-delegation can be viewed as punishment of inactive voters.

Moving governance from human hands to a smart contract challenges the legal binding [48], [49] and makes it difficult to hold individuals accountable when things go wrong. Accountability of DAO participants for intentional wrongdoing is one of the most fundamental challenges of DAO. Without accountability and eventual punishment free-riders and short-profit mentality can destroy DAO or lead to a crisis. In the case of special-purpose financing, the Foundation is a central authority responsible for money flows. As an established not-for-profit organization, the Foundation is accountable to the public and auditable. For example, the Foundation can be sued for money appropriation. Other decision-makers are known at least by the Foundation and thus have legal accountability; likewise with innovators, since they are known publicly.

IV. INNOVATOR CAPABILITIES

Which innovation is valuable and doable? The answer to this question is subjective and can cause speculations, especially on the border proposal examples. The vision board is a group of elected experts to resolve the issue. One needs the relevant information to make the right decision. Innovators can send their proposals to the pool. The Foundation specialists also search for suitable projects and help them with the application.

The submission procedure has to be transparent: everyone is allowed to submit the proposal freely via special form, the pool processing rules are pre-defined, the vision board's decisions are openly available, innovators' progress monitoring after they get the money is needed. Even though the workflow is straightforward, the proposed architecture needs to be resistant to various attacks.

A. CENSORSHIP-RESISTANCE OF PROPOSALS

The Foundation censors a proposal without the Vision board's consideration.

1) SCENARIO

Suppose the capacity of the Foundation to support proposals is limited, and the Foundation team is related to the innovator Irvine. Irvine has a border proposal: his project will be supported if there is enough room. But Iris's proposal is better than Irvine's. So the vision board will support Iris's proposal, and Irvine's proposal will be below the border. So the Foundation ignores Iris's proposal. The vision board does not consider Iris's proposal, and Irvine's application remains above the border and gets funding during this round.

2) DISCUSSION

Applicants broadcast proposals as blockchain transactions. The blockchain maintainers' and auditors' roles are distributed among various entities. Applicants may have neither blockchain expertise nor voting power. So proposal transactions have zero fees, and the Foundation provides the web form to generate the correct transaction based on the innovator's input. To prevent censoring in the web form, the transaction format is publicly available. One can generate and broadcast the correct proposal locally with the help of one of the popular programming languages.

B. DISTRIBUTED DENIAL OF SERVICE WITH PROPOSALS

The attacker floods the system with proposal transactions.

1) DESCRIPTION

The attacker automatically generates a huge amount of different proposal transactions and broadcasts them. If the transaction flow is bigger than the blockchain bandwidth, then the system denials of service.

2) DISCUSSION

As a system's throughput is limited, the ability to send transactions should be limited in some honest and transparent way (a viable alternative is to require a stake in voting power to submerge a proposal and increase the stake for each next proposal if the previous one is not processed). Otherwise, the pool of unconfirmed (pending) transactions memory pool could be overloaded, and it may cause Denial of Service. In Bitcoin, users pay a fee for each transaction to address this issue. Steem.io introduced an alternative approach based on the fractional reservation of the blockchain block space. The classic approach to handle the problem is to introduce a priority function for the transaction pool, for example, via relative transaction fees in tokens. In the case of the Foundation, backers increase their score functions for free and can use them to prioritize proposals in the pool.

The review process is supposed to enable the vision board to be straightforward in their comments and appraisals without fear of conflicts [50]. No appeal is allowed, but the proposal resubmission is allowed.

V. BACKER CAPABILITIES

The Foundation finances innovators with ''traditional'' means (e.g., fiat money) as required by accounting/compliance requirements. The Foundation provides incentives to achieve targets for such financing, significant part of which originates from backers' donations. No universally effective marketing strategy to increase charitable behavior is known [51]–[55]. And we are not going to invent it but rather to provide best practices as options for backers. Firstly, the backer's identification with the Foundation is required for compliance, but it does not need to be disclosed publicly [56]. Each backer gets voting power proportional to the donation. If the backer does not need any benefits, for example, due to religious reasons, it is ok to do nothing with the voting power. Otherwise, the backer is welcome to use all the available options. The possible benefit categories are

- Voting power is used for liquid democracy-based **governance** [17], [19]. Each backercan either vote on each issue directly or delegate the voting power to another backer. This backer becomes a delegate to perform certain tasks for any period of time, but the delegation authority can be revoked at any time. To fund an innovation proposal or not and election of the vision board are examples of the questions for voting. Potentially, any backer can be a delegate. For example, the visioners are experts in innovations and thus backers can find it reasonable to delegate to them to vote for proposals.
- The backer's identity public disclosure is optional. One may disclose the identity for **recognition and honors**. If the person or organization decides to disclose the identity, the Foundation generates the electronic certificate for the backer in a non-fungible token (NFT) [41], [57], [58]. Such NFT is not for the transfer but to share the fact of the donation only. In addition, the Foundation is going to generate NFTs per major event in the project's ecosystem. For example, NFT for financed innovation will contain the names of all the disclosed backers with larger backers featured more prominently [59]–[61].
- To express gratitude to the top backers, the Foundation provides special capabilities for persons with a certain amount of voting power [62]. It can be viewed as **membership** in a social club **or** a **free subscription** and gives, for example, access to podcasts with innovators or meetups with visioners.
- A **reward** is a common way to thank backers. Backers can permanently destroy (burn) their voting power for rewards. Examples of a reward are pledges by innovators or the honors in the NFT for the selected project along with the top owners of the voting power. The innovators may receive extra funding for rewards chosen by backers.

The list of benefit categories above is not complete. However, other types look less preferable due to various reasons. For example, the approach with equity-based benefits may be difficult due to regulatory issues [63], [64], and it is not applicable for proposals like education grants. Lottery and gamification-based mechanics may cause irrational behavior such as gambling and ludomania [65]–[68].

VI. BLOCKCHAIN BACKEND

With the beginning of Bitcoin [8], it became possible to transfer digital value with unprecedented transparency and security. Blockchain–the underlying technology of Bitcoin–guarantees data tamper resistance and availability. The openness of the blockchain architecture allows anyone to verify integrity and validity of the data on it [42], [43]. Another cryptocurrency, Ethereum [9], enables the transfer of digital value more flexibly with blockchain-based programs–smart contracts–that can encode a complex, stateful business process.

Ethereum cryptocurrency introduced Solidity, a Turing-complete programming language for smart contracts. Ethereum Virtual Machine (EVM) executes compiled Solidity (i.e., EVM bytecode) in a platform-independent environment. Different projects propose their own languages and approaches to implement smart contracts, such as Cardano [69], Hyperledger Fabric [70], Exonum [71], Corda [72]. However, Solidity is a de facto industrial standard for smart contracts by now and has spread beyond Ethereum. One can use any EVM-compatible blockchain to develop Solidity contracts, including Binance Smart Chain [73], TomoChain [74] and TRON [75] blockchains, as well as Polkadot [76], Polygon (Matic) [77] and Hyperledger Fabric [78] frameworks.

The unexpected software behavior–bugs–is an integral part of programming. We can not eliminate it but only decrease probability and impact and fix it once revealed [20], [79]. The need for the open-source code of the launched smart contracts imposes increased requirements on the quality of their writing since the cost of one error can reach hundreds of million USD [21]. For example, the hack of the decentralized autonomous organization The DAO in June 2017 used a recursive call to the splitDAO function, in which, after the withdrawal of funds, the balance was erroneously written off, about 50 million USD in the Ethereum cryptocurrency were stolen. Later, this fact led to the split of the network into Ethereum and Ethereum classic. In addition, in July 2017, during an attack on Parity's smart contract wallet, around 250 million USD was permanently frozen. A user devops199 discovered a vulnerability in the contract code that allowed to designate anyone as the smart contract's owner. It was impossible to appropriate the funds, but one of the available actions was to close the contract, which, in turn, made it possible to freeze all the funds managed by the smart contract.

The security analysis of the Ethereum smart contracts attracts close attention from scientists and developers. The description of vulnerabilities at the moment is presented in [80]. The number of unique launched smart contracts exceeds a million, but most large-scale studies include only one hundred marked contracts and the automatic testing of up to fifty thousand of them [81]. Note that the small coverage is due to the cost of expert time for marking up contracts and the computational complexity of the available automatic tools–semantic analysis and symbolic computations [82], [83]. Nevertheless, Solidity is a deliberate choice for writing smart contracts due to its high popularity and extensive experience accumulated by the community, the availability of modern verification tools [84], and the presence of formalized EVM semantics [85].

Choosing a language for smart contracts is easier than choosing a network architecture. Public blockchains provide state-of-the-art security and decentralization. On the other hand, public blockchains host smart contracts with arbitrary semantics and may face throughput and fee issues

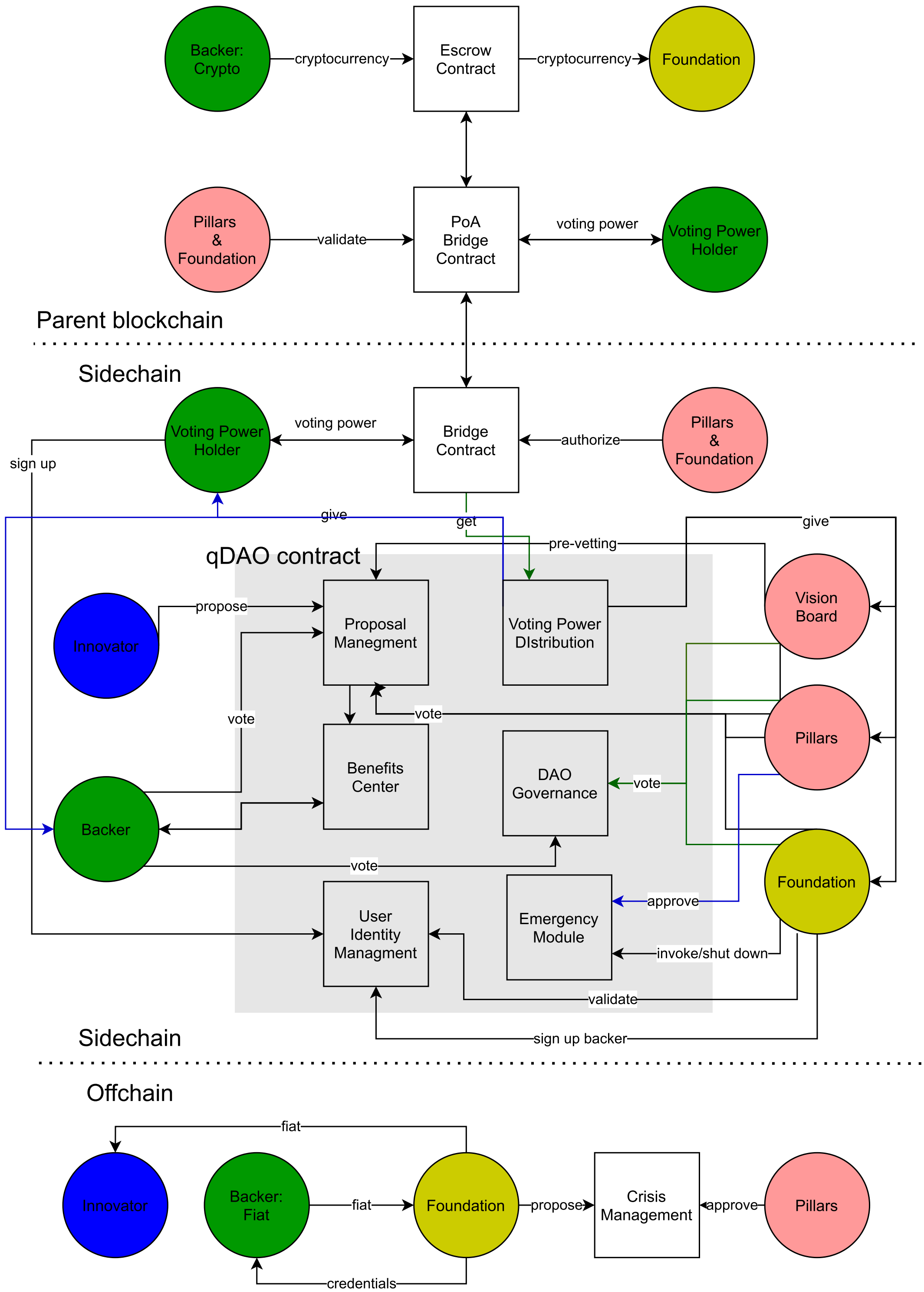

FIGURE 1. qDAO system.

due to the surge in popularity of the underlying blockchain or of projects built on top of it [86], [87]. The presence of a separate currency for fees smooths the fluctuations. Still, as many participants in the vast decentralized network execute all transactions in parallel and independently, it is impossible to neutralize the effect. Private or at least permissioned blockchains can handle transactions almost for free at the cost of centralization. Time-stamping [88] a private blockchain on a public one can bring a reasonable level of security to the former. Such a two-layer construction is commonly used in blockchains [76], [89], [90]. The second (private) layer is not required to be a blockchain, but for the qDAO using a blockchain enables build-in support of Solidity and EVM. At the same time, the token circulation logic is well-developed and can be represented as a fungible token [10]. So it is reasonable to keep it at the first (public) layer. The architecture with multiple chains per project has additional composability risks [91] to be considered.

VII. PROPOSED SYSTEM

Based on the previous observations, we present a possible high-level architecture of the special-purpose financing system in this Section. Firstly, the system consists of three parts: parent and side blockchains [92] and offchain. Most of the logic is concentrated in the sidechain. It includes the qDAO smart contract, connected via a bridge to the parent chain and indirectly (via the Foundation) connected to the offchain part. Pillars and the Foundation are authorities for the bridge and other cases where authorities are needed. The offchain part contains fiat backer's workflow, donations to the innovators with the accepted proposals, and the crisis management part. The parent blockchain allows accepting cryptocurrency donations from backers and provides additional consistency guarantees. Ethereum [9] is a possible example of the parent blockchain. Hyperledger Besu [93], Polkadot/Substrate [76], and Polygon (Matic) [77] are examples of frameworks/platforms allowing to create or host the sidechain. Some of these frameworks (Polkadot and Polygon) have built-in bridge support.

The general workflow looks as follows (see Figure 1). A backer chooses either fiat money or cryptocurrency to donate.

- In case of a fiat donation, a backer reveals his identity to the Foundation and donates offchain. The Foundation reserves voting power for this donation. The backer is then provided with credentials to use voting power within the platform.
- In case of a cryptocurrency donation, the donator sends crypto assets to the Foundation's escrow contract at the parent blockchain. The escrow contract informs the bridge about the event, which is delivered to the qDAO smart contract on the opposite end of the bridge on the sidechain. Cryptocurrency from the escrow contract is locked (vested) under certain conditions, hence not immediately available to the Foundation. Upon receiving the cryptocurrency donation event, the qDAO smart contract gives the voting power to the donator. The donator needs to reveal his identity to the Foundation via offchain mechanisms in order to become a backer, enabling such features as voting and backer benefits. Notwithstanding, any voting power holder (including backers) can use the bridge in both directions.

Pillars, the vision board, and the Foundation get voting power without donations.

The exact rules for the voting power distribution should be stated in the qDAO smart contract as its subsystem. The rest of the qDAO's subsystems are proposal management, DAO governance, benefits center, emergency module, user identity management.

- **Proposal management** is a subsystem to select the proposals for donating in. The innovators submit the proposals, which are then formally pre-vetted by the Foundation and substantively pre-vetted by the vision board. Afterwards, the backers, vision board, pillars, and the Foundation vote for the proposals. The support parameters, for example, the minimum and maximum amounts and minimum and maximum number of proposals to be supported annually, are the subsystem parameters along with the voting procedure. The **benefits center** manages the backers' benefits, for example, the emission of honors NFTs.
- The **DAO governance subsystem** includes the vision board re-election mechanisms and other design and parameters decisions, non-emergency updates to smart contracts, and the Foundation offchain activity reports.
- The **user identity management** subsystem records backers that have passed the Foundation's identity check and is responsible for public identity disclosure as a part of backers' incentives.
- The **emergency subsystem** deals with crises. The Foundation launches it with pillars' approval. The emergency state blocks the normal qDAO operation, for example, voting power transfers and proposal processing. The Foundation needs to provide a solution to the crisis offchain. The qDAO returns to the normal flow after the pillars agree on the proposed actions, which is reflected as a special-purpose transaction to the qDAO contract.

VIII. CONCLUDING REMARKS

The traditional centralized governance model does not enable shareholders to participate in the daily organization's decision-making process. DAO incorporates modern information and communications technology enabling simple voting setup and adherence to rules by design. It brings self-organization to a new technological level including venture capital, social media, and funding allocation. However, DAOs have problems without standard solutions: crisis management and efficiency, to name a few.

A quasi-DAO (qDAOs) is an intermediate solution between the traditional centralized and the decentralized autonomous governance. The qDAO can meet legal space like centralized governance. The qDAO involves its participants in decision-making like the DAO. Although the qDAO implementation is possible, many details should be specified first.

While rapidly developing, the field of longevity has been prone to several drawbacks, slowing its progress and decelerating its clinical transition. qDAO is a novel interpretation of a traditional non-profit and non-equity mechanism, can boost early-stage research and help humanity extend a healthy lifespan up to at least 120 years.

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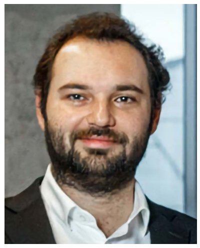

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