The Lambda Network

SkyLab, Inc
May 27, 2018
Version 0.6

Summary

Bitcoin's proof-of-work algorithm for distributed consensus and Ethereum's generalization of blockchain for distributed computing have sparked an internet revolution. These innovations finally make possible a new class of applications built on decentralized, trustless networks, which equitably reward their participants rather than centralized, proprietary services. Through distributed and decentralized consensus on a single logically centralized ledger, these networks have processed and transacted trillions of dollars worth of assets. The smart contracts built on top of this ledger system allow trusted parties to be replaced by verifiable computation, thereby enabling wholly new forms of decentralized governance.

In this paper we propose the Lambda Network, a network of integrated smart contracts and distributed applications (dapps) which introduces this revolutionary technology to the $1.1 trillion research funding market. The Lambda Network will both streamline the public research grant proposal/award system, and allow private research institutions to finally move away from paper records by hosting provably secure and immutable lab records on the blockchain. At the heart of this new R&D marketplace is the ERC20 token: Lambda, which will be the network's primary currency of exchange. We also present a possible method of governance for research grants through distributed autonomous organizations (DAOs) and explore other applications of smart contracts for improving the efficiency of research funding.

Specifically, this whitepaper:

1. Reviews the current research marketplace and offers motivations for decentralization.
2. Introduces a protocol to build a network of verified identities and trust on the blockchain via trusted off-chain interactions.
3. Discusses methods for managing DAO membership through that trusted network of verified identities.
4. Introduces a DAO method of governance for research grants which equitably rewards high quality research.
5. Introduces a method to transparently and automatically track research funding and spending on the blockchain via smart contracts. It also discusses other use cases of network contracts for applications such as restricted use, milestone vesting grants, and crowdfunded research campaigns.
6. Introduces a marketplace for publishing and discovery of research proposals and funding opportunities.
7. Introduces the Lambda Journal for publishing research on the Lambda network.
8. Introduces a marketplace for research services such as cloud computing and data storage.

The Lambda Network and the Lambda token are conceived and developed by SkyLab, Inc. SkyLab will also introduce the SkyLab research platform as the Lambda Network's first adopter, providing the network with deeply integrated storage and computation services from the start.

SkyLab, Inc., will also oversee the establishment of two community grants for the Network, the Lambda Research Grant and the Lambda Ecosystem Grant. The goal of the Lambda Research Grant is to continuously fund high quality research and reward researchers who participate in the Lambda Network of applications. The Lambda Ecosystem Grant incentivizes developers to adopt the Lambda Network in their applications and allocates funds for improving the infrastructure of the Network.

Disclaimer

This whitepaper is meant to describe the currently anticipated plans of Lambda tokens and the Lambda Network (together, the "Network"). This whitepaper is non-binding in all respects and does not create any legal obligation of any kind on any person (including SkyLab, Inc.). The ultimate implementation of the Network is dependent upon several factors and risks outside of the control of SkyLab, Inc., including regulatory risks, contributor participation, the adoption of blockchain technology, and the continued use and adoption of the Ethereum network. Nothing in this whitepaper or otherwise shall require SkyLab, Inc., to take any steps to develop or otherwise implement the Network. SkyLab, Inc., reserves the right to abandon the Network and/or to change the implementation of the Network contemplated by this whitepaper at any time and for any reason. Prospective users of the Network and other contributors to the Network are advised to contribute and/or participate at their own risk and without reliance on any statement contained in this whitepaper.

Contents

1 Introduction

The OECD and The Royal Society of London estimate that total international spending in the research market, encompassing both public and private funding, is over $1.1 trillion per year [1][2]. The NSF alone has a budget of $7.5 billion and receives approximately 40,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded [3]. This spending occurs across a large network of parties.

We assert that the public blockchain can solve two of the most serious issues in research as it exists today. Both issues are a source of an enormous amount of wasted time and effort.

Firstly, in grant funded research, as much as 40% of a principal investigator's time is spent seeking funding and the grantors spend a corresponding amount of effort processing the thousands of proposals they receive [4]. The Lambda Network will logically centralize this marketplace for both grantors and grant recipients and thereby drastically reduce the amount of time and resources that each spends managing funds and grant proposals [5]. Transitioning this market to a decentralized, blockchain-based economy also means that we can create powerful new tools and smart contracts that provide grantors and grant recipients with entirely new capabilities.

Secondly, in industry, paper lab records predominate as there is no accepted way to secure electronic records for legal use. Current good manufacturing practice (CGMP) requires a witnessed signature of paper documents which may be scanned electronically [6] but are still not searchable. The Lambda Network will provide a mechanism for industry research institutions to publicly attest to the contents of their data on the blockchain without revealing the contents of that data. The integrity of the data will therefore be as secure as the trillions in assets exchanged via the blockchain.

1.1 Market Size and Incentives

Broadly speaking, there are two types of research funding: nonprofit and for-profit. While not a perfect fit, generally nonprofit funding is provided by the government and for-profit funding is provided by private/industry institutions.

Government funded research seeks to achieve an ROI for the general public/taxpayers, whereas privately funded research is generally motivated by near-term commercialization prospects and an ROI on intellectual property. This typically means that government institutions fund research that is important but does not have a clear path to commercialization (e.g. nuclear fusion) or fund basic research which produces a general benefit to the public (e.g. health & science research) [7]. This implies that penetrating each market requires overcoming separate sets of challenges, but we assert that both benefit from a marketplace on the blockchain.

Both public and private funding constitute a significant percentage of the market. In the US, government funded research and private funded research accounted for 24.04% and 64.15% of all categories of research spend in 2015 [8], respectively. As with funding organizations, nonprofit and for-profit research institutions each constitute a large part of the market. Generally these correspond with academic and industry institutions, respectively, although there is some amount of overlap. Industry researchers and organizations seek to earn a profit directly by providing research as a service. For example, Contract Research Organizations (CROs) carry out clinical trials and other lab work, and are worth north of $29 billion worldwide as of 2015 [9]. By contrast, academic researchers are motivated not by financial incentives, but rather by the desire to contribute to their field as well as by the prestige that results from those contributions.

1.2 Reimagining Research Grants

1.2.1 Advanced Fund Tracking and Analysis

The immutability of the secure Ethereum blockchain provides an excellent opt-in mechanism for auditing transactions, which is critical for both nonprofit and for-profit funding. Additionally, for-profit research organizations are increasingly funding basic research which they may want to advertise publicly within the Lambda marketplace [10]. We can also use this public record to analyze the spending patterns of both research institutions and researchers to measure the efficacy of funding projects. In this paper, we also present a optional trust mechanism to link real-world identities to blockchain addresses. This mechanism functions as a powerful tool which is able to link grants to the work that they fund. With this tool we can also utilize the blockchain to track off-chain metrics such as citations or collaborations. This paves the way for creating advanced analytics tools which can track complex interactions within the community.

1.2.2 Grant Matching Marketplace

Through smart contracts that support the tracking of grants, we can build a marketplace which connects researchers directly to their funding, enabling brand new applications in research crowd-funding. For example, grassroots research funding campaigns (e.g. The ALS ice-bucket challenge) can link their funds directly to the research they enable, thereby demonstrating impact directly to donors. In addition, this distributed marketplace opens up exciting opportunities to use machine learning to connect researchers to possible funding based on their research history. A marketplace for this makes opportunities easily discoverable and allows the market to determine the price of research.

1.2.3 Expert Decentralized Governance

Within the current system, allocation of public funds is determined by a small number of centralized government research councils or agencies (e.g. NIH, NSF, etc). These councils are responsible for deciding how each grant should be spent and for reviewing each grant application. This method has the significant drawback that researchers, who by the nature of their work are the most qualified to assess the merit of a grant application, are also powerless to direct the flow of research funds. We propose that blockchain technology provides a mechanism for a new system of funding via DAOs, whereby those who provide the funds can delegate control to verified individuals to distribute the funds in the most efficient manner. This technique is already approximated by governments who offer tax incentives to businesses which spend on R&D in order to delegate control of funds while still supporting innovative progress. In 2013, this strategy accounted for $50 billion of research funding globally [11]. This form of allocation delegation may also be attractive to private foundations which fund research, but do not have the operational capacity or expertise to evaluate the merits of dozens or hundreds of research grant proposals.

1.2.4 Integration with Research Services

One of most exciting aspects of the Lambda Network is the ability to integrate directly with external applications which provide services on the network. These could range from peer review services to cloud computing and data storage services to robotic cloud laboratories such as those being developed by Emerald Cloud Lab [12] and Transcriptic [13].

SkyLab, Inc., will build direct integration into its own electronic lab notebook, data storage, and computational resources from the start. This means that researchers can directly spend their Lambda utility tokens on highly sought after resources from day one.

Third party software applications unlock the true potential of the Lambda Network through highly fluid and transparent channels for money to be quickly spent on research expenses. Encouraging developers to adopt the Lambda Network in their applications and services is the primary motivation behind the Lambda Ecosystem Grant.

1.3 Redefining the Open Access Journal

Using the power of decentralized governance and the inherent transparency of the blockchain, the Lambda Network is positioned perfectly to create the Lambda Journal. It will be an open access, peer reviewed journal managed by a DAO. Centralized, subscription-based journals take cuts from both sides of the publishing process. The Lambda Journal obviates the need for a middleman with smart contracts that will equitably reward the authors and the platforms that provide the hosting and storage for submitted papers.

1.4 Blockchain Secured Data Integrity

The same security that makes the blockchain an excellent means of auditing transactions also makes it a great candidate to audit data and lab records as well. In this paper we present a way to secure the integrity of data on the blockchain through Lambda Network applications. SkyLab will integrate with the network to provide lab notebook tools for editing, storing, and versioning data. Through the Lambda Wallet app, researchers will be able to attest to the contents of their lab notebooks and all version history at any time, publicly on the blockchain. This public attestation is not reversible so all research data remains private. As mentioned above, for industry researchers this ability to provide an audit trail for lab records is requisite.

1.5 Capturing the Market

The prevailing thesis today within cryptocurrency networks is that the majority of the value in blockchain is captured at the protocol layer rather than the application layer [14]. Understanding the nature of and incentives within this market is thus critical to estimating the size and number of transactions which could conceivably take place across the Lambda Network.

Networks which rely on a critical mass of users before they become useful often face a chicken and egg problem of adoption and user acquisition. The Lambda Network intends to overcome this problem via proven cryptoeconomic business models which offer financial incentive and network ownership for all network participants as well as create strong incentives for early adopters to participate. This network bootstrapping is a crucial tool which is required to disrupt a market as established as research.

Both funding institutions and researchers spend an outsized amount of time seeking competent researchers and available funds, respectively. This opaque market is impenetrable to analysis even by the largest, most centralized players, because there is no single source of truth regarding the flow of money. A politically decentralized, yet logically centralized blockchain market can equitably incentivize network participants while immutably recording the issuance of grants and the work that they fund [5]. This blockchain network will be supported by a set of simple applications which

match the ease of use and utility that users have come to expect from high quality, centralized software applications.

2 Establishing Identities & Trust

Typically, blockchain technologies like Bitcoin and Ethereum are referred to as trustless. This implies that the protocol does not require a participant to trust any other participant in the network. Satoshi Nakamoto famously achieved this property with the Bitcoin protocol through the proof-of-work consensus algorithm and published the results in a 2008 whitepaper [15]. The Ethereum blockchain platform employs this same technique in order to create a generalized trustless computation platform [16]. This property provides for the decoupling of a real-world identity within the network without compromising the security of the network or protocol. All that is required for participation is a public and private key pair.

By harnessing the fact that these anonymous identities exist entirely within their own cryptographic world, Ethereum is able to build a verifiable computation engine separate from the messy world of trust. This is an extremely powerful tool which can be used to create arbitrary contracts and applications within the Ethereum blockchain, such as the currently popular game Cryptokitties [17].

While powerful, it is inescapable that leaving this cryptographic world once again requires trusting a third party. For example, in the case of a fiat currency exchange, the seller of a crypto-asset must trust that the exchange will deliver the appropriate fiat currency to the sellers bank account (or the exchange must trust that the seller will transfer the crypto asset after the fiat currency has been deposited). Thus we find that if there is an exchange of goods which are not verifiable cryptographically, some element of trust and/or real-world verification is required by least one party.

Consider the case of issuing a research grant from a grantor to a recipient by way of cryptocurrency. In order to send the funds to the correct address, the grantor must confirm the recipient's address directly from the recipient off-chain or else trust a third party to associate the recipient's address to their real-world identity.

Furthermore, the grantor must trust that the recipient will make good on the promise to deliver satisfactory results or hold the recipient accountable off chain. Even if the grantor makes the release of funds contingent on the satisfactory results, the recipient must trust that the grantor will release the funds upon completion of the work.

Both types of trust are a fundamental requirement for this kind of transaction. Real-world identity is inherently not cryptographically verifiable and, being subjective in nature, the same is true for satisfactory results. Two reasonable questions to ask are: can we introduce an opt-in trust layer on top of the foundational trustless protocol and what would that buy us?

2.1 The Lambda Identity Attestation Protocol (LIDAP)

We seek to formalize a method of reasoning about trust in the network and to mitigate the security risk of relying on trusted authorities by reducing the surface area of a trust-based attack on transactions in the network.

At the most fundamental level, there is only one extremely important piece of information that we will need to rely on. It is simply that we need to know that the private key that corresponds to a particular blockchain address is controlled completely and exclusively by a specific real-world

identity. It is impossible to record that link since it spans the physical and digital worlds, but we can instead establish that the private key for an address is controlled by an identity which is described by a set of Personally Identifying Information (PII). If we can establish that fact with a significant amount of confidence then we can again operate entirely in the world of provably secure cryptography. Furthermore, the more confident we are about this association of address to identity, the more confident we can be about the security of contracts relying on this assumption. We therefore also utilize methods of Byzantine Fault Tolerance to distribute trust amongst many trusted authorities and thereby increase the security of this trust based link.

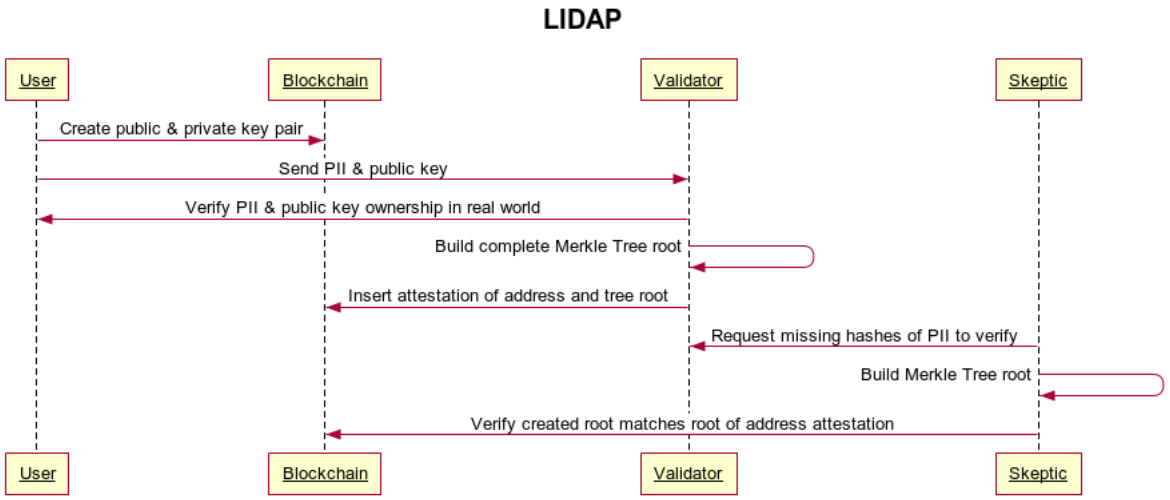
We offer one possible algorithm to accomplish this real world linking called the Lambda Identity Attestation Protocol or LIDAP. The protocol involves the Ethereum blockchain as well as three parties: a user (U), a validator (V), and a skeptic (S). Below we provide an outline of the protocol. U represents a real-world identity, V is the trusted third party authority, and S is a participant which would like to prove that a given address belongs to U.

Protocol 1 Lambda Identity Attestation Protocol

1. U generates a new Ethereum public/private key pair.
2. U sends a set of PII (S_{pii}) and the newly created address (A) to the validator.
3. V verifies that S_{pii} belongs to the real-world identity U via existing methods off-chain (e.g. background check).
4. V uses S_{pii} to construct a Merkle tree from its component parts.
5. V inserts an attestation of identity comprising the address, A, and the root hash of the Merkle tree of S_{pii} into the blockchain via a smart contract (C).
6. S seeks to verify that the owner of A can be described by a query subset (Q_{pii}) of S_{pii} which U provided to V. S requests from V the hashes of the complement of Q_{pii} in S_{pii} ($\overline{Q_{pii}}$) off-chain.
7. S builds the Merkle tree root from Q_{pii} & $\overline{Q_{pii}}$.
8. S makes a transaction to C which compares the root in the contract and the root sent by S.

If the skeptic trusts that the validator did its due diligence in verifying the validity of the PII and that the validator is not a bad actor, then the skeptic knows that the address in question belongs to a real-world identity who is described by the data in Q_{pii}. The protocol is summarized in the diagram below.

The only trust that LIDAP requires is that the skeptic trust the validator. By repeating this process with n validators the skeptic can increase its confidence in the attestation of the validators. The skeptic can choose to accept or reject the attestation by simple majority rule, in which case it can tolerate $f < n/2$ failures. Alternatively, it could choose to have a complex, possibly dynamic, trust weighting distribution over validators. Note that the validators need not all have the same PII of the user, as each validator is queried separately. Furthermore, the validator may choose to salt the PII components before building the Merkle tree. This guards against dictionary attacks on the hashes that the validator distributes to skeptics, meaning that skeptics can only verify the information that they are attempting to validate. In this way, public information like names can be easily verified by any skeptic, but private information such as social security numbers cannot be



reverse engineered from the hashes. Also note that this method of linking off-chain PII to on-chain addresses is both explicit in its declaration of trust (addresses exist in whitelists per validator) and opt-in. Skeptics may choose to operate exclusively in a trustless environment if they do not need to interact with off-chain identities.

This explicit declaration of trust for mapping addresses to identities is absolutely critical for adoption by entities such as the US government, which must abide by strict regulation for the distribution of funds [18]. It is required to allow blockchain technology to permeate more of our society and capture these types of resistant markets.

3 DAO Governance

3.1 Membership Governance

We can see the power that trusted PII affords us when we consider distributed autonomous organization (DAO) membership. Storing a verifiable identity mapping on-chain allows us to write contracts for DAOs which consider the identities of the individuals who comprise it. This allows us to create arbitrary DAO trustee contracts for the managing of funds with verified trustees. Consider the following trustee (a member charged with distributing the grant equitably) membership protocol for establishing a truly autonomous grant distribution DAO:

This is just one possible configuration for a charitable or delegated grant DAO trust. The real power is that the historical effectiveness of a given DAO member can be analyzed across the network. This enables researchers or other trustees to build a reputation for being able to deploy funds effectively and equitably, all permanently stored within the blockchain and secured by the proof-of-work algorithm of the Ethereum network.

3.2 Grant Governance

Delegation of grant governance is a powerful tool for funding institutions and imperative for both the Lambda Research Grant and the Lambda Ecosystem Grant. Research grant application reviews

Protocol 2 DAO Membership Protocol

- The DAO contains a list of beneficiaries (i.e. funders) who are allowed to fund the contract. A beneficiary may not wish to, or perhaps is not allowed to, have control over distribution of funds.
- The beneficiaries may elect N trustees to bootstrap the membership of the DAO.
- Beneficiaries may veto trustee proposals if there are discrepancies between addresses and the expected identities.
- Confirmed trustees may vote to add additional trustees.
- Trustees must be added at a proportional rate to the amount of money granted to the DAO. Funds are frozen if this money and number of verified trustees is inconsistent.
- Trustees are required to participate in the grant distribution on a regular schedule or else have their trustee status revoked.
- New trustees can be added through a vote of trustees and a confirmation by funders.

require a significant amount of expertise in very specialized subjects. Additionally, entrusting a grant on the scale of the Lambda Research Grant to a single party may result in inadvertent mismanagement, or a reluctance to use the network given the outsized influence of said party.

Therefore, we introduce a preliminary method of governance for a research grant which is delegated to a DAO comprising verified experts in research and whose membership is in part supervised by the community of Lambda holders.

These rules in combination with LIDAP provide a mechanism to ensure that the power to distribute funds for research projects is sufficiently decentralized among experts. It is also in the best interest of beneficiaries to choose capable trustees, given that they hold a non-trivial stake in the Lambda Network ecosystem.

4 Tracking of Research

4.1 Tracking Funds

One of the most time consuming aspects of managing a grant, from the perspectives of both the grantor and recipient, is maintaining and reviewing the audit trail of transactions. Grants often come with a set of restrictions on how the funds can be spent. For example, some restrictions require that a grant must be spent on computing resources like AWS or must be spent on travel expenses [19]. Other restrictions require that money only be withdrawn from the grant if it will be spent within three days [20]. Platforms such as AIDCoin [21] track the flow of funds only to the edge of their ecosystem. Since their currency can be readily exchanged for fiat currencies, this leaves the potential for abuse. The Lambda Network, by contrast, enables opt-in transaction tracking and restriction all the way to the edge services through careful constructions of contracts and the use of LIDAP. Note that this system uses fungible tokens, although we consider non-fungible tokens (NFTs) below.

Protocol 3 Lambda DAO Grant Governance Protocol

- Any account within the Lambda Network which holds over 10,000,000 Lambda is considered to be a beneficiary, as their stake demonstrates commitment to the Network.
- The beneficiaries may elect N trustees to bootstrap the membership of the DAO.
- Beneficiaries may veto trustee proposals if there are discrepancies between addresses and the expected identities.
- Confirmed trustees may vote to add additional trustees.
- Trustees must be added at a proportional rate to the amount of money granted to the DAO. Funds are frozen if this money and the number of verified trustees is inconsistent.
- Trustees are required to participate in the grant distribution on a regular schedule or else have their trustee status revoked.
- New trustees can be added through a vote of trustees and a confirmation by beneficiaries.
- A grant application can be accepted by no fewer than $\frac{2}{3}$ of all trustees.
- No more than 2% of the funds available may be granted to a single address.
- An accepted grant application must go through a review period of at least 2 weeks, during which time greater than $\frac{1}{3}$ of the trustees can vote to veto the grant issuance.
- A majority of beneficiaries may vote to remove a trustee from the DAO.
- The DAO will also receive Lambda from each grant application received by way of a small bounty sent alongside. Applicants pay this small bounty with their grant application to make sure that applicants are taking time to deliver quality applications and reduce application spamming available Requests for Proposals.

4.1.1 Tracked Grant Distribution Contract

In this section we introduce this opt-in method of transaction tracking and a community wallet tool which provides non-technical users a means to explore the graph of transactions and audit the use of the grant funds that they issued. It is critical that the method of tracking transactions be opt-in only. This affords all users of the platform the option to choose the level of transparency they desire and does not restrict the Lambda platform exclusively to tracking research grants. Given that the adoption of the platform may lead to other use cases beyond research generally, this is a small but crucial detail. We also introduce methods for funders to restrict their funds to the purchase of certain external services through the use of LIDAP.

For every cryptocurrency, transactions are recorded permanently and immutably on the blockchain. However, for most types of transactions the information recorded on the chain is only half of the story. The other half takes place off of the blockchain in the form of an exchange of fiat currency, goods, or services. The obvious issue is that, while the blockchain is a perfect audit trail for crypto-assets, it lacks any kind of audit trail for the off-chain exchanges. Indeed, this anonymity of real-world exchange is often seen as a feature of cryptocurrencies.

Therefore, even if funding institutions were to adopt other cryptocurrencies to distribute their grants, they would still have to manually track and audit real-world progress and success metrics off-chain. Even more, they would have no way of restricting the use of funds. We can, however, create

a Tracked Grant Distribution Contract (TGDC), which is designed to securely and automatically track and audit off-chain research progress through the use of the version control software Git or new decentralized storage applications such as IPFS [22]. These contracts implement the following Tracked Grant Distribution Protocol which is defined as follows:

Protocol 4 Tracked Grant Distribution Contract

1. A grantor creates and funds a TGDC.
2. The grantor adds a Git commit SHA to the TGDC which points to a Request For Proposal (RFP). This RFP defines requirements for the use of the grant and what constitutes success. This proposal can take the form of any Git repository (or IPFS node).
3. Prospective recipients submit their own Git commit SHAs to the TGDC which points to a Proposal.
4. The grantor (or grant trustees) select the winning grant proposal and release the funds to the corresponding address after verifying the identity of the applicant via LIDAP.
5. The applicant carries out the research off-chain.
6. The applicant submits another Git commit SHA which points to a repository which includes their final publication along with any data that they must certify they created from the grant.
7. The research goes through a peer review process on the blockchain where each peer signs that they reviewed it and are paid in Lambda for their review services by the TGDC. Note that peer review is often done on a volunteer basis currently. However we can create a new peer review token, if necessary, which can only be used to incentivize faster peer review and can only be earned by peer reviewing papers. This will establish a point system similar to StackOverflow's points and bounties system for asking and answering questions.

Fortunately, in the realm of research the resulting product takes the form of information. We can harness this to leave a record of it directly on the blockchain. This protocol utilizes this fact to record exactly what was exchanged in the real world for anyone in the network to verify. If the research is published in a journal, then anyone can construct the hash from the advertised research results. If the research is unpublished, there is no known way to reverse engineer the research results from the hash stored publicly on the blockchain. For ease of use and verification, grantors or recipients may choose to host the contents of these repositories on third party applications, such as SkyLab.

4.2 Tracking Data Integrity

This same Lambda Network mechanism for publishing the Git digest of a research publication on the blockchain can also be trivially extended to secure the integrity of lab records such as lab notebooks. This means that even industry labs, which do not publish, can use the blockchain as a permanent witness of their lab records, instead of having unsearchable, mutable, paper records signed and witnessed in triplicate.

4.3 Fund Restrictions

In addition to permanently and irreversibly corresponding research publications to the grants that funded them, these TGDCs can also restrict funds to be spent in a certain manner. Such restrictions can take at least two forms: through explicit spending restrictions to specific service contracts or through the use of colored Lambda tokens. The former method works by the grantor restricting spending to a set of valid contract addresses that the grantor trusts can only be used for a specific

purpose. As an example, a service provider (e.g. SkyLab) can have a contract which it asserts will only be used as compensation for computing resources. The grantor may also issue its own colored Lambda tokens which can only be transferred to whitelisted addresses which provide services approved by the grantor. At the time of issuance of the colored tokens the grantor will deposit an equal amount of Lambda into a reserve. The grantor will then exchange the colored tokens for Lambda tokens at the request of the trusted service providers, thereby closing the loop.

In the near future the Ethereum platform will release a new token class: ERC721 Non-Fungible Tokens (NFTs) [23]. We will investigate implementing NFTs using ERC721 tokens for enhanced tracking of the flow of research funds through the Lambda Network.

4.4 Exploring the Transaction Graph

The combination of the blockchain record and the contents of its respective repository allows Lambda Network applications to calculate advanced statistics on the graph of grant distributions. We imagine a graph query engine which computes complex queries, e.g., Show me all authors who received funds from the NIH and NSF in 2013. Standard formats for Git repositories can also give funders the ability track performance metrics of their grants like citations per dollar by tracking the document object identifier (DOI) of the published paper off-chain. Formats can also allow third parties to build a cryptographically secure network of citations upon which funders and others can base their decisions. Similarly, these same metrics can be calculated for each researcher. This will give funders unparalleled insight into who is best suited to make use of their research funds.

5 The Research Funding Marketplace

The graph of grant transactions is the perfect foundation for constructing a new research marketplace which can act as a grand exchange of funds and knowledge. In order to make this marketplace accessible to researchers we will build a user-facing Lambda Network application on which funders can publish funding opportunities. The application will link with both the blockchain records and the hosted Git repositories that they point to. This will allow researchers and funders alike to transparently review and approve RFPs, proposals, and publications all in one place. Machine Learning, AI, and Natural Language Processing techniques will also enable Network applications, like the one proposed above, to match researchers to RFPs which best reflect their qualifications.

We can even go beyond the individual level and calculate aggregate statistics such as the amount of funding available in each field. This type of information is not easily accessible today, which means that researchers cannot easily set long term plans based on the trends and current amount of research grants available in a given field.

With this open marketplace, contract research organizations (CROs) can bid on research contracts from large corporations all arranged and secured by smart contracts on the blockchain. This type of pricing transparency has never before been available to the funders of research projects.

6 An Open Research Journal for the Blockchain Era

Most of the established, traditional research publishers are large, centralized companies that charge individuals and institutions for the privilege of reading their published work. After a paper has been accepted, the journal owns the rights to the paper and figures contained therein; the authors

of the work have to obtain permission to use their own text and figures. In 2016, the world's 50 largest book publishers topped $50 billion in revenue [24]. Are publishers really contributing that much to research as the middlemen to get to essentially levy a tax on research?

The alternative to these traditional publishers is open access journals like the Public Library of Science (PLOS). These journals license authors' works with a Creative Commons Attribution License (CC BY), which allows anyone to view and use the paper free of charge as long as they attribute the work to the respective authors. This system of publishing has become more and more popular, so much so that PLOS ONE is the largest journal in the world, despite shrinking in size the last few years due to traditional journals like Nature providing their own open access journals to keep up [25]. Another reason that open access has become popular is many public sources of funding require the resulting papers and data to be open access, such as the NIH [26] and Harvard [27]. Indeed, open access research papers have proven their own merits over subscription journals: a study analyzing over 27,000 published articles has revealed that open access articles receive more citations than articles for which subscriptions are required, even after controlling for possible confounding variables including the country of origin, journal IF, and area of study [28].

Still, open access journals charge authors money to publish to offset costs from distribution, peer review, editing, and hosting online papers and data. At time of writing, publishing a paper in PLOS costs between $1,500 and $2,900, depending on the journal [29]. True political decentralization of the open access publication market is possible with the Lambda Journal, where authors can submit papers through platforms on the network like SkyLab. Editing and peer review will be carried out by other peers on the Lambda Network, and peers who review will be reimbursed as mentioned in subsection 4.1.1. Administration of the journal will be regulated and administered by a DAO much like the ones mentioned in 3.2. Additionally, author identities will be established via the LIDAP protocol detailed in 2.1. The platform through which the author submits papers will be responsible for hosting the paper and data as needed. The costs to administer this journal will be a fraction of the current open access journals because there will be no central authority taking a cut. Smart contracts will be available to transparently distribute the costs of publication for each party in the process, and new smart contracts can be added at any time. The Lambda Journal will seek to become a reputable open access journal by seeking membership to the Committee on Publication Ethics (COPE) [30] and Directory of Open Access Journals (DOAJ) [31].

7 The Research Services Marketplace

Yet another important aspect of the Lambda Network is that it provides a convenient method for researchers to pay for services with the grants that they receive. Third party applications can easily integrate with the network to trade services for Lambda, which they can then sell back to the research funders on the open marketplace.

Offering services directly within the network without first converting to a fiat currency ensures that every expense is permanently recorded on the blockchain. This self-contained market affords benefits to the service providers by greatly simplifying their payment systems. The marketplace also provides an environment for a new type of peer to peer research services exchange. Research is very much a distributed enterprise with small to medium sized research labs comprising a substantial component of the market. Frequently, smaller labs lack the necessary equipment to carry out complex experiments and expensive equipment sits unused in larger labs. For certain types of research (e.g. chemical vapor deposition), smaller labs must apply for outsized grants in order to

purchase their own equipment or else forgo that kind of research. The Lambda Network creates the opportunity for larger labs to sell access to their equipment and services directly to smaller research institutions and labs, without going through a large proprietary intermediary.

The SkyLab platform will be the first third party application to offer services on the network. Others will be encouraged to do so through the Lambda Ecosystem Grant.

7.1 The SkyLab Platform

SkyLab provides a GitHub-like social networking service for open research, a version control system based on blockchain technology, online editing tools, publication and promotion tools, and computing and data storage resources for researchers. Researchers will be able to redeem Lambda for these services within SkyLab, driving demand for the Lambda utility token. There is currently enormous demand for these resources as big data becomes an increasingly integral part of many research fields, particularly genetics. Indeed, the Big Data to Knowledge fund issued $200 million of grants in between 2014 and 2017 for exactly these services [32].

Lambda also enables features in SkyLab that would not otherwise be possible if it weren't in the network. SkyLab records every edit that a researcher makes to their lab notebook on the website. For industry research institutions like Genentech, it is absolutely imperative that all information in lab notebooks be immutable and auditable in case of legal disputes or ethics violations. Currently, SkyLab acts as a trusted authority for the contents of these lab notebooks. However, by using the Lambda Network, a digest (irreversible hash) of these contents can be published to the blockchain thereby conferring all of the security of Ethereum's proof-of-work algorithm and mining network.

7.2 Earning Lambda in the SkyLab Application

Researchers will be able to earn Lambda within the SkyLab application through the referrals and peer review programs. The referrals program will offer Lambda to researchers who successfully get their peers to join the SkyLab application which in turn grows the network. Other applications that join the Lambda Network can use this Lambda referral bonus as well to incentivize their users to join the network.

The architecture of SkyLab provides an excellent and convenient place to publish papers along with the associated data and code. As such, we intend to provide tools and services for researchers to peer review papers and offer feedback before publication on the website. The current peer review process can take months due to its arcane and non-interactive nature [33]. This entire process can be tracked with blockchain-related technology to bring a level of speed, auditing, and transparency to this process which was not previously possible. This process is described in more detail above in section 4.1.1.

8 Planned Development

SkyLab, Inc., currently plans to develop eight software features, services, or applications to bootstrap and support the Lambda Network of apps. All source code for these features, which exist outside of the SkyLab platform, will be open sourced under a permissive license and made available on GitHub. A summary list is included below.

1. Mobile and Web Wallet

2. SkyLab Services Integration
3. Grant Funding Delegation DAO Contract
4. Research Grant Issuance and Tracking Contract
5. Research Grant Blockchain Explorer
6. Funding Opportunity/Proposal Marketplace Explorer
7. Research Efficiency Analysis Explorer
8. Miscellaneous Network Contracts

8.1 Wallet

Although blockchain based software is growing more popular daily, for a majority of users Lambda will be their first introduction to cryptocurrencies. While this is an exciting opportunity to introduce millions of new users to blockchain software, it also means that we have a responsibility to create a secure and simple experience. A key component of that experience is to present a unified view of the platform through the Lambda Wallet application. This application will be the primary entrypoint for end-users to access their Lambda balance and Lambda Network applications.

The wallet will be available through the web and mobile apps. User wallets will be created automatically and synced between devices with an encrypted cloud backup. As users or institutions become more familiar with cryptocurrency they can opt to take control of their wallet and move their keys off device for additional security. We will seed new user wallets with a small amount of Lambda for a limited time from the Lambda Ecosystem Grant as an incentive for users to sign up and get involved with the platform.

The wallet will also be the gateway to other Lambda Network applications and features. It will house some of the explorer functionality discussed below. This promises to offer users a familiar location and a consistent brand to associate with the Lambda Network. We will also investigate allowing third parties to offer plugins to the application so that they can feature their own apps prominently within the ecosystem.

8.2 SkyLab Services Integration

The SkyLab platform will be fully integrated as a third party application with the Lambda Wallet. Users will be able to manage their billing and transactions through the wallet application. Git repositories that are referenced in the blockchain and publicly hosted on SkyLab will be seamlessly integrated into the Wallet application as if the entire repository were hosted on the blockchain itself. The SkyLab platform will also be altered to allow users to purchase SkyLab services through the wallet using Lambda. Additionally, SkyLab, Inc., will serve as the first trust authority for LIDAP and will implement the necessary APIs to be able to verify user identities on the blockchain. SkyLab, Inc., will therefore carefully review each application for identity verification and ensure that the information a user provides is consistent with a single identity in the real world.

8.3 Grant Funding Delegation DAO Contract

We will develop and propose a grant funding delegation contract for governing both the Lambda Research and Lambda Ecosystem grants. This contract will be made public and will go through a

period of review before it is published to the blockchain and control of the funds are transferred to its address.

8.4 Research Grant Issuance and Tracking Contract

We will also develop a standard interface for developing grant issuance contracts described in section 3.2, which the Wallet will be capable of tracking by default. We will propose one such implementation of that contract for use by the Lambda Research Grant.

8.5 Research Grant Blockchain Explorer

The Lambda Wallet will include a built in grant tracking explorer. Through this explorer users will be able to see the granting institution, the applicants for the grant, the grant recipient, and the associated Git repositories as well as their respective public profiles as available on SkyLab.

8.6 Funding Opportunity/Proposal Marketplace Explorer

In addition to the grant tracking explorer, the Lambda Wallet will include a marketplace explorer for finding new grant opportunities within the network and for estimating total available opportunities by field.

8.7 Research Efficiency Analysis Explorer

The Wallet will also include a basic analysis of citations created per Lambda spent once a sufficient amount of research has been funded through the platform.

8.8 Miscellaneous Network Contracts

SkyLab will also develop a set of miscellaneous contracts to meet specific research and funding institution requirements as they are needed. An example of one such grant might be a milestone-based vesting grant which only releases funds provided the project is proceeding as planned.

9 Development Roadmap and Timeline

- August 2018: Token presale
- September-October 2018: Token sale
- October 2018: Lambda Network SkyLab integration
- Q3 2018: Wallet and web applications (first version)
- Q4 2018: Research grant tracking contract and wallet application explorer
- Q1 2019: Wallet based peer review tool
- Q2 2019: Lambda Research Grant using non-fungible ERC721 tokens
- Q3 2019: Efficiency analysis explorer
- Q4 2019: DAO management of grants
- Q4 2019: Machine learning based grant matching

- Q1 2020: Lambda Journal launch
- Q1 2020: High performance computation integration

10 Lambda Grant Programs

Perhaps the most important responsibility of SkyLab will be to administer the Lambda Research Grant and Lambda Ecosystem Grant programs. Together, these grants constitute 33% of all tokens so it is critical that the tokens are distributed in a fair and equitable manner. All tokens distributed under these programs will be used to grow and raise awareness of the platform and none will be used to benefit a particular network partner to the exclusion of others. It is in our best interest to grow the value of the network with these tokens in accordance with the principles of network value [34]. In general we believe that the power to distribute tokens should be controlled by a DAO or at least by a separate non-profit foundation. SkyLab will therefore work aggressively towards achieving political decentralization, by transferring control to a separate organization. Some elements of the platform, however, will remain centralized until decentralized options become feasible.

In the interim period, interested parties can apply for the Lambda Research and Lambda Ecosystem grants through SkyLab, Inc., which will review and distribute the funds in a transparent and inclusive manner after a period of public review.

10.1 Lambda Research Grant

This grant is intended to drive Lambda Network interactions and to incentivize users to adopt services that are provided through the platform. Grant applicants will be granted Lambda in proportion to the probability that they will produce peer-reviewed and highly cited research. A proven track record of publishing to well regarded journals or contributing to research tracked by the network will be used as a measure of network contribution.

SkyLab will establish a Lambda Research Grant commission comprised of accomplished researchers in the fields of distributed systems, biology, materials science, and biochemistry to review applications. The members of this commission will eventually form a DAO with the power to distribute the grant subject to the rules in 3.2. Each grant will enter a period of public review and will be accompanied by a statement of intent from the Lambda Research Grant commission. This will be a statement declaring the reasons this research provides value to the Lambda Network.

10.2 Lambda Ecosystem Grant

The Lambda Ecosystem Grant is designed to drive token network effects for Lambda. The Ecosystem Grant will be distributed in two main ways.

1. Partner applications which support the Lambda Network.
2. Ecosystem & infrastructure investment.

10.2.1 Partner Applications

Applications will earn rewards from the Ecosystem Grant in proportion to the utility that they contribute to the network. The rewards mechanism will be based on a token staking model to measure network contribution. SkyLab will determine application-level rewards based on the

accumulated balances of each application's users. The Ecosystem Grant awards will compensate partner applications or platforms similar to, but excluding, SkyLab which attract researchers to use their services. This means that new Lambda Network participant organizations will be able to earn Lambda both through providing services to researchers and also through the grant program.

In order to receive the grant, partner applications must stake a portion of the grant they receive. This form of staking correctly aligns incentives for participants to positively impact the Lambda Network, thereby reducing the possibility for malicious behavior. As with the Research Grant this process will eventually be administered by a DAO of beneficiaries.

10.2.2 Open Source Ecosystem & Infrastructure Investment

The second purpose of the ecosystem grant is to fund the development of critical and fundamental infrastructure improvements to the Lambda Network. As a decentralized network it will be open to all developers to build on and improve. SkyLab will be responsible for overseeing the development of wallets, fund tracking tools, and other services for spending and storing Lambda.

SkyLab will also work towards the development of new transformational blockchain improvements, such as including data and experimental integrity management on the blockchain. This type of guarantee is frequently necessary to maintain ethical standards and to settle legal disputes in research. SkyLab will further invest in developing new contracts for the management of the Lambda Ecosystem Grant. This would include creating a DAO or mining scheme based on citations and peer review to distribute the grant equitably amongst network participants in accordance with their contribution.

Beyond directly funding infrastructure improvements, SkyLab will use the grant to sponsor conferences, promotions, and hackathons for the development of new Open Source Lambda Network software. SkyLab may also publicly sponsor bounties for specific Open Source projects.

11 Lambda Token Distribution

The token generation event will create and distribute a maximum of 10 billion Lambda.

11.1 Token Sale

Title	**Value**
Symbol	λ (LMDA)
Maximum Supply	λ10,000,000,000
Type	ERC20
Price	1 LMDA = 0.00002 ETH
Total Sale Issue Cap	λ3,200,000,000
Presale Issue Cap	λ500,000,000
Soft Cap	1000 ETH
Unsold tokens	Tokens not distributed shall not be generated

11.2 Token Distribution

Entity	**Percentage**	**Amount**	**Description**
Token Sale	32%	λ3.2B	Sold in token sale and pre-sale. Vest immediately.
Research Grant	16%	λ1.6B	Distributed at a maximum equivalent to 12% of the remainder per annum, indefinitely ($\tilde{2}$% of total token supply in first year.)
Ecosystem Grant	16%	λ1.6B	Distributed at a maximum equivalent to 12% of the remainder per annum, indefinitely ($\tilde{2}$% of total token supply in first year.)
Token Sale Costs & Bounty Program	4%	λ0.4B	Allocated for expenses and legal fees of token sale. Vest immediately.
Company (SkyLab, Inc)	30%	λ3.0B	Subject to a 3 year vesting period.
Advisors	2%	λ0.2B	Subject to a 3 year vesting period.

References

1. *Knowledge, networks and nations: global scientific collaboration in the 21st century.* The Royal Society, 2011.
2. OECD, *OECD Science, Technology and Industry Scoreboard 2017 innovation for growth and society.* OECD, 2017.
3. "About the national science foundation." https://www.nsf.gov/about/. Accessed on 2018-01-10.
4. J. Cook, "Chasing grants." https://www.johndcook.com/blog/2011/04/25/chasing-grants.
5. V. Buterin, "The meaning of decentralization." https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274, Feb 2017. Accessed on 2018-01-10.
6. FDA, "Current expectations and guidance, including data integrity and compliance with CGMP." https://www.fda.gov/downloads/AboutFDA/CentersOffices/OfficeofMedicalProductsandTobacco/CDER/UCM561491.pdf/.
7. "Fy 2014 budget request." https://www.nsf.gov/about/budget/fy2014/. Accessed on 2018-01-10.
8. "Gross domestic expenditure on r-d by sector of performance and source of funds." http://stats.oecd.org/viewhtml.aspx?datasetcode=GERD_FUNDS&lang=en#. Accessed on 2018-01-10.
9. "CRO Industry Primer." https://research-doc.credit-suisse.com/docView?language=ENG&format=PDF&source_id=csplusresearchcp&document_id=807217850&serialid=1ggpgyhrjr4IPVVZwUx5fnTCUvsypJvd%2FzOj4zPA7Us%3D, June 2016. Accessed on 2018-01-10.
10. J. Mervis, "Data check: U.S. government share of basic research funding falls below 50%," *Science*, Sep 2017.
11. "Oecd science, technology and industry scoreboard 2015: Innovation for growth and society." http://dx.doi.org/10.1787/9aa45b52-en. Accessed on 2018-01-10.
12. E. C. Laboratory. https://emeraldcloudlab.com.
13. Transcriptic. https://www.transcriptic.com.
14. J. Monegro, "Fat protocols." http://www.usv.com/blog/fat-protocols, Aug 2016. Accessed on 2018-01-10.
15. S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system." https://bitcoin.org/bitcoin.pdf, 2008. Accessed on 2018-01-10.
16. "A next-generation smart contract and decentralized application platform." https://github.com/ethereum/wiki/wiki/White-Paper. Accessed on 2018-01-10.
17. "Cryptokitties." https://www.cryptokitties.co. Accessed on 2018-01-10.
18. CFR, "45 c.f.r. §75," 2018.

19. NIH, "NIH Grants Policy - 14.10 allowable and unallowable costs," 2017. https://grants.nih.gov/grants/policy/nihgps/html5/section_14/14.10_allowable_and_unallowable_costs.htm.

20. NIH, "NIH Grants Policy - 6 payment," 2017. https://grants.nih.gov/grants/policy/nihgps/html5/section_6/6_payment.htm.

21. C. Stars. https://www.aidcoin.co/.

22. J. Benet, "Ipfs - content addressed, versioned, p2p file system." https://ipfs.io/ipfs/QmR7GSQM93Cx5eAg6a6yRzNde1FQv7uL6X1o4k7zrJa3LX/ipfs.draft3.pdf.

23. "Erc721," 2017. https://github.com/ethereum/EIPs/issues/721.

24. J. Milliot, "The world's 54 largest publishers, 2017," Aug 2017. https://www.publishersweekly.com/pw/by-topic/international/international-book-news/article/74505-the-world-s-50-largest-publishers-2017.html.

25. C. Straumsheim, "The shrinking mega-journal," Jan 2017. https://www.insidehighered.com/news/2017/01/05/open-access-mega-journal-plos-one-continues-shrink.

26. NIH, "Nih public access policy details," March 2016. https://publicaccess.nih.gov/policy.htm.

27. Harvard, "Harvard faculty of arts and sciences open access policy," Feb 2008. https://osc.hul.harvard.edu/policies/fas/.

28. G. et. al., "Self-selected or mandated, open access increases citation impact for higher quality research," Oct 2010. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0013636.

29. PLOS, "Publication fees," 2015. http://journals.plos.org/plosone/s/publication-fees.

30. COPE, 2018. https://publicationethics.org.

31. DOAJ, 2018. https://doaj.org.

32. NIH, "Press releases." https://commonfund.nih.gov/bd2k/pressreleases.

33. NIH, "NIH Grants Policy - peer review policies and practices," 2017. https://grants.nih.gov/policy/peer/index.htm.

34. C. Shapiro and H. R. Varian, *Information Rules*. Harvard Business Press, 1999.