Introduction

Gridcoin

Gridcoin is an open-source multi-incentive permissionless blockchain that mints and distributes cryptocurrency to various contribution-based and point-accruing systems. It currently distributes currency according to the relative processing power a network participant directs toward data-driven analysis and scientific discovery across the Berkeley Open Infrastructure for Networked Computing and Folding@Home. The Gridcoin blockchain is secured through the proof-of-stake v2 protocol and utilizes several mechanisms to assure network, data, identity, and economic security. Access to Gridcoin's computational resources is free for any project with data to process while contributors to the Gridcoin network are incentivized with cryptocurrency minted and distributed by the Gridcoin protocol.

The Gridcoin Network and Protocol Overview

Gridcoin Blockchain and Economic Protocol		
Incentivization Mechanism		
Oracles		
Beacon ID		
Statistics Providers (BOINC or other point-accruing system)		
Participant Computer	Participant Mobile	Participant Server

The Gridcoin blockchain is secured through proof-of-stake (pg. 10). The economic protocol mints and injects the GRC currency into an incentive mechanism that distributes the currency among blockchain consensus providers and contributors to approved statistics providers (pg. 6).

While technically capable of incorporating any point accruing system, Gridcoin's incentive mechanism currently incorporates records of participant computation contributions to BOINC projects elected for inclusion by members of the Gridcoin network and Folding@Home (pg. 7). Currently, 75% of the currency minted by the economic protocol is distributed to contributors to these computation projects in a process defined by the rules of the incentive mechanism. The incentive mechanism includes rules that encourage participants to evenly distribute their crunching power across the included BOINC projects (pg. 12, 13, 15).

Oracles connect to approved statistics providers, digest the provided data, and publish hashed and signed contribution statistics to all nodes of the network to form a consensus around contribution data. This consensus is used by the incentive mechanism to determine a contributor's owed GRC reward (pg. 10).

Beacon ID verifies, secures, and stores a contributor's contribution identity and associated statistics (pg. 12).

Statistics providers, currently Folding@Home and BOINC projects, are incorporated into the Gridcoin system through a network-wide vote. They independently track contributor contributions to their own project which are then collected by Gridcoin oracles, associated to a user through beacons, and converted into GRC owed to a beacon via the incentive mechanism (pg. 8).

The resulting stack of these layers produces a robust and secure network of distributed computing and continuing education that guarantees processing power to any project approved by the greater Gridcoin network.

The Berkeley Open Infrastructure for Network Computing (BOINC)

The Berkeley Open Infrastructure for Network Computing (BOINC) is an open-source, permissionless grid computing infrastructure which provides open access to a global distributed computing network. To date, BOINC has been the driving force behind numerous computationally intensive research programs; There have been over 400 scientific papers published using results from BOINC projects. Some notable achievements include producing an accurate 3D model of SARS-CoV-2 faster than crystallization-based models (Rosetta@home), developing a manufactured and distributed COVID-19 vaccine (Rosetta@home), finding new subatomic particles (LHC@Home), identifying pulsars (Einstein@Home), advancements in cancer marker and treatment research (World Community Grid), simulation of candidate molecules for next-generation solar panels (World Community Grid), advancements in climate research (ClimatePrediction.Net), along with many others.

While BOINC has been used primarily for science and mathematics, it can facilitate distributed computing for any open or commercial field so long as the distributing computing problem and associated data sets can be formatted for BOINC's processes. Examples of projects include tasks on engineering, cryptography, rendering, weather and climate prediction, as well as social, market, and resource analytics. Enigma@home, for example, worked to break remaining WWII messages encrypted by an Enigma machine.

Computation Power

As of November 2021, BOINC hosts about 20 petaFLOPS of processing power.

Gridcoin contributes 3.88 petaFLOPS of processing power to BOINC (August 2022), making up 19% of BOINC's processing power.

Folding@Home

Folding@Home is a permissioned distributed computing project run out of the University of Pennsylvania by Greg Bowman. The project's primary focus is protein folding simulations and biomedical research. The project reached over 2 exaflops of processing power in April 2020 during the early spread of Sars-COV-2.

Through the development of a unique adapter mechanism, Gridcoin incorporated Folding@Home as a statistics provider in late 2022.

The Gridcoin Network

Organization, processes, and decision making

As of August, 2022 there are over 16,000 active network participants incentivized by Gridcoin. The Gridcoin network offers between 3 and 5 total PFLOPs across all Gridcoin approved BOINC projects.

As of 2019, there were over 3,400 unique nodes supporting the blockchain.

Organization

Gridcoin was launched by an anonymous developer in 2013 under a PoW bootstrap model. It transitioned to PoS in 2014. It currently functions under a permissionless blockchain-based open-source operation and governance model. There are no owners, proprietors, executives, board of directors, or other assigned titles. Necessary responsibilities are entrusted to reputable contributors to the project.

Participants

There are four technical participants in the Gridcoin network. A single participant can perform several functions simultaneously.

Crunchers

Crunchers are nodes with registered beacons. They contribute computation power to approved statistics providers. Participants utilizing a staking pool to record their computational contributions are also considered crunchers, however only the pool owner with the registered beacon is technically a cruncher.

Stakers

Stakers are nodes securing the Gridcoin blockchain. They maintain an active balance in an attempt to be chosen as a block producer.

Stakers are responsible for forming consensus on statistics published by Oracles while also executing the superblock algorithm that calculates and publishes each participant's Earned Research Rewards.

As of August 27th, 2022, stakers also fulfill Manual Reward Claim contracts.

Statistics Providers

Statistics providers are third party entities that record participant statistics for collection by Gridcoin oracles. Current statistic providers are BOINC projects and Folding@Home. In future iterations, statistic providers could include any verifiable record keeper such as Bacalhau or Blockless.

Oracles

Oracles are verified nodes that collect, hash, sign, and publish participant contribution statistics from statistic providers.

Currency

A necessity of a permissionless blockchain is a currency which incentivizes participation in securing the integrity of the ledger and its recorded transactions. GRC is the currency of the Gridcoin blockchain.

Economic Protocol

The Gridcoin economic protocol is a permissionless, trustless, and transparent open economic system defined and enforced by open-source code run by a set of network nodes. It evolves through node consensus around the system code.

Economics

Gridcoin's GRC has evolved through several protocol shifts. Currently, the protocol mints 37,600 GRC per day. From those minted GRC, blockchain consensus is incentivized with a 10 GRC reward for securing a block. Block timing is 90 seconds. This results in 960 blocks and 9,600 GRC distributed to stakers per day. The remaining 28,200 daily minted GRC is distributed to participants contributing to statistics providers.

Below are the current economic rules of the system.

Total Supply as of August 20th 2022

463,000,000 GRC

Total Minted per Year

13,724,000 GRC

Distributed to Crunchers per Year

10,293,000 GRC

Distributed to Stakers per Year

3,431,000 GRC

Block Reward

10 GRC

Cruncher Currency Distribution

Essentially, Gridcoin's incentive mechanism splits the GRC allocated for crunchers evenly among all approved statistics providers. It then distributes each statistic provider's GRC to that provider's contributors based on the contributors' contributions relative to one another. On a technical level, this process utilizes magnitude and produces several beneficial outcomes including currency security and several unique incentives.

The Gridcoin Foundation

The Gridcoin Foundation is a community-managed wallet of about 15 million GRC. The fund consists of GRC abandoned during the protocol shift from PoW to PoS in 2014. There was no premine, token launch, or other funding mechanism used to create the foundation wallet. The Gridcoin Foundation's expressed purpose is to support the development of the Gridcoin protocol and growth of the Gridcoin network.

The GRC of the Gridcoin Foundation is held in a non-staking, multi-signature wallet. The keys to this wallet are held by a group of long-standing, reputable, verified, and trusted individuals. The wallet requires approval from a majority of key holders to enable any transfer of GRC out of the foundation wallet.

Voting

Changes to the functionality and structure of the Gridcoin network are implemented by software alterations by Gridcoin developers that are committed to a public repository. By installing or refusing to install upgraded software incorporating these changes, a permissionless network of nodes ultimately exercise final decision-making authority.

To facilitate unified decision making among nodes, the Gridcoin network utilizes an open and transparent blockchain-based polling mechanism. Polls inform participants on decisions, give developers direction on where the network wants to go, and seek common ground or otherwise mediate arguments on network protocol and operation.

The polling process also helps manage Gridcoin's list of statistic providers approved for inclusion in the incentivization mechanism.

Additionally, if a contributor wants to seek foundation reimbursement for their work, they can create a poll with a proposal or reimbursement request.

There are currently 7 types of polls. Each poll type has unique requirements and validation parameters formulated from prior poll experiences and bootstrapped by prior network polls. The poll types are:

1. Survey
2. Protocol Development
3. Marketing
4. Outreach
5. Governance
6. Community
7. Project Listing

These categorizations assist in defining the issue at hand and increase the likelihood of a poll reaching a clear and definitive result. Details on the specific types of polls are beyond the scope of this document and should be viewed on GitHub at the following link:

https://github.com/gridcoin-community/Gridcoin-Tasks/issues/227

Gridcoin Approved List

The list of Gridcoin approved projects is a fundamental asset of the Gridcoin incentivization mechanism. The current technical implementation of this list is as a network-elected list of URLs for BOINC project statistics, along with a unique Folding@Home adapter, which are periodically pinged to request updated figures of participant computation contributions.

To qualify for inclusion on the approved list a project must satisfy a number of criteria. These criteria are designed to ensure that projects are legitimate, offer a fair chance for all participants to receive work and credit, and are not designed specifically to manipulate or damage the Gridcoin network by reporting false or unvalidated contribution figures.

Technical Requirements

A summary of the approval requirements are as follows. To qualify for inclusion, projects must:

- **Validate work units** and detect possible cheating or hardware malfunctions.
- **Consistently generate work units** at a level that handles the computation power offered by the Gridcoin network.
- **Fairly** distribute work units to all viable crunchers.
- **Produce statistics information daily** at the user, team, and (preferably) host level.
- **Employ reasonable standards** for reliability and availability of the project resources, such as project website, forums, and contact information.

A full list of technical requirements can be found on GitHub at the following link:

https://github.com/gridcoin-community/Gridcoin-Tasks/issues/227

List Management

A project is automatically removed from the Gridcoin approved list if it stops complying with a critical requirement, such as allowing new user sign-ups. A project can also be removed from the approved list through a network poll.

A network poll is required to re-approve a project once it is removed.

The Gridcoin greylist is an additional sub-ledger of the Gridcoin network. It serves as an intermediary ledger for projects which might temporarily fail a non-critical technical requirement of the approved list. When such a failure occurs, the project is removed from the approved list and placed on the greylist. If the failure is remedied within the greylist protocol's allotted time the project is removed from the greylist and placed back on the approved list.

GRC is not distributed to participants contributing to projects on the greylist.

The greylist helps ensure fair distribution of GRC to participants actively contributing computation to approved projects. It also serves to lessen the need for removal polls for technical reasons.

This focuses removal polls on the management and merits of the project in question.

Project Share of Network Computation Power

Gridcoin's current system produces an expected 1/n percentage of the network's computation power directed to each approved project, where *n* is equal to the number of approved projects.

This structure is detailed further in the section titled *process-based incentives* (pg. 13).

Project Diversity

Instead of requiring specific computational standardization, Gridcoin incentivizes a diverse array of computation projects through its approval and statistics collection, aggregation, and consensus processes. This greatly reduces the threat of ASIC and currency distribution monopolization in the Gridcoin network. Additionally, the different computational requirements of each project enable greater public participation – each participant has different hardware better suited for different projects. Finally, project diversity combined with the currency distribution structure ensures the continued decentralization of computational power as there is no benefit to pooling computational resources behind a project, or other forms of collaboration among crunchers.

Currency Security

Dividing currency distribution evenly among a diverse array of computation projects means that each project is responsible for only 1/*n* of the GRC distributed to crunchers, where *n* equals the number of approved projects. This, combined with the entirely separate PoS mechanisms means that the network will progress normally should a computational project be compromised. When a project is found to be compromised, it can simply be removed from the approved list without disruption to the greater Gridcoin network. In fact, should all projects somehow be simultaneously compromised, the approved list can be reset and Gridcoin will progress as a standard PoS blockchain.

As the number of approved projects increases, so too does the security of GRC distribution.

The Gridcoin Blockchain and Protocol

Process Details

Blockchain Consensus

Gridcoin utilizes a proof-of-stake algorithm to secure and progress its blockchain. PoS consensus frees participant computing power for contributions to computation projects while ensuring a secure ledger and avoiding the consumption of staggeringly large amounts of electricity to maintain that security.

A detailed overview of the Gridcoin PoS consensus protocol can be found at the link below.

https://gridcoin.us/assets/docs/grc-bluepaper-section-1.pdf

The Gridcoin Oracle and Superblocks

The Gridcoin network must collect user computation statistics from computation projects in order to accurately distribute GRC based on participant computation contributions. The protocol does this automatically once per day. At the end of each collection, the network agrees on the statistics for all active Gridcoin participants. These statistics are recorded on the Gridcoin blockchain in unique blocks called superblocks. The recorded information consists of project names, network average and total contributions, and active beaconholder user CPIDs with their associated magnitude. No private user information is recorded as a part of this process.

The Gridcoin Oracle

Gridcoin implements a unique, decentralized, inbound oracle mechanism and consensus algorithm. A Gridcoin oracle fetches network participant crunching contribution statistics and distributes them across the network. The implementation of this oracle currently serves three additional purposes:

1. To maintain low connection loads to statistics providers' servers
2. To accommodate scaling the statistics collection and processing mechanism to one hundred thousand crunchers or more
3. To enable collection of statistics from GDPR-compliant computation projects

Process Overview

Superblocks

1. **A superblock contains** the officially sanctioned network statistics encoded in the blockchain.
2. **A superblock is due** 24 hours after the previous one is staked.
3. **Superblock staking of the consensus statistics** generally occurs on the first staked block after the superblock is due. Very rarely, due to a delayed consensus, it can take longer.
4. **Oracle nodes and the network retain 48 hours** of filtered statistics from the oracles for cross-checking by the nodes to ensure no corruption by an oracle node occurred and to allow bridging over of short term outages by statistics providers.
5. **Oracle nodes can use username/password authentication** for access to the project statistics if the statistics are not publicly accessible. In these cases,

statistics are only collected from users who have given permission to allow their statistics to be used for this purpose.

Oracle Node and Project Server

1. **The Network Authorized Oracle nodes (currently six) connect** to each project server 4 hours before a superblock is due on a 5 minute cycle.
2. **Statistics files** from all network approved projects are downloaded during the 5 minute cycle by each oracle and are locally cached. The etags (essentially web asset hash) are checked for each statistics provider before the download. Only if the etag has changed or the prior stats have aged beyond the 48 hour window and have been deleted are the statistics downloaded again. This saves an enormous amount of bandwidth. The statistics are then filtered to include only the crunchers with a verified beacon on the network and then compressed before the oracles send the statistics out to the rest of the network. The oracles hash and sign the statistics when they send them out to the network so that all nodes can quickly verify consensus on the statistics.
3. **Consensus on statistics** is attempted/maintained on each node on a five minute cycle, similar to the statistics collection cycle for the oracles.
4. **Superblock staking** will occur by the node that stakes the next block after the superblock is due if that node has determined that the statistics from the Oracles are in consensus. This staked superblock is then verified by every node in the network using the same algorithm for consensus that the staking node used to stake the superblock.
5. **If the staking node cannot verify the oracles are in consensus** then the statistics collection process described above will continue until a consensus can be verified by a staking node and the superblock successfully staked.

A full write-up on this process can be found at the link below.

https://docs.google.com/document/d/1SQEGDPGqnb9as9XUraoLqNn7uTQSrabmHqEXwFaxiGE/edit?usp=sharing

Beacon ID

A Gridcoin beacon is a private/public key pair stored in the Gridcoin wallet where the public key has been linked to one or more of the approved projects via the beacon advertisement and validation process. Since BOINC projects are independent from one another, the BOINC software provides a way to identify the same contributor across projects. This is the

“Cross-Project Identifier” (CPID). Currently, registered beacons associate a contributor’s BOINC CPID with the contributor's beacon public key. Beacons are necessary to track a participant’s magnitude and release the appropriate earned research rewards to the corresponding participant.

Magnitude

The nature of distributed computing and rewarding varying point-accruing systems guarantees confusion among statistics providers. Different statistics providers utilize different hardware and reward contributors using different internal metrics. For example, a sensor project might not measure cycle contributions; a fundraiser doesn’t even use computing; a publication’s impact might be measured by citations or impact certificates.

Magnitude is a Gridcoin-specific statistic assigned to each registered beacon. It creates an internal metric used to measure relative contributions to statistic providers. It is derived through a calculation involving that beacon holder’s contribution to a project relative to all active beacon holders contributing to that same project, the total number of approved projects, and the magnitude-unit. The magnitude-unit is a protocol tool used to control the emission rate of GRC. It is currently hard-coded at 0.25.

Magnitude is also the driver behind a unique process-based incentive structure within Gridcoin.

Distributing Cruncher Earned Research Rewards

Distributing a cruncher’s earned research rewards (ERR) is a resource-intensive task comparable to sending a transaction across the blockchain. The protocol currently handles this task by releasing a participant’s ERR to the staking UTXO signed by the CPID’s beacon private key.

Staking Pools

Prior to the introduction of Manual Reward Claims (2022), the only way for a cruncher to receive their ERR was by staking a block. Following the introduction of CBR (2018), staking difficulty across the network increased by 700% making it impractical for many users to stake a block and receive their ERR. These combined bottlenecks pushed many new users into the already existing staking pools.

A staking pool is a BOINC project manager that tracks its users' contributions across approved projects. The pool itself registers a beacon, stakes a block, and distributes the crunching rewards to the appropriate cruncher, sometimes for a small fee.

Manual Reward Claims

Manual Rewards Claim (MRC) is a form of delegated staking introduced in 2022 through which a cruncher can create an MRC request contract and receive their research rewards without the cruncher themself having to stake a block. It is designed to lower the barrier of entry for new crunchers. MRC makes Gridcoin the first effectively no-cost entry PoS blockchain. Users can crunch approved projects and claim their rewards until they have a staking balance of their own.

Operation

- There is a 14 day minimum between receiving a research reward, whether from a staked block or a previous MRC, and clicking the MRC button.
- There is a fee for using the MRC feature.
- That fee is a percentage of a cruncher's owed rewards.
- If a cruncher claims rewards at 14 days, that fee is 40% of their rewards.
- After 14 days, the fee reduces based on the formula: (40% * 14 / t) where t is equal to the number of days since the cruncher's last received reward.
- 80% of the fee is distributed to the foundation wallet.
- 20% of the fee is distributed to the staker fulfilling the MRC claim.
- Each block can accommodate up to 9 MRC requests, supporting more than 8,000 MRC payments per day network-wide.

Side-Staking

Concept and initial implementation credit: PINK and the Pinkcoin community.

Side-staking enables automated percentage-based splitting and transfer of staking and earned research rewards. This mechanism offers security to major GRC network stakeholders while enabling automated funding of development, initiatives, entities, and businesses, and automated donation to external entities accepting GRC. Side-staking in combination with MRC-fees has initiated a proof of concept for GRC decentralized treasury funding.

Gridcoin adopted and implemented a unique side-staking mechanism based on the concept first implemented by PINK.

https://github.com/gridcoin-community/Gridcoin-Research/pull/1265

Gridcoin Incentives

Gridcoin is a multi-incentive blockchain uniquely capable of incentivizing any leaderboard-style ledger at an emissions level. The network's current and foreseeable incentive focus is on data analysis, science and scientific contributions, research, science participation, and education.

Protocol-based Incentives

The Gridcoin blockchain protocol mints a cryptographically secured cryptocurrency, GRC, and distributes it to participants that perform two tasks:

1. The task of ledger security and progression.
2. The task of contributing computation cycles to approved BOINC projects.

Emissions level distribution of GRC to participants contributing to these tasks drives block creation and incentivizes computation contributions to data analytic research projects.

It is possible that future iterations of Gridcoin will include protocol-based incentives for oracles, or additional network participants.

Process-based Incentives

Gridcoin contains several processes that incentivize distributions of resources, education, participation, and expansion of science literacy and participacy.

Crunching Contribution Distribution

In order to give fair treatment to all approved projects, each approved computation project is assigned an equal portion of total network magnitude. The share of generated GRC corresponding to a project's assigned magnitude is then distributed to its participants based on each participant's computation contribution relative to the project's remaining participants.

This distribution structure monetarily incentivizes a significant portion of network participants to seek the highest individual magnitude by distributing their computation contributions across different projects or by seeking out projects that lack contributors. The end result is a fairly even distribution of Gridcoin's computation power across approved projects regardless of a project's perceived value or marketing capabilities.

Active Education Through the Gridcoin Approval Process

The Gridcoin network offers a significant total amount of computation power to all approved projects. A project is approved through a network poll. A project is more likely to be approved if it can clearly communicate its research, operation, and value to the network at large.

This process encourages projects to develop communication tools and materials that are useful and informative to the general population of the Gridcoin network and not solely for publication.

Passive Education Through the Gridcoin Approval Process

Each project approved by the Gridcoin network adds or detracts value to or from the network based on the project's perceived social impact or contribution to science and its foundations. Incentivizing a project pursuing illegal activities produces a different value than incentivizing a project pursuing a treatment for cancer.

As a result, Gridcoin network participants are incentivized to remain literate and aware of the research, capabilities, and execution of computation projects already approved or seeking network approval. These participants play an active role in ensuring included projects are conducting high-quality research or otherwise align with the value-set of the network. They also have a strong incentive to detect hacking or fraud that might affect their individual rewards.

Passive Education Through Blockchain Principles

A participant with an active stake in a system is more likely to pay attention to that system. In doing so, the participant will learn more about the driving forces of the system.

Democratized systems based on financial technology, such as DLT systems, educate their participants on money, incentives, and monetary policy, protocol, and process.

A democratized system based on financial technology and science, such as Gridcoin, educates its participants on the incentives, policies, protocols, and processes of both money and science.

Gridcoin Values

Gridcoin is an open-source organization with no central decision making authority. While flexibility is required in relationships and partnerships, these base principles must drive ultimate mediation of direction when all other avenues of merit based discussion fail.

Open Source

Gridcoin software is hosted on GitHub under the MIT license. Anyone may access, view, modify, learn from, experiment with, or copy the software. Gridcoin's commitment to open-source software brings several benefits. Since anyone familiar with the programming language (currently C++) may contribute, the software is easily extended, audited, and maintained. This inherent flexibility of open-source means that Gridcoin development can quickly respond to challenges as they arise. Open-source empowers programmers and contributors to recognize issues in the code before they present in production.

Open Data

The data on the blockchain is accessible either through the wallet software or through web-based blockchain explorers. As a global open-ledger system, blockchain technology keeps the data both open and secure.

Gridcoin supports the open publishing of data which in turn allows more people to analyze and otherwise experiment with the data.

Open Access

Access to the Gridcoin network and its services is systematically unrestricted. Network consensus is the only barrier to access of the network's computing services. This permits nearly instant, entirely borderless, censorship resistant transactions between parties.

Gridcoin supports open access to academic publications, as this encourages public engagement with science and open data, consistent with Gridcoin's ideals.

Open Education

The aforementioned open-knowledge principals culminate in open-education. Being an open-source community means that Gridcoin supports the development of Open Education Resources.

A more educated society means a more educated network and more educated contributors from all relevant fields.The current approved distributed-computing platform, BOINC, enables not only massive laboratories, organizations, or research universities to produce projects for discovery, but individuals as well. Gridcoin values this type of open education initiative and whitelists projects of all size and scope.

Decentralized Operation

'A decentralized system is where some decisions by the agents are made without centralized control or processing. An important property of agent systems is the degree of connectivity or connectedness between the agents.'

- Norman L. Johnson

Decentralization solves the single point of failure problem, allows for diversity, larger participation in decision-making, provides equality, and limits encroachment by centralized authorities

Additional Resources

Website and Wallet Software
Website and Wallets
https://gridcoin.us
https://gridcoin.world

Development Repositories
Gridcoin Research Client
http://github.com/gridcoin-community/Gridcoin-Research/

Gridcoin Research Community - For non-wallet based projects
https://github.com/gridcoin-community

Block Explorers
Gridcoin Switzerland
https://gridcoin.ch

Gridcoin.Network
https://gridcoin.network

Gridcoinstats
https://www.gridcoinstats.eu

Social Media
Twitter
https://twitter.com/GridcoinNetwork

Reddit
https://reddit.com/r/gridcoin

Discord
https://discord.gg/jf9XX4a

Facebook
https://www.facebook.com/gridcoins

Telegram
https://t.me/gridcoin