Open Internet Economy

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Abstract

Syntropy is an alternative connectivity layer for the public Internet. It is designed to solve issues prevalent in the current Internet framework, including security, privacy, governance, performance, reliability, and ineffective resource utilization. Syntropy helps address these issues through a combination of a technology architecture that includes blockchain, encryption, and optimized routing, and an economic model that enables and fosters deployment of this architecture. This paper introduces the economics of an overlay network of devices assisting each other in the delivery of a more secure and optimized network path over the public Internet. Syntropy's blockchain-based economy is decentralised, trustless, and secured through its staking mechanism. Staking ensures fairness and rational, sustainable financial value exchange between those sharing and those using spare network bandwidth. A programmable token supply and smart contracts allow for the introduction of various incentivization mechanisms, such as rewards for nodes participating in consensus as well as a reward redistribution pool for network infrastructure nodes. This new open economy model helps to align incentives for all system participants and create a new, valuable interconnectivity layer over the public Internet.

Keywords: Internet, blockchain, utility token, tokenomics, decentralization, SDN, routing, security, networks

1 Current Internet Economy

Over the last four decades, the Internet has organically evolved into a combination of heterogeneous networks managed by different entities [1]. Each network has its own purpose, operating model, physical footprint, topology, routing policies, and corresponding performance characteristics. The current Internet economy is built upon commercial use of existing interconnections. There are two parts to any internet transaction: the content side and the end user or device side. As the Internet has grown in scale and global reach, it is now increasingly likely that the content is connected to one network, while the end device to another[2].

When originally conceived, the Internet design model assumed that "peer" networks would have the incentive to maximize the performance between customers. In reality, Internet Service Providers (ISPs) are forced to minimize costs by employing various tactics in order to compete in a market where transit prices continue to decline 15-30% per year[3].

The demand for Internet Protocol (IP) traffic as well as quality of service (QoS) is increasing at an unprecedented pace. Mobile connectivity, the Internet of Things, 4K streaming, and many more recent trends contribute to an explosive growth of IP traffic each year[1]. Moreover, infrastructure is getting even more complex with new innovations, such as 5G, edge computing, and multi-cloud. Thus, even more optimisations for performance are needed to accommodate the upcoming infrastructure complexity. However, emerging demands for performance and security are hard to meet with networks that are optimised for cost.

Three key factors make the current Internet system inefficient and unreliable:

[1] Formally, these networks are called Autonomous Systems. These are interconnected via Border Gateway Protocol (BGP)[5], which routes traffic by minimizing the number of network hops from the source to destination.

[2] According to Equinix study (`https://www.equinix.se/gxi-report`), global interconnection bandwidth is forecast to grow at 45% CAGR in the next 3 years, which means that two communicating endpoints are increasingly likely to be on different networks.

[3] See [4] for a comprehensive review of tactics employed by ISPs.

1. *Misaligned economic incentives.* Internet service today provides global connectivity but is unable to guarantee the network performance of the connectivity provided. ISPs generally seek to minimize costs and maximize profits. Content providers (CPs) seek to deliver the best end-user experience to maximize revenues and customer retention while minimizing costs, especially for IP transit. Whereas, end-users want the best QoS from both ISPs and CPs for free.

2. *Lack of outbound routing control.* Content providers cannot control how their outbound traffic is routed. As a result, routers typically forward the traffic along congested and suboptimal network paths to the destination, even when better alternative network paths do exist.

3. *Reliance on third-party security.* The Internet's position as a zero-trust network fails to meet the challenges associated with online data sensitivity, increased cybercrime risk, and user inexperience. The vast majority of security solutions are guaranteed by a third party, such as a certificate authority or cloud provider. Consequently, traditional Internet use cases bear the risk of that third party being compromised.

These issues are addressed in this paper by introducing a new type of Internet economy: a globally intelligent routing overlay and blockchain-based payment system that serves as technical pillars for this economy. It incentivizes and draws value from high quality secure connections between end-users and content providers.

2 Open Internet Economy

Bandwidth is the commodity of the Internet. A new Internet economy should allow its participants to create valuable interconnections despite their conflicting goals. These key areas of the Internet have to be upgraded to enable bandwidth sharing[4]:

- infrastructure,
- pricing model, and
- technology.

Infrastructure includes hardware and software deployed across the Internet to perform network connectivity, data transport, security, and management. The existing underlay infrastructure can be utilized better with a value-add interconnectivity overlay implemented with peer-to-peer tunneling. In this overlay network, created with specialised software, bandwidth resources can be shared between all participating nodes.

Pay-per-use pricing is a much better fit for such a system as compared to flat-rate fees that are currently a default pricing model for network services or content subscription. The price of stable connection between source and destination can vary a lot depending on the path length, geography, added benefit versus public internet path, and time of use.

Technology must accommodate dynamic pricing and configurable infrastructure. Open source software is needed for an overlay network with secure communication and outbound routing control. The exchange of bandwidth resources should be performed in a decentralised way using a cryptographic token, as it allows anyone to become a relay node.

A digital token economy is needed to power this overlay, enabling and securing value exchange. Financial mechanisms for aligning goals between all participants is best accomplished with a blockchain-based solution to facilitate scaling. It is a self-sustaining, self-regulated, and open economy based upon democratic principles, where all systemic changes are voted on by all system participants.

3 Syntropy

Syntropy provides a decentralized, open-source solution that implements the bandwidth sharing economy presented above. A device—such as a PC, Raspberry Pi, virtual private server, IoT device, or bare-metal server—can connect into an intelligent, optimizing overlay network (the Syntropy network) and share its bandwidth with other nodes. It is a network connectivity service that provides data routing performance and built-in security as its core services.

The Distributed Autonomous Routing Protocol (DARP) modernizes transport and network layers of the well-known OSI model, as shown in Figure 1. It uses state-of-the-art encryption and routing protocols, such as WireGuard[5] and segment routing[3]. DARP employs an innovative network measurement scheme, globally intelligent path finding, and grants control over outbound traffic.

Syntropy Stack brings innovations to upper lay-

[4] Bandwidth sharing in the context of this paper refers to the relaying of Internet datagrams, or making use of relays for better network performance.

[5] `https://www.wireguard.com/`

ers of the OSI model. It has a wide array of programmable APIs, an SDK, and a friendly UI for simple and easy deployment of endpoints plus agile configuration and continuous optimization of networks.

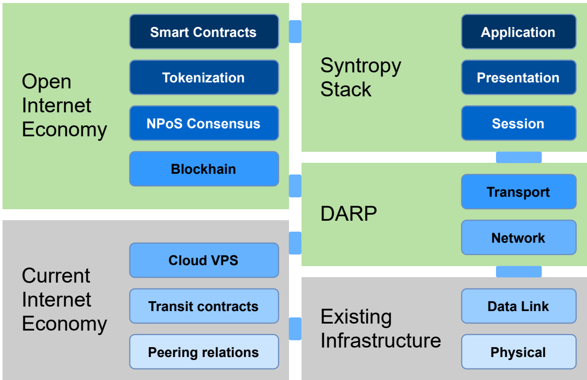

Figure 1: ***Current and new generation of economies and network layers***

To enable the functioning of the overlay, Syntropy introduces an additional layer of economy which directly addresses the problems in today's Internet economy. Incentives for all participants are better aligned due to the tokenization of bandwidth resources. This leads to the creation of high-value connections in a cost-effective way. The payment system is secured by blockchain-based solutions such as Nominated Proof of Stake (NPoS) consensus[6], smart contracts, financial staking, reward redistribution, and inflationary/deflationary mechanisms.

The following sections give more details about each of these components.

3.1 DARP

DARP, developed by Syntropy, allows nodes to connect into a secure, encrypted, and automatically optimised virtual mesh network which acts as an alternative connectivity layer. It is an upgrade to the current system, making the transition from physical to completely virtual network operation and governance. The Syntropy network provides trustless encrypted connectivity and performance services for the vast majority of use cases and applications.

DARP removes third-party security risk that can arise from the use of a certificate or cloud service provider. It establishes user-owned security instead, as all communication is end-to-end encrypted using WireGuard technology. Only the end-points themselves can decrypt their messages.

DARP is designed to address the performance problems inherent to currently used Internet routing protocols. It constructs the smart network intelligence service by optimizing the mesh network to contain only the most stable and best performing connections based on route latency, jitter, packet loss, node uptime, and bandwidth capacity. After connecting to the network, the user can query the system for better alternatives to the public Internet path between source and destination via the Syntropy network and start using them. This overlay network is designed with reliability and performance in mind to serve the specific needs of any application deployed on it.

3.2 Syntropy Stack

Created for the users of the Syntropy network, this technology stack helps to establish secure and globally optimized connections between any two or more machines instantly, scaling connectivity to thousands of endpoints seamlessly. Syntropy Stack advances application development and deployment utilizing end-to-end encryption.

More specifically, Syntropy Stack is a collection of tools and libraries to seamlessly create, automate, scale, and optimize encrypted connections between any devices or services running on a cloud, on-premise, or edge location. It is built for non-professional users, developers, and DevOps alike, enabling them to fully automate the deployment of their applications on the encrypted Syntropy network.

3.3 Blockchain

Decentralization effectively removes barriers to entry as it allows anyone to join the open Internet economy. Tokenization brings a full suite of blockchain-based solutions for constructing additional web services, dApps, and derivative financial instruments to drive adoption of this new economy.

Tokenization enables the exchange of bandwidth resources. Nodes enter into smart-contracts with each other to construct and use stable network paths. Prices are set by nodes sharing their capacity and may depend on the amount of bandwidth required, time of contract, quality delivered, etc. There is an uptime-based reward mechanism for nodes, acting as relays, to support their micro-economy and ensure their reliability at the same time. This is only possible because it can be programmed into a token economy.

Within the Syntropy network, payments and validity of service delivered are confirmed and governed by NPoS consensus. Nodes, who run consensus, receive inflationary rewards for their work.

[6] `https://wiki.polkadot.network/docs/en/learn-consensus`

The financial staking is mandatory for these nodes to secure against possible security breaches. In case of malicious behaviour, stakes are slashed, so it is beneficial for all nodes to act in the best interest of the whole network.

4 Utility

The core of Syntropy's alternative connectivity system is tokenization. The exchange of bandwidth resources is enabled by microtransactions on blockchain and smart contracts. The bandwidth within the Syntropy network has multiple layers of value added by DARP, as shown in Figure 2. Thus, it is easier to make the economy of spare network resources viable: default Internet routes are turned into encrypted and optimised tunnels that can form paths due to the collaborative efforts of the community of nodes.

4.1 Syntropy token

The Syntropy token (called "NOIA" from here forward) is the "gas", which facilitates the value-based economy for this system. All bits of data sent through any device are accounted in tokens. Additionally, it creates the initial financial incentives for this network to be created and then operated by, and for, the user community. The community can invest into the growth of the network via a financial staking mechanism and earn yield depending on the health of the whole system. Hence, the token represents the unit of value derived from an Internet relay and its intrinsic value within the economy.

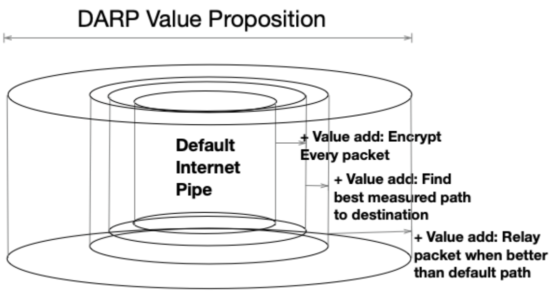

Figure 2: ***Value added by the new economy***

Via smart contracts, Syntropy's token economy enhances the fundamental process of information exchange between endpoints, ultimately accelerating the global digital economy. Transactional system, structured as smart contracts with Proof-of-Bandwidth (PoB) and Proof-of-Uptime (PoU) algorithms, enables bandwidth resource sharing. It also establishes and enhances the transparency and visibility of the fair market price for every network segment, creates incentives for the self-governed economy, and secures it with financial staking.

4.2 Token utilities

A unique digital asset allows the ecosystem to create and redistribute value within its own decentralized economy. The ways this token is utilized can be grouped as follows:

1. User utility:
    (a) transaction fee for network configuration and other computationally demanding tasks;
    (b) the direct means of crediting bandwidth suppliers with tokens from bandwidth users;
2. Network utility:
    (a) governance of the network through NPoS consensus protocol;
    (b) network security through financial staking;
    (c) support measure for network growth.

Syntropy's utility token derives value from the usage of secure and optimised Internet traffic, similar to the way that Ethereum is the "gas" for building blockchain-based products.

5 Tokenomics

This chapter dives deeper into the inner workings of the token economy. We refer to the Polkadot tokenomics model, which is based on Nominated Proof-of-Stake consensus. This serves as a base economy for the governance layer; the existing Polkadot model is extended to support the economy of the Syntropy network.

For the purposes of this paper, we assume the blockchain is built using Substrate[7]. This provides the architecture with a more general blockchain implementation, less dependent on external factors we cannot control[8]. However, the exact implementation may vary and is not in the scope of this paper.

5.1 Base tokenomics model

This section presents the main concepts of the Polkadot model. Whereas, major deviations from it are introduced in the next section.

[7] https://substrate.dev/
[8] One such factor would be winning the Parachain slot on the Polkadot's relay chain.

5.1.1 Consensus protocol

Consensus is a method for coming to agreement over a shared state. In order for the state of the blockchain to continue to build and move forward, all nodes executing the consensus protocol must agree on the same state.

The Syntropy blockchain implements NPoS consensus, a relatively new type of scheme introduced by Polkadot to select the Validators who are allowed to create and agree upon the new shared state of the system.

NPoS is known as hybrid consensus, as there are two separate parts that comprise the consensus protocol: GRANDPA and BABE. Hybrid consensus splits up the finality gadget from the block production mechanism.

BABE (Blind Assignment for Blockchain Extension) is the block production mechanism that runs between the Validator nodes and determines the authors of new blocks. Validators will participate in a lottery in every slot that will tell them whether or not they are the block producer candidate for that slot.

GRANDPA (GHOST-based Recursive Ancestor Deriving Prefix Agreement) is the finality gadget that is implemented for the Polkadot Relay Chain. In a nutshell, as soon as more than 2/3 of Validators attest to a chain containing a certain block, all blocks leading up to that one are finalized at once.

5.1.2 Validators

Several times per day, the consensus mechanism elects a group of entities called Validators. Validators play a critical role in protocol[9], such as block production and the finality gadget. New Validators are elected every few hours.

Validators need to ensure high communication responsiveness, and build a long-term reputation of reliability. They also must stake their tokens, as a guarantee of good behavior. The stake is slashed whenever the deviation from the protocol is found. In contrast, they get paid well when they play by the rules. Any node can offer itself as a Validator candidate. However, for technical and operational reasons only a fixed number of Validators can be elected each cycle.

Validator role includes:

- Staking tokens;
- Performing computational validation on on the network and producing blocks based on that information;
- Finalizing blocks;
- Earning interest rate on the tokens bounded to it by Nominators and sharing a part of these rewards with their Nominators;
- Collecting transaction fees.

Validators earn small amounts of NOIA tokens for every transaction performed on a blockchain, such as creating digital entries about Clients and Relays on blockchain, creating end-to-end secure tunnels for relaying the data, and configuring network paths for that data to travel.

Computationally intensive tasks evaluating the correctness of the network interconnectivity are performed by Validators during the block formation. These tasks include:

- Proof-of-Uptime validation
- Proof-of-Bandwidth validation
- Health-score and reward calculation for Relay nodes

It would be infeasible and unsafe to keep all the raw network metrics on-chain, thus a decentralized storage solution, such as IPFS[10], can be used or Validators can additionally act as storage nodes.

5.1.3 Nominators

Syntropy encourages any token holder to participate as a Nominator. As in Polkadot, a Nominator subscribes to a list of Validator candidates that they trust[11]. This trust is expressed as tokens at stake to support them with. If such a candidate is elected as actual Validator, it shares both the rewards and the sanctions with the Nominators, who have bound their stakes to it, proportionally to their staked tokens.

Nominator role includes:

- Staking tokens;
- Binding staked tokens to up to 16 Validators;
- Earning interest rate on the tokens bound to Validators.

There can be any number of Nominators. However, as long as Nominators are diligent in choosing which Validators to support, their role carries low risk and provides a continuous source of revenue.

[9] https://wiki.polkadot.network/docs/en/learn-validator
[10] https://ipfs.io/
[11] https://wiki.polkadot.network/docs/en/learn-nominator

5.1.4 Transaction fees

Tokenomics of Syntropy's governance layer are based upon that of Polkadot. There are 3 major components:

- transaction fees;
- inflation (block rewards);
- the Treasury.

Transaction fees on the Polkadot relay chain[12] are calculated based on three parameters:

- a per-byte fee (also known as the "length fee");
- a weight fee;
- a tip (optional).

The length fee is the product of a constant per-byte fee and the size of the transaction in bytes.

Weights are a fixed number designed to standardize the time it takes to validate a block. Each transaction has a base weight that accounts for the overhead of inclusion (e.g. signature verification) as well as a dispatch weight that accounts for the time to execute the transaction. The total weight is multiplied by a per-weight fee to calculate the transaction's weight fee.

Tips are an optional transaction fee that users can add to give a transaction higher priority.

Together, these three fees constitute the inclusion fee. This fee is deducted from the sender's account prior to transaction execution. In Syntropy, a 100% of the fee will go to the block producer. So, no remainder will go to the Treasury.

5.1.5 Inflation and Treasury

Polkadot's token supply is inflationary, i.e. there is no maximum number of DOT coins as in Bitcoin. In Polkadot, Inflation is designed to be 10% in the first year, with Validator rewards being a function of amount staked and the remainder going to treasury. In Syntropy, we lower the inflation rate to 5%, as discussed below.

Depending on the staking participation, the distribution of the inflation rewards to Validators/Nominators versus the treasury will change dynamically to provide incentives to participate (or not participate) in staking. For instance, all of the inflation would go to the Validators/Nominators if 50% of all token supply is staked[13], but any deviation from the 50%—positive or negative—sends the proportional remainder to the treasury and effectively reduces staking rewards.

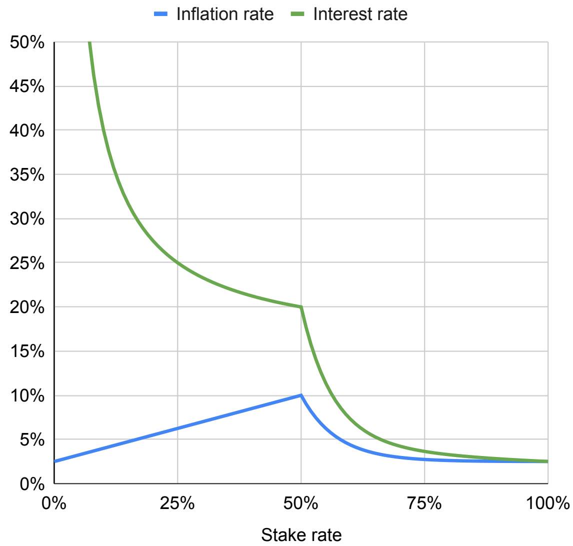

Figure 3: ***Inflation rate and interest rate as a function of stake rate targeted by Polkadot***

The Treasury[14] is a pot of funds collected through transaction fees, slashing, staking inefficiencies, etc. The funds held in the Treasury can be spent by making a spending proposal that, if approved by the Sytnropy Council[15], will enter a waiting period before distribution.

5.2 Extended tokenomics model

While the Syntropy Blockchain tokenomics is based on that of Polkadot, we also need to account for Syntropy's unique features. There are three major points where the tokenomics between the two chains will differ:

- optimal stake rate;
- inflation;
- additional utility layer with its participants and their economy.

5.2.1 Optimal stake rate

Optimal stake rate is the share of tokens relative to the initial total token supply, at which the inflation paid out to Validators is maximised. Polkadot sets this rate at 50%, based on assumptions[16] for:

[12] https://wiki.polkadot.network/docs/en/learn-transaction-fees
[13] https://wiki.polkadot.network/docs/en/learn-staking
[14] https://wiki.polkadot.network/docs/en/learn-treasury
[15] https://wiki.polkadot.network/docs/en/learn-governance#Council
[16] https://w3f-research.readthedocs.io/en/latest/polkadot/overview/2-token-economics.html#introduction

- 50% of tokens locked in staking;
- 30% of tokens locked for parachain slots.

As a reference, the percentage staked in other PoS-based projects is as follows[17]:

- Tezos is 77.93% staked;
- DASH is 47.04% staked;
- Lisk is 51.39% staked;
- EOS is 46.29% staked (note, that it implements Delegated PoS).

In the case of Syntropy, we currently do not have tokens locked for parachain slots, but we do have a Reward pool (RP), which de-facto also takes tokens out of circulation. Since RP is an important economy balancing mechanism (as explained in a dedicated section below), we have opted to give it a more prominent role in determining the system's inflation. The staking target for Syntropy remains at 50%, while the funds locked in the RP will count as "staked" funds for the purposes of determining the final inflation rate.

The implications of the above are:

1. Upon system launch, 15% of the tokens will be in the pool, which means that the consensus members will need to only stake an additional 35% of all tokens to reach optimal inflation.
2. If the RP is at its optimal intended level of 15%, the staking requirements would be identical to those of Polkadot at 35%.
3. As the RP expands, the optimal staking requirement for other network participants is reduced and vice versa.

Note, that optimal level of RP is lower than upon system launch. We expect net inflow to RP to be negative when the economy is still young. These outflows will support relay nodes in the early phases of the system.

5.2.2 Inflation

Inflation rate is a result of targeting the optimal interest rate on staked funds. Within the Polkadot model, optimal interest rate is set at 20%. The relationship between staking, inflation, and interest rates is as follows:

$$InflationRate = StakeRate \times InterestRate \quad (1)$$

[17] All data as of 2021-04-28.

or:

$$I = S \times Y \quad (2)$$

The targeting mechanism includes base inflation, which is 2.5% in Polkadot. The relationship for the part of the curve, when the stake rate is lower than optimal is linear and given by:

$$I_{Actual} = I_{Base} + S_{Actual} \times (Y_{Target} - \frac{I_{Base}}{S_{Target}}) \quad (3)$$

For the part above optimal stake rate, additional security from staking has a decreasing marginal benefit, thus incentives are reduced rapidly. The relationship is given by:

$$I_{Actual} = I_{Base} + (Y_{Target} \times S_{Target} - I_{Base}) \times \times 2^{\frac{S_{Target} - S_{Actual}}{DecayRate}} \quad (4)$$

The above relations result in inflation rate and interest rate (or yield) curves given in Figure 3. However, taking into account tokens accumulated in the Reward pool as staked tokens increases the interest rate paid to nodes running the consensus. The actual interest rate earned by these nodes is shown in Figure 4.

Normally, 5% inflation at 50% staking would result in 10% interest rate. However, since RP is expected to contribute 15% to the staking ratio, the inflationary tokens created will result in a higher flat interest rate of 14.3% paid to the Validators, who in-turn also share these returns with their Nominators.

Regarding Syntropy token economy, we believe that:

- The yield, which consensus members gain, should not be solely based on a flat interest rate on the staked amount, but it should also take into account possible capital gains and transaction fees.
- Overly high inflation has a negative effect on capital gains.

Based on the above, the target initial inflation rate for Syntropy will be set to 5% (similar to Ethereum and EOS at launch), with the option of it being further reduced down the line via a governance vote.

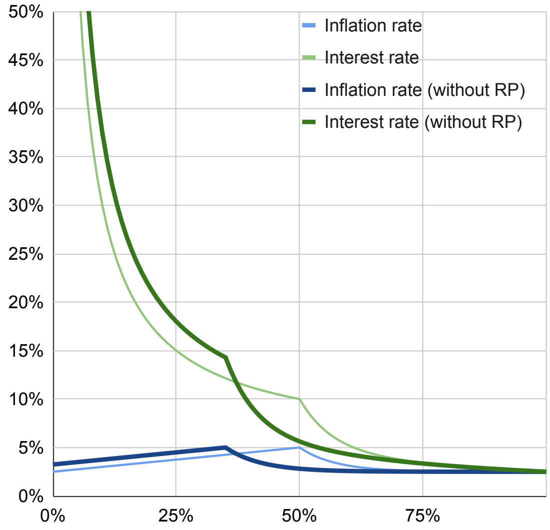

Figure 4: ***Syntropy's inflation rate as a function on stake rate and interest rate received by nodes (assuming 15% tokens in the Reward pool)***

Additionally, yield is increased by all transaction fees earned by Validators, as well as Nominators, given their stakes are bound to Validators and they receive a share of rewards set by Validators. We are maximizing this dynamic part of the yield, by allowing Validators to earn 100% of transaction fees.

Due to the nature of Syntropy network interconnections being controlled by algorithms within DARP, we expect that a significant amount of transaction fees are collected, which in turn increases yields for the governance layer nodes. Within the Syntropy network, every new node configuration, route configuration and network path configuration requires a microtransaction on the blockchain, so the amount of fees collected is positively dependent on the network size. We assume that any given time, each Syntropy network node, Relay or Client, will hold hundreds of configured routes to other nodes. Some of these routes will be occasionally reconfigured into better ones to boost the value created by the interconnectivity.

5.2.3 Relays

Relay nodes participate in the DARP network and can route data packets within it. Their role includes:

- Running DARP to securely interconnect with other Relays and Clients;
- Finding paths on Syntropy network;
- Relaying data through the Syntropy network and earning data relaying income;
- Running Proof-of-Uptime (PoU) and earning uptime-based rewards from Reward pool;
- Running Proof-of-Bandwidth (PoB) to withdraw data relaying income;
- Staking tokens for additional benefits and security.

Relays interconnect by executing DARP—a self-organization protocol, which is based on the objective to find the most valuable neighbours for each and every Relay node.

DARP is a transport layer protocol. Traffic within the Syntropy network is DDoS-resistant, because the WireGuard protocol silently drops unauthenticated packets at the kernel layer. Authenticated packets are allowed to traverse the forwarding plane and are paid for in tokens for the amount of data forwarded.

Relay nodes connect with Clients, who consume the network services by Relays. Relays find paths by running the decentralised path discovery algorithm and can route the data through these paths.

Relays are running PoU protocol, which is designed to incentivize them to stay connected to the network as long as possible.

While performing data routing, they must run PoB protocol, which ensures that Relays are fairly rewarded for their work. The rewards that Relays earn are accumulated in a special smart contract. The lump sum of tokens can be withdrawn on demand only by this Relay.

It is recommended for Relays to stake[18], i.e. to perform both roles: utility layer node as well as governance layer node. By staking as a Validator or Nominator, a functioning Relay node increases its reward. More importantly, the inflationary token supply means that those nodes, who do not stake, are slowly losing the value of their token holdings.

5.2.4 Clients

Clients are nodes that consume the network services. Every Relay can also be a Client. A Client runs an algorithm allowing it to connect to a well distributed set of Relays in order to gain access to the large part of the Syntropy network, which results in better paths found for this Client.

A Client can purchase the optimized routing paths through the network, by depositing enough tokens for the intended amount of traffic within a special smart contract. Afterwards, a Client can search and configure optimal paths to other Clients,

[18] In order to secure the protocol, a minimum stake amount for Relay nodes can be introduced. This will be detailed in a separate white paper.

usually controlled by the same user, by sending path-finding requests to Relays. To prevent flooding attacks, there is a minimum required amount of tokens for deposit in the escrow. Finally, after paths are found, Clients send traffic forwarding requests to the Syntropy network that are handled by Relays.

Client participates in the PoB by reporting the hash info of the data that was sent and received through the Syntropy network.

5.2.5 Fees

There are several different operations nodes can execute on blockchain that have token-based fees attached. Some are fixed within the system, some are decided by organizing an auction, so price is negotiated between the buyer and seller of the service.

Network configuration fee. The cost attached to setting up of a fully functional node ensures that there is a financial burden to even start a Sybil attack.

Route configuration fee. Every connection, which is configured for two way routing, is priced so that nodes only enter into valuable relationships. There is a balance of tokens each node has to dedicate for configuring routes with other nodes.

Path configuration fee and data relaying price. A Client can purchase the data routing service by bidding a specific amount of tokens per standard data unit (e.g. Gigabyte) and also indicating the amount of data units it wants to be able to route through the Syntropy network. Conversely, Relays are asking for certain data routing prices that are economically feasible for them to perform as routers. Path configuration fee is charged once the path is agreed upon and configured for routing.

A Client deposits necessary funds in the smart contract similar to escrow account, also indicating the maximum price it is willing to pay for relaying the data, similar to gas price in Ethereum. Consequently, data relaying can commence until the funds are depleted by the amount of data that was relayed via nodes running DARP on the Syntropy network. This deposit may have a time limit, thus, the unused balance is returned to the Client.

The data routing service deposit has a preset minimum amount of tokens. This is required to protect DARP and the decentralised path discovery algorithm from spamming attacks.

Smart contracts. Any type of interaction with smart contracts, e.g. redeeming the reward form the Reward pool, involving Syntropy token will require a small transaction fee.

5.2.6 Data relaying income

Income from data relaying service is the main source of income for every Relay node. The node's ability to decide the transmission price on its own makes its individual economy flexible. Nodes with lower throughput capacity and lower cost will be offering lower prices and vice versa. Supply and demand on this free market will regulate the prices for data routing.

An additional premium of 10% will be imposed on every data routing price offered by Relay nodes. This premium will be used to fund the Reward pool, which redistributes wealth among the nodes. Well-established Relays support newcomers, which is beneficial for everyone, as the more nodes participate within the system, the more valuable interconnections can be found.

When a Client pays a specific amount of NOIA tokens for the Gigabyte of data, 90% of this payment is shared among the Relays who have performed the actual relaying of Client's data. Whereas, the remaining 10% of Client's payment is directed towards the Reward pool.

5.2.7 Relay evaluation

Every route on the Syntropy network is represented by a health-score multiplier. A route is a bidirectional WireGuard connection with the following metrics:

1. One-way latency;
2. Uptime of each of the nodes forming a route;
3. Median jitter of the route;
4. Median bandwidth of the route;
5. Average packet-loss of the route;
6. Actual usage of this route (a sum of bytes routed both ways).

Route's *health-score multiplier* is a derivative metric describing the health of the route between two nodes. It is a weighted average of all the above metrics, where weights describe the importance of each of these. The exact weighting, which results in a stable network topology requires further research that can only be done within a test-net environment. The health-score multiplier of the route between nodes i and j is given by:

$$\begin{aligned} multiplier_{ij} = w_U uptime_i + w_U uptime_i + \\ + w_J h(jitter_{ij}) + w_B bandwidth_{ij} + \\ + w_L g(packetLoss_{ij}) + w_T throughput_{ij} \end{aligned} \quad (5)$$

In the above, h and g are functions for inverting the jitter and packet-loss metrics. The higher the uptime, bandwidth and throughput, the larger is the health-score multiplier. However, the opposite effect is required for jitter and packet-loss, as we want them as low as possible. So the lowest values of jitter and packet-loss should contribute to the multiplier the most. To achieve this effect, they must be inverted.

Relay's *health-score* is a metric describing the usefulness of that node within the system. It is a weighted sum of the average of its routes' health-score multipliers. The health-score for node i is then given by:

$$health_i = C_j \sum_j^J multiplier_{ij}, \tag{6}$$

where J is the total number of routing neighbours node j has. C_j denotes the convergence criteria individual for every node, as it depends on the time node has spent in the system. New nodes have large convergence, as it is harder for them to compete with well-established nodes. With time, it drops down to $1/N$, where N is the maximum allowed connections per relay node, hard-coded within DARP.

Node's *reward multiplier* is a normalized version of its health-score adjusted by the share of node's stake in the total amount of tokens staked. Reward multiplier is used to calculate the exact reward attributed to a node, as it represents the fraction of the daily portion reward pool payable to that node:

$$\overline{health_i} = health_i + w_S \frac{stake_i}{\sum_z^Z stake_z} \tag{7}$$

$$reward_i = \frac{\overline{health_i}}{\sum_z^Z \overline{health_z}} \tag{8}$$

Weight w_S regulates the importance of staking as compared to being a healthy node. We don't want nodes to be able to "buy" their health, so this weight should not give more significance to stake as compared to actual health coming from multipliers. Note, that a Relay is not required to stake. However, if it does stake a minimum required amount tokens and in doing so also performs the role of Nominator, its stake counts towards better reward for that Relay, as it is financially bound to the system and less likely to underperform.

5.2.8 Reward pool

The Reward pool (RP) is an incentive redistribution mechanism within the Syntropy network. Relay nodes get the majority of their income based on the amount of traffic that they actually relay. Nevertheless, the economy needs a mechanism to ensure the wealth is well distributed and even newer nodes with lower workload have enough incentives to keep participating in the system. The initial size of the reward pool is set to 15% of all NOIA tokens (or 150 million tokens).

To facilitate this, a Reward pool is established which collects 10% of value from all data relay transactions within the network and re-distributes this value among all network participants. This re-distribution is done by splitting 0.1% of the RP, on a daily basis, between all participants, based on their reward multiplier.

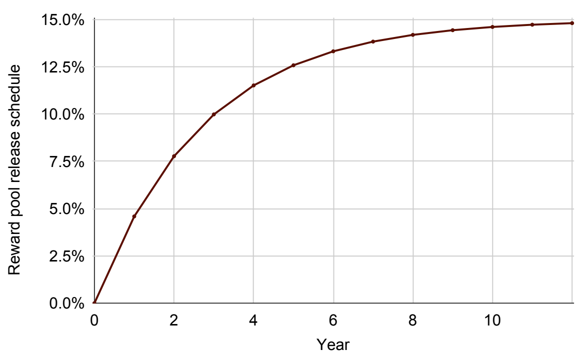

Figure 5: ***An example of the reward pool release schedule as a percentage of total supply, assuming no fees collected.***

The 0.1% daily distribution is based on the outstanding tokens in the Reward pool, which de-facto means that the RP is perpetual: it can never be depleted, since the reward is always a fraction of the remaining token balance. This serves several purposes:

- During times of heavy network usage, the Reward pool will fill up, and network participants will receive higher rewards.
- During times of low network usage, there will still be incentives for network participants to continue their functions.
- As the network load stabilizes, this mechanic ensures that the rewards will also stabilize, since the system will eventually reach an equilibrium point where the fees collected will be equal to the fees re-distributed.

As shown in Figure 5, under extreme conditions (no fees collected at all), it would take two years for the daily reward to halve and three years in order for it to become 1/3 of the original.

It is possible to introduce an inflationary mechanism to refill the reward pool in case the daily

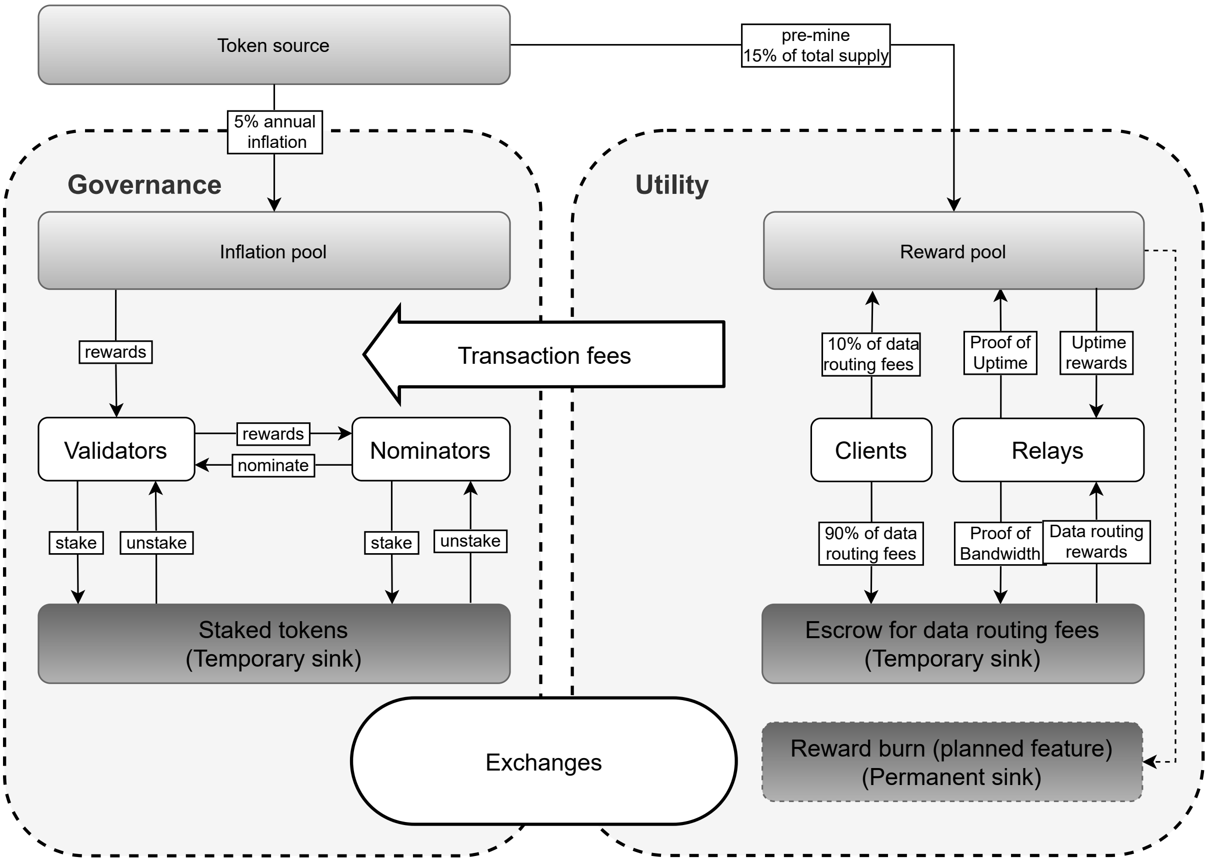

Figure 6: ***Token flow***

inflow resulting from the bandwidth sharing economy is too low. However, due to our commitment to keep the inflation low, we leave this as a possible proposal only. The complete token flow is visualized in Figure 6.

5.2.9 Token supply sinks

Both Validators and Nominators are required to stake in order to earn inflationary rewards. Staking creates the largest temporary sink of token supply in the economy. Tokens are taken out of circulation for a prolonged period of time. Such a supply sink makes the token value more stable.

Clients are paying for data routing. However this happens through a special escrow account, which holds the tokens paid in-advance for some preset periods of time, until they are redeemed by Relays who have routed the data. This escrow account is the second temporary sink, as it locks away payments for some time.

A third temporary sink is a Reward pool, created for remunerating all Relays for their uptime. This is especially helpful for new entrants into the Relay economy, who can't earn enough data routing income. RP has a significant part of circulating supply reserved for uptime rewards. Uptime rewards are assigned each day, but redeemed only when a Relay demands it.

All these supply sink mechanisms not only secure the economy from various types of attacks, but also reduce token velocity, since the average token holding time (H) is inversely related to the velocity (V) of the medium of exchange token[2]:

$$V = \frac{1}{H} \tag{9}$$

Long term inflationary effects, especially with compounding, may lead to excessive token supply, which is not matched by the demand. In the future, a permanent sink might be introduced. A fixed percentage of the rewards collected into RP can be burned[19]. Burning would reduce the token supply created with inflation and bring down the circulating supply to a stable level, supported by demand within the bandwidth sharing economy.

[19]Ethereum has introduced deflationary burning mechanism in its EIP-1559 proposal as a way to bring natural scarcity to the system `https://github.com/ethereum/EIPs/blob/master/EIPS/eip-1559.md`

5.2.10 Economy equilibrium

The most important equilibrium point to consider is the potential token value loss due to inflation. New token supply created through inflationary rewards should be offset by additional demand for tokens in the economy.

With 1 billion tokens of supply, and 5% annual inflation, there should be an additional 50 million tokens in transaction volume per year. In such an economy, this boils down to 137k tokens in transaction volume per day. Otherwise, a burning of collected transaction fees could be introduced, as detailed in the previous section.

To keep the Reward pool balanced, daily inflow amount (F) should be between minimum constraint, that would result in continuous decrease of the RP, and maximum constraint, that would theoretically result in all tokens being in RP:

$$M \times d \geq F \geq M \times I \times d \tag{10}$$

Here d is the percentage daily distribution from the Reward pool, which we have set to 0.1%. Analyzing the lower constraint will give us the number of tokens that need to be transacted per day to keep the reward pool stable.

$$t_{RP} = \frac{M \times I \times d}{r_{RP}} \tag{11}$$

The r_{RP} denotes target percentage of total token supply always present within RP. Plugging in r_{RP} set before to 10% together with other constants results in a requirement of 0.5 million tokens in bandwidth transactions each day. This is a long-term goal, this is why the initial RP size is set at a higher 15%. These additional 5% are subsidies that are meant to support the growth of the Syntropy network when the value of bandwidth transactions is not sustainable yet.

5.3 Token utility summary

In this paper, we have introduced the following utilities of the NOIA token:

Governance layer:

1. *Governing the economy through the Nominated Proof-of-Stake consensus.* Inflationary supply model created by the Polkadot stabilizes the governance layer by increasing or decreasing the inflation level based on the stake rate of circulating supply. Nodes are willing to stake in order to get a stable yield.

2. *Securing the economy by financial staking.* At the same time, staking ensures the security of the blockchain asstakes are slashed for malicious behaviour. With staking yield, all participants are incentivized to perform to the best of their efforts.

Utility layer:

1. *Providing the means to exchange utility tokens for using the network services.* Clients are provided with easy-to-use decentralised service for creating and managing networks as well as routing their data securely and in an optimized way. Nodes, who perform data relaying, are fairly rewarded for this work.

2. *Providing payment fees for all blockchain transactions.* Validators earn a small commission for their work on all blockchain transactions. Transactions related to DARP, such as node, route and path configuration, allow nodes to securely connect to the Syntropy network and use it for bandwidth exchange.

3. *Supporting the growth of Syntropy network infrastructure.* No software defined network can exist without a backbone of servers. A fixed remuneration incentive, presented in the paper as the Reward pool with initial subsidies, fosters easier adoption of the DARP network. Relay nodes who cannot earn significant returns from data routing are still getting rewards for their uptime. This should cover server maintenance costs and keep them connected to the network, thus, effectively lowering the barriers of entry into the Syntropy network for any server and making it stable at the same time.

6 Conclusion

This paper primarily addressed the security and performance problems of locally optimized routing as well as misaligned economic incentives. It introduced an overlay network on top of existing infrastructure, which delivers globally optimized and secure routing. The functioning of this overlay is enabled by the digital token economy, which aligns incentives for all participants.

This paper presented a theoretical economy model based on the Polkadot economy model and extended it with several features, such as a Relay node economy and reward pool incentivization mechanism. Syntropy's token economy helps to provide and sustain access to the globally optimized and publicly open network of nodes for relaying internet traffic, which was not possible before. Further research is needed to validate the best possible implementation of this economic model.

Within the digital token economy, all key players—ISPs, CPs, and end-users—can maximize their value gain by acting as Relays, using this overlay network to route their traffic, participating in the consensus as Validators, investing in the system through the stake nomination mechanism as Nominators, or any combination of the above roles. With Syntropy, the tokenization of a bandwidth sharing economy allows the creation of high-value interconnectivity between different networks.

This alternate connectivity system is designed to be governed in a decentralized way. Safeguarding micro-payments for connectivity and routing with NPoS consensus, smart contracts, and built-in inflationary reward mechanisms paves a way to create the first decentralized autonomous organization (DAO) for Internet connectivity.

References

[1] Cisco Annual Internet Report (2018–2023) White Paper. Technical report, March 2020. `https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html` (visited 2021-04-27).

[2] Vitalik Buterin. On Medium-of-Exchange Token Valuations. `https://vitalik.ca/general/2017/10/17/moe.html`, 2017. Accessed: 2019-06-25.

[3] Clarence Filsfils, Stefano Previdi, Les Ginsberg, Bruno Decraene, Stephane Litkowski, and Rob Shakir. Segment routing architecture. Technical Report RFC-8402, IETF, July 2018.

[4] William B. Norton. *The Internet Peering Playbook*. Amazon.com, 2014. Parts available online at `http://drpeering.org/HTML_IPP/ipptoc.html` (visited 2021-04-27).

[5] Y. Rekhter and T. Li. A Border Gateway Protocol 4 (BGP-4). Technical Report RFC-1654, IETF, July 1994.

7 Disclaimer

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The author developed the document based on an evaluation method generally accepted by the cryptocurrency community (quantity theory of money and discounted cash flow analysis) and relies on a generally accepted school of economic thought (monetarist school of economics). It is important to note that the blockchain and cryptocurrency area is still very new. There is little to no historical data, past performance result and academic research on the topic of cryptocurrencies, let alone on the tokenization, economics and long term valuation of those asset classes.

Furthermore, the current model relies on several assumptions, forecasts and requirements explicitly specified by the company behind the token offering. As such, this model is only as good as those assumptions are. Any significant deviation from the input numbers would subsequently impact the outputs of this model. The model presented here aims to provide a fair token price valuation based on the merits of the business behind it (as far as they are known/estimated at the time of the creation of this model) and cannot account for any possible speculative actions and market manipulation by any party as well as for irrational market behaviour.

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