Token economics of Decentralized Physical Infrastructure networks - Part II: the cost of supply

***Abstract*—DePINs (Decentralized Physical Infrastructure Networks) are decentralized networks of nodes providing hardware resources for a wide range of use cases like compute, wireless networks, or data measurement. In a series of articles we aim to understand how these networks design their policies and mechanisms around the economics of their flywheels, i.e. the incentivization of supply needed to attract usage and adoption which will eventually lead to the generation of income for the network helping then to further scale the supply and the network as a whole. Our first part focused on reward emissions and incentivization. Observing monthly emissions worth millions of dollars across the different mechanisms raised the question: „what level of incentivization is adequate?"As this leads to the consideration of the profitability of node operators, understanding the cost base of the supply side is fundamental to this question, which we want to analyze here as first step. Due to the decentralized nature of those networks and its contributors this is not trivial. We present a framework to understand and estimate the cost components and provide examples across variety of use cases.**

***Index Terms*—tokenomics, depin, web3 infrasturcture, cost**

I. Introduction

DePINs are networks of nodes providing hardware resources for a wide range of use cases like compute, storage, wireless networks or data indexing. Following [1] and [2], we can classify the DePIN networks into two broad categories:

- **Physial resource networks (PRNs)**
  - Wireless networks, e.g. Helium [3], XNET [4]
  - Sensor networks, e.g. Dimo [5], Hivemapper [6], Silencio [7], Onocoy [8]
  - Energy networks, e.g. Akreen [9], Starpower [10]
- **Digital resource networks (DRNs)**
  - Compute, e.g. Dfinity [11], Livepeer [12], Akash [13], Pocket network [14]
  - Storage, e.g. Filecoin [15], Arweave [16]
  - Bandwidth, e.g. Orchid [17], Mysterium [18]
  - AI, e.g. Bittensor [19], Modulus Labs [20]

In the first part of our analysis [21] we discussed the different incentive mechanisms of various DePINs and analysed the data of their reward emission schedules. Observing substantial amounts of millions of dollars of monthly rewards emitted, we asked ourselves how those emissions relate to the profitability and hence cost of operations. Only very few networks incorporate any data to the cost base of their contributors into their reward structure (e.g. Dfinity or NYM [22]). Hence, we aim to provide a framework for a structured estimate of the dollar-based costs for DePIN supply-side contributors and the networks as a whole with global assumptions when data points of the costs are not available. We are well aware, that the output will be a mere indication. The main purpose is to provide a framework that helps understanding the cost structures at a fixed point in time. Together with the ability to adjust e.g. assumptions and inputs on the cost estimates, we will get those indications around the cost base, their sensitivities to made assumptions, proposed changes in the settings of economic parameters or to assess how those relate to the emitted rewards, incentives and overall income which will be part of further analysis.

The paper is structured as follows: In section III we provide definitions of the roles of the supply side of DePINs and different economical terms related to costs. Section IV explains the three dimensions forming the structure of the framework, which is explained in section V. We focus on DePIN specific aspects for the assessment of cost components. An in-depth example on that for the Pocket network is provided in VI, yet we provide to links to the same analysis for Livepeer, Helium and other networks.

II. Related research

Existing literature on the costs and economics of DePINs focuses on the structural advantages that DePINs have over established, centralized infrastructure providers. According to [23] those are i) cost-effectiveness of maintenance due to shared workload and site occupation costs related to the decentralized setup, ii) Economies of scale due to crowdsourcing, and in general reduction of labor costs, operational costs and others, iii) improved unit economics due to utilization of idle resources, e.g. on storage and compute. Similar advantages are listed on [1]. These advantages are often assessed on a case-by-case basis, e.g. [24] acknowledges the potential benefits but adds a critical view if this will be enough to compete with established, centralized providers. Research more specific on cost components is yet either focused on blockchain networks, e.g. [25] identified cost of verification and cost of networking as the two key components, or on general web3 operations, as e.g. [26] provides a framework to assess the costs of general web3 operations.

III. Definitions

The supply-side roles of DePINs (as presented in our first part [21], but see also [27]) are:

- **Service nodes/producer:** provide the service DePINs offer (e.g. compute, measurement data) and its required physical infrastructure (e.g. server, antenna, dashcam)
- **User/consumer:** request the service, directly or via gateways as coordinator in between user and service node.

- **Payer:** sometimes the end-user does not (directly) pay for this service themselves (e.g. when a dApp integrates with the network and covers its fees).
- **Validators/ watcher nodes/ fishermen**[1]**:** These nodes check the work done by service nodes, either directly or via the accounting layer. The result of those checks is sent to the accounting layer.
- **The accounting layer:** refers to the blockchain (with potentially separate validators). It tracks the flow and status of work/services provided and corresponding payments. There are two parts:
  - The settlement layer (a public L1 like Ethereum, a sovereign L1 (i.e. run/owned by the network), a public L2 or a „sovereign L2“, i.e. an App-chain)
  - The accounting logic, which defines how work and payments are tracked and stored on the blockchain
- **Gateway:** functions as coordinator between users, service nodes, and the accounting layer when it comes to managing access or aggregating services[2].
- **Delegators:** can participate in the economies of service - or watcher nodes via staking.

These roles are in line with the more holistic taxonomy of DePINs presented in [28][3]. User/consumer and payer form the demand-side of the network, hence all remaining roles are agggregated as supply-side roles. Not every DePIN has all roles present nor do all roles need to be separated, e.g. for some networks service nodes also fulfill the validator role. We provide a detailed overview of almost 50 DePINs and their roles in [27]. We do not consider Governance related activities as supply-side role and hence do not include related costs.

a) CAPEX and OPEX: **Capital expenditures (CAPEX)** refers to the funds used to acquire physical assets such as property, technology, or equipment [29]. Whilst these are one-time investments, **operational expenditures (OPEX)** are spent for day-to-day activities to run the business[4].

b) Fixed and variable costs: **Fixed costs** do not change with an increase or decrease in the amount of service provided [30] whilst **variable costs** do.

c) Network capacity: This distinction raises the question of how we define the amount of service provided. This **network capacity** is network specific and an input to our framework. This can be more than a single variable. Section VI will provide examples for this consideration.

d) Economies of scale: refers to cost advantages businesses obtain due to the size of their operations [31].

e) Sharing economy: DePIN network are well positioned to realize the benefits from the **sharing economy** [32]: allowing the sharing of goods and services, ensuring security, and direct compensation without intermediaries, as blockchains replace those intermediaries present in current sharing economies (e.g. Uber, Airbnb)[5].

f) Capital cost: is the required rate of return on a company's existing securities [33]. We do not intent to examine the cost of equity and debt for supply-side node operators, since: 1) this data is hardly accessible and 2) we want to provide a general framework that focuses on the costs of the provided infrastructure rather than differences and impacts of accounting and credit market conditions.

IV. Dimensions for Cost Estimation

The cost structure of supply-side roles can be broken down into different cost components like hardware- or labor costs. These two aspects define *what* costs we like to estimate. A third dimension focuses on *how*, i.e. we need to assess if the cost structures are the same e.g. for all service nodes, or to which extent some participants benefit e.g. from economies of scale (see III). These are the three dimensions for our cost estimation framework[6]:

1) Supply side roles
2) Cost components
3) Homogeneity of those costs

A. Supply side roles

A first step in assessing the cost for a network's supply-side is to break it down into the different roles. This can be achieved consulting public documentations like whitepapers. Examples for those are provided in [27]. Note that sometimes network users can be the bearer of costs as well, e.g. when networks use a public settlement layer (e.g. Ethereum) users or supply-side nodes pay the gas fees related to transactions they initiate (e.g. to claim rewards). Our framework accounts for that by attributing the transaction costs on public blockchains to the accounting layer costs[7].

B. Cost components

Analyzing the supply side roles in the current DePIN landscape of over 650 networks[8], we identified four common cost components:

1) Hardware/infrastructure
2) Labor
3) Bandwidth, power and other OPEX
4) (opportunity) cost of staking

[1]There are even further names for this role (e.g. oversight node, snitch node), yet no established term that has wide adoption.

[2]E.g. data in sensor networks

[3]Compared to the taxonomy, service nodes and gatways are part of the physical infrastructure network (PIN), validator nodes and the accounting layer are part of the distributed ledger technology (DLT), and Delegators (as well as User/payer) are part of the crypto-economic design (CED).

[4]E.g. in the context of servers, buying the hardware is considered CAPEX whilst the maintenance typically falls under OPEX. Yet, using cloud compute providers moves the CAPEX into OPEX.

[5]One example is the sharing of storage capacity, where users can rent out their unused storage capacity to other users and hence overall costs for storage can be drastically reduced.

[6]One can argue that there can be cost for the demand side as well (both direct e.g. paying sales teams or indirect in form of discounts), yet we do not include those in our framework given the supply-side focus. We plan to include these in a subsequent analysis when looking into the demand-side and the overall profitability on DePIN networks.

[7]This has some challenges and consequently limitations: Not all transactions are related to the accounting layer, e.g. swaps or other DeFi transactions, yet it is often not trivial to separate these transactions. From a cost component/category perspective, we classify those costs to „bandwidth and other costs“, which we will introduce in the next section.

[8]An estimate presented in [1]. A current overview of the increasing number of projects is presented e.g. in [34] andd [35].

1) Hardware/infrastructure: Those costs are related to actual inventory of the physical infrastructure, e.g. server, antenna, dashcam. The actual amounts can be quite transparent, e.g. when the network requires specific devices sold via licensed manufacturers. This is common for physical resource networks (PRNs, see section I). This applies to so called BYOD (Bring Your Own Device) networks as well in case we can assume that the required device is idle[9].
For digital resource networks (DRNs, see section I) the required hardware is often specified in the developer documentation, yet networks specify a minimum hardware requirement, which specifies a lower threshold on the server setup in order to be able to participate in the network. Meeting those does not guarantee participation and subsequently deriving hardware costs from those minimum requirements is misleading.
Even when the hardware costs are known, there is differences to account for when it comes to

- **Depreciation of the hardware:** When seen as CAPEX (see III), node operators might take different periods and approaches when deprecating hardware costs over time, which raises the question how to make monthly costs comparable. See section V for our approach to this.
- **Different cost bases** related to the time of purchase, e.g. Helium hotspot prices are lower now than they were two years ago. The impact of that aspect needs to be assessed on a network specific basis, see section VI.
- **Sharing economy aspects:** For some DePINs it is possible to utilize the hardware accross multiple use cases and networks[10]. It is not practicable to asses which part of the network contribution might also be used for other purposes (even outside DePIN), which is why we ignore these potential cost savings. One exception is when the hardware needed are widely available items (and consequently the attributable cost can be assumed to be zero), like smart phones, as enabled e.g. by Grass [40] and Silencio [7].
- **Economies of scale:** This aspect will be discussed in more detail in section IV-C.
- **Financing-, lease- or rental agreements:** When we consider rental agreements e.g. when computation is operated via cloud service providers, we can assess monthly costs, yet need to identify the share of network operated in such manner to account for different cost structures to a bare-metal/on-prem operation. See section VI how we approach this case by case. As mentioned in section III we ignore the capital costs for e.g. borrow/loan agreements for the acquisition of hardware.

2) Labor costs: Contribution for any supply-side role requires human labor, like setting up and operating the infrastructure. Assessing the time and costs is even more challenging than for hardware costs:

- **Degree of professionalization:** Some node operators are enterprises having paid employees taking care of operations. On the other side of the spectrum are „hobbyist“ where profitability is less of a motive[11]. Consequently, the amount of time it takes to fulfill a given role in the network will vary widely.
- **Need for specialization:** On top of the above, some networks require more specialization to be able to contribute: Downloading the app and pressing the record button is basically all it needs to measure noise for the Silencio network [7]. Hence, the time invest for contributors is quite uniform relative to their output produced. Setting up operations as transcoder in the Livepeer network requires knowledge around video transcoding and server setups and hence time investments might vary substantially between transcoders.
- **Sharing economy:** Besides the aspect that contributors would not assign a wage to the contributed labor given they view it as „side-hustle“ or hobby, some networks allow to contribute via activities node operators already do[12]. In line with the comment above (IV-B1), we ignore the potential cost savings of such cases, unless we can assume those to be zero.
- **Economies of scale:** This aspect will be discussed more in depth in section IV-C, but it is worth noting that the above aspects on sharing economy and degree of specialization are factors that can lead to lower labor cost per node when less nodes are operated.
- **Heterogeneous labor costs:** A lot of DePINs can source their contributors globally and consequently contribution costs vary widely depending on local wages. In our first version of this framework we make the simplifying assumption of a general hourly wage across all node operators.

3) Bandwidth, power and other OPEX: The decentralized nature of DePINs requires data exchange and consequently bandwidth (which we use as aggregated term for both speed and volume of data transfer). Similarly, there are further (typically variable) cost components like power or datacenter rental costs needed to operate.

4) Opportunity cost of staking: Multiple DePINs require a minimum amount of capital (in form of tokens) to be staked (locked) in order to be allowed to contribute to the network. This can be task specific, e.g. with deals in Filecoin [43]

[9]BYOD PRNs are networks that allow any sensor or device to contribute, provided it meets certain compatibility standards [2]. Examples from the list in section I are Silencio and Onocoy. Silencio for example relies on smartphones leveraged via App and consequently there are no explicit hardware costs for the service nodes here

[10]E.g. Livepeer advertised in its early days that hardware can be used for mining operations and transcoding in parallel [36], or parallel use with Filecoin [37]. io.net [38] allows GPU owners supporting Filecoin [39], Render and other DePINs relying on GPUs to also provide them to their network.

[11]See e.g. surveys we conducted for Pocket and Livepeer network on those motives and contributor distribution, [41], [42].

[12]E.g. Hivemapper [6] allows vehicle-drivers to record imagery to contribute to the creation and update of maps - Uber drivers, commuters, delivery service personal are just a few examples where they are anyway „on the road“ and hence raises the question how much of the time spent driving can be (if any) attributed to the Hivemapper contribution.

or a general requirement[13]. Acquiring this amount might be enabled via delegation or related mechanisms. Whilst this changes the cost of capital from a node operators point of view it does not from a network viewpoint. We simplified the assessment of this cost component by focusing on the risk-free rate alone, i.e. we ignore other aspects and only consider the possibility that any stake can be invested in a risk-free asset alternatively[14]. This simplification is also motivated in the fact that node operators typically do not account for this cost based on the interviews and surveys we conducted. Having these staking requirements be significant compared to the cost of operations is also mostly a deliberate choice of protocols in their token design, which is why we provide the comparison with vs. without these costs with mere informative intentions.

C. Homogeneity of costs

Whilst sections IV-A and IV-B lay out *what* we need to consider for our overall cost estimate, this third dimension is about *how*. Due to the decentralization it is not feasible to know the exact cost structure of each node operator. This means, we need to make assumptions to which extent differences of the costs node operators mentioned in previous sections matter for the overall costs. This includes the question how the actual distribution of node operators and their number of nodes operated unlock economies of scale both in the narrow sense (i.e. more of the same comes at cheaper cost per unit) and in a wider sense (i,e, more specialization leads to cost advantages per unit). A wide range and related concentration in node operator's share across the network is common in web3 networks[15].

1) On hardware and labor costs: We need to differentiate impacts of economies of scale per role:

a) Service nodes and validator/watcher nodes: If node operators can run a multitude of nodes e.g. on general server setups, there are economies of scale for both hardware and labor. This also applies to sensor networks as e.g. networks like Hivemapper or Dimo offer bulk discounts. To which extent these have impact on the overall cost base is different:

- **Cost advantages through quantity:** Cost benefits when running multiple nodes as node operator are typically unlocked when the hardware setups required are rather simple and fungible, i.e. each node follows the same setup. However, running multiple nodes might be limited or dis-incentivized by the network, for example by high requirements to join the network on the staking side or on the hardware side. Examples are TheGraph, where it needs a minimum of 100k GRT, currently worth over 15k$ to run an Indexer [47] or Filecoin where it used to cost over 200k $ to purchase sealing servers needed as part of storage provider operations [48][16]. Some networks cap (e.g. NYM's stake saturation [50]) or even lower the rewards when running multiple nodes[17].
- **Cost advantages through specialization:** Increasing the size of operation must not automatically lead to lower unit cost per node, e.g. running a single node can come at zero incremental costs in a sharing economy setting. Similar is true for BYOD networks (see section IV-B1) or networks requiring more specialization (e.g. Livepeer, Render), where optimization on a smaller amount of nodes might lead to lower unit costs than potential scale effects by operating multiple nodes[18].

b) Accounting layer: In general, considerations around economies of scale for different approaches are worth a separate analysis. Currently, we see discussions around economies of scale when it comes to rollups on the settlement layer architecture themselves (see e.g. [52]), hence for each of the three cases, i) public L1/L2s, ii) sovereign L2 (app-specific rollup, app-chain) and sovereign L1 there is limited economies of scale[19].

c) Gateways: There are i) multiple gateways, where the gateway role also fulfills another role, typically the service node as e.g. for the Pollen network, Fluence or Livepeer (see [27]). In these cases, economies of scale on the hardware- and labor cost are the same as for the service nodes. Or ii) there might one gateway operator, which is typically run by an entity close to the founding team (e.g. Dimo, Dfinity, Hivemapper or Arkreen, see as well [27]). For these cases there is typically no transparency on the requirements and consequently, costs and their economies of scale[20].
Regardless of the case, per their purpose, the largest cost category for Gateways is typically bandwidth, power and other OPEX, which overall limits the room for economies of scale on hardware- and labor costs.

d) Delegation: It is fair to assume that hardware- and labor-cost for this role is negligible.

2) On bandwidth, power and other OPEX: Bandwidth, power and other OPEX that are not labor- or hardware costs offer little room for economies of scale in general. Bandwidth costs typically increase with consumption when exceeding limits of standard fiber connections or caps of cloud-setups. This is why service- and watcher-node operators running these below those limits can unlock some economies of scale by setting up multiple nodes[21]. For gateways we can revisit the three cases from above.

3) On the opportunity cost of staking: On the capital needed for staking requirements there is little efficiency node

[13]Often related to the Work-Token model [44])

[14]How such risk-free rate is chosen in the context of DePINs is a input to choose in our framework.

[15]E.g. Bitcoin [45], Ethereum [46] or the DePINs like Pocket network, where the top node runners operate each several thousand nodes, whilst there are dozens of node runners operating just one or two nodes.

[16]Accounting for the over 80% reduction, they are still substantial, see [49]

[17]E.g. Dfinity's reduction coefficient [51]

[18]Advantages through specialization vs. quantity is obviously a spectrum and no dichotomy.

[19]The third case has some scale effects when service- and validator-nodes are tied into the consensus of the blockchain and hence, economies of scale on hardware and labor cost of those nodes can be applied to the cost for the accounting layer as well.

[20]There is networks in transition from one to multiple gateways, e.g. Pocket network [53]

[21]Using different connections/ports, of course.

operators gain by running multiple or larger nodes. An argument can be made that larger operations attracting larger stake delegation helps increasing the income of node operators, since many networks with delegation allow node operators to take a commission (e.g. Livepeer, Covalent, NYM, see [27]). From a network point of view that changes little on the overall opportunity cost of the staked amounts.

V. The general framework

The steps to estimate the cost of the supply side of DePINs are as follows:

1) **Asses the roles and their operators:** understand who is fulfilling which of the roles laid out in section IV-A and if multiple roles are filled at once
2) **Define the unit of network capacity:** The cost of operations are always tied to the service the DePIN provides - we need to define a unit to measure the amount of service the network can provide that also provides a connection to the cost components across the identified roles[22].
3) **Estimate the cost components:** For each supply side role, we estimate each of the four cost components, ideally in direct relation to the unit of network capacity.
4) **Adjust estimates to account for (lack of) homogeneity:** This step typically happens in parallel to the estimation to account for economies of scale and the other factors leading to different costs across each cost component for a given role. As those are typically assumption based in order to extrapolate to all node operators, a notion of lower and upper bounds on the cost estimates needs to be added as well.

The main challenge for all steps is the lack of holistic data. Blockchain data providers like Dune, Covalent and others as well as network specific providers are a good starting point to identify the distribution of roles and their operators. For cost estimates, one needs to conduct interviews/surveys to assess these off-chain data points. However, this might not always be feasible, which requires assumptions and hence lower and upper bounds for those[23]. Yet, we want to emphasize that the main goal is to have a framework that can be refined e.g. by getting input from community members and node operators.

VI. Estimating supply side costs for Pocket

For the purpose of this paper, we focus on Pocket network as detailed example. Those analysis are also available for Livepeer [54], Dfinity/ICP [55], Dimo [56] and Filecoin [49] and we are further expanding this list. The Pocket network serves RPC relay requests, hence the daily number of relays served is the unit when analyzing the change cost related to change in capacity.

1) The three dimensions:

a) Service nodes: provide hardware and bandwidth to service RPC relay requests. Node operators (also Node runners) operate one or more nodes. We conducted a survey on node operators of the Pocket network in Summer of 2023 [41] providing a good overview on hardware and labor costs of service nodes. Bandwidth and other costs have been included in the hardware cost estimates. There is stake required to operate a node[24]. There are roughly 150 node runners operating around 15,500 nodes. We refer to our survey, [57] and [58] on details for data and estimates. To our knowledge, these costs are mostly fixed costs: an increase in the number of relays served, at least when considering an order of magnitude (i.e. 10-50x) should not require a significant increase in node count (and hence costs).

b) Validators/watcher nodes: The verification is handled by the proof of relay [60] conducted by the service nodes (and consequently, costs are included there): For each session and application, servicing node collects relay evidence (request hash, unique nonce, block height etc). In order to claim their rewards, nodes need to prove they completed the work providing all collected relay evidences.

c) Accounting layer: The top 1,000 service nodes by stake operate as validators for the Pocket sovereign L1 blockchain[25], which is why we use the same cost structures as other service nodes. Claim/proof transactions can contain many relays[26], so the transaction count is not expected to increase with increasing relay count.

d) Gateway: Until recently, there was only one Gateway operated by Grove (formerly Pocket Network Inc). Meanwhile, this role has been opened up with one additional gateway operator [53]. Given the cloud setup of the Grove gateway, we use the data volume per month in relation to daily relays served and the estimated $-costs for the egress volume via Google Cloud Platform [64] as estimate of the bandwidth costs as main cost component. These costs are variable, and we assume a linear relationship of daily relays served and the egress volume needed.

e) Delegators: There is no explicit delegation[27].

2) Cost estimates, sensitivities and conclusions: See the cost estimation sheet [65] for the detailed cost estimates and input parameters. Figure 1a shows the output. The overall supply-side of pocket costs around 300k $ per month. The actual cost base is likely more on the lower end of the range, i.e. 150-200k $ per month since 1) at time of the survey LeanPocket [62] has not been fully rolled out, which might translate to cost decrease beyond 30% to the average case and 2) we did not account for potential effects around sharing economy[28]. When we assume a 3% risk-free rate to assess

[22]Ideally, we can gather data on how this is distributed across node operators in the network.

[23]Choosing the lower/upper bounds can be straightforward, e.g. when a regression model is used for cost estimates. Other approaches are different ranges on assumptions made.

[24]The node operator can decide between 15k, 30k, 45k and 60k staked POKT. Higher stake comes with higher rewards [59].

[25]This will change with the upcoming Shannon upgrade [63], where Pocket will migrate to a Layer 2 solution.

[26]See for example [61].

[27]Some node operators offer staking, yet we assumed costs for delegation with 0, Attributing delegated stake to the node operator.

[28]E.g. node operators running chain nodes and hence these costs might not be attributable to Pocket network

Absolute	Total		
Component	Lower	Avg	Upper
service node	$120,856	$225,352	$329,849
watcher node	$0	$0	$0
gateways	$40,000	$50,000	$60,000
accounting layer	$8,368	$15,603	$22,838
delegation	$0.00	$0.00	$0.00
Total	**$169,224**	**$290,955**	**$412,687**
Relative			
service node	71%	77%	80%
watcher node	0%	0%	0%
gateways	24%	17%	15%
accounting layer	5%	5%	6%
delegation	0%	0%	0%

Global assumptions/variables		
risk free rate (annual)	0%	
token price	$0.25	
delegated stake	0	
# Relays served/day	500	Millions

Relative shares by component	Lower	Avg	Upper
Hardware	52%	63%	68%
Labor	24%	20%	18%
Bandwidth/other	24%	17%	15%
Capital	0%	0%	0%

Absolute	Total		
Component	Lower	Avg	Upper
service node	$548,818	$653,315	$757,811
watcher node	$0	$0	$0
gateways	$40,000	$50,000	$60,000
accounting layer	$60,541	$67,776	$75,011
delegation	$0.00	$0.00	$0.00
Total	**$649,360**	**$771,091**	**$892,822**
Relative			
service node	85%	85%	85%
watcher node	0%	0%	0%
gateways	6%	6%	7%
accounting layer	9%	9%	8%
delegation	0%	0%	0%

Global assumptions/variables		
risk free rate (annual)	3%	
token price	$0.25	
delegated stake	0	
# Relays served/day	500	Millions

Relative shares by component	Lower	Avg	Upper
Hardware	14%	24%	31%
Labor	6%	7%	8%
Bandwidth/other	6%	6%	7%
Capital	74%	62%	54%

Figure 1: Cost estimates for Pocket with (right) and without (left) cost of staking.

the opportunity cost of staking, the overall costs increase to 650-800k $ per month[29]. As an example scenario we assumed 5 billion relays served per day (a 10x increase in demand). In this case, mostly bandwidth costs from gateways grow and make 60-75% of total cost. The total costs grow by 2.5x to 550-750k$ per month. With prices of 4.5$ per million relays served via gateways[30] or 0.85$ directly from the network [14] the monthly income would suffice to cover the costs. It is worth noting that we have seen a 10x increase in relays served per day before (in 2022). Furthermore, it will be interesting to see how optimizations like LeanPocket impact the overall network costs when implemented across all node runners.

VII. Conclusion and Outlook

Understanding the supply-side costs is a key-part of the token economics of DePINs. This paper provided a structured framework to assess these together with an overview of the key considerations across the whole spectrum of DePIN use cases. Assessing and comparing those for multiple DePINs is a successive research of ours. The framework will also be made publicly available, so we can get more involvement on the improvement of the estimates.

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[29] Caused by the fact that almost half of all circulating supply is staked related to the token-/reward-mechanism of Pocket.

[30] That might have changed as it was removed form the website