Analysis

A Comparative Analysis of the Openness of Proof-of-Stake Blockchains

Summary

The comparative analysis focuses on eleven blockchain networks that operate on a Proof-of-Stake consensus basis, analyzing their characteristics and assessing their levels of openness using five metrics. Amongst the metrics related to network decentralization, such as the number of validators and concentration of capital, and metrics related to participation, such as the capital required for participation and network stability from an economic perspective.

Highly open blockchain networks include Solana and Avalanche, while BNB Chain, Klaytn, and Polygon are less open.

Ethereum scored high on openness in terms of the number of participants and the cost of running the chain, but scored low on capital concentration and staking ratio, due to a relatively small ratio of staked Ether to the circulating supply and a large percentage of stakes within staking pools such as Lido.

Klaytn and Polygon, which are permissioned blockchains, show a low level of openness, and it seems that their openness levels should be taken into account to transform into a network architecture with a more permissionless setting, even if it is later transitioned into a network architecture with a more permissionless setting from their current state, they could likely be less open and more work towards a permissionless setting would be expected, given their user experience focuses balancing the scalability and security for the sustainable development of their blockchain ecosystem.

1. Introduction

In this article, we would like to compare the openness levels of different blockchain networks running on a Proof-of-Stake (PoS) consensus basis, identify their strengths and weaknesses, and suggest ways to enhance their network openness.

Proof-of-stake is a method of creating blocks and achieving consensus based on the number of assets staked. Typically, it uses a consensus method proportional to the stake (therefore the "Proof of Stake"), which means that validators with a larger stake have more influence on block creation and consensus process. The problem with this approach is that some validators with a large stake can become more powerful. To mitigate this, some blockchain networks limit the usage of stake to validator qualifications and achieve consensus in proportion to the number of validators. Once you become a validator on such a network, you can participate in the consensus process on the same footing as other validators, regardless of the size of your stake on the blockchain network.

The openness of a blockchain is related to decentralization to some extent, but not exactly the same. First of all, openness focuses on the accessibility to blockchain network participation. Considering whether anyone can join as a validator, create and verify blocks, and how much each network participant can contribute to be important, it also looks at how reliably a network can be operated and maintained against potential security attacks or any malicious actions from the network participants. These factors help measure the openness of a blockchain network.

Meanwhile, decentralization focuses on how evenly functions, control and information could be distributed amongst participants on a blockchain network. Openness, in other words, includes some concept of decentralization but has a broader meaning.

While there has yet been a standard for assessing the openness of a blockchain, we can look into decentralization factors such as the number of network participants, the number of meaningful participants, accessibility, sustainability and network security from an economic perspective. In this article, we would like to compare the openness levels of blockchains based on the following *five* metrics.

1) *The number of validators*: The number of validators refers to the number of nodes that directly participate in a blockchain network and create and validate blocks, and it can serve as one of the important indicators of openness. In general, the number of validators on an open blockchain is higher than that of validators on a permissioned blockchain.
2) *The capital required for participation*: The capital required to participate is closely related to the openness of a blockchain network. Networks with lower capital requirements for participation become more economically accessible, and this can help broaden the base of users participating in running validators.
3) *Capital concentration*: A blockchain with an even distribution of staked capital can maintain high security through a consensus with a large number of validators. Proof-of-Stake blockchains often determine consensus in proportion to staked capital. If too many stakes are clustered in particular validators, a block can be created with the

consensus of only a few validators, which is not appropriate for an open network. Therefore, we can say that the more evenly staked capital is distributed, the more open the blockchain is.

4) *Operating costs*: The lower the cost of running validators, the more users can be encouraged to participate as validators on an ongoing basis.
5) *Network stability from an economic perspective*: The economic stability of a blockchain network plays an important role in protecting the network from external attackers. There are two factors to consider for network stability;
   a) Staking ratio: The higher the percentage of staked assets in circulation, the more stable the network. A higher staking ratio can make it harder for attackers to acquire the native tokens they need to disrupt a network.
   b) Cost of attack: The cost for an attacker to compromise a network is an important factor for network stability. The higher the cost of an attack, the more economically disadvantageous it is to attack the network, which may decrease the chance for the attacker to make such an attempt.

In this article, we look into nine permissionless blockchain networks and two permissioned blockchain networks that plan to gradually transform to become permissionless and measure and analyze the levels of openness respectively.

2. Measuring Openness Levels

1) The Number of Validators

First, let's look at the number of validators: the more validators a network has, the more open it is, as the opinions of more participants can be taken into account. In general, we may expect that an open blockchain network would have a higher number of validators than a permissioned blockchain network because it is structured to be open to anyone. For instance, Bitcoin, one of the open blockchains, has about 17,000 nodes. In contrast, EOS, one of the permissioned blockchains, has only 21 validators.

[Table 1] Number of validators by blockchain network as of end of March 2023

Type	Blockchain Network	Number of Validators	Maximum Number of Validators*
Permissionless	Algorand	183(estimated)**	5,000
	Aptos	104	1,000
	Avalanche	1,200	5,000
	BNB Chain	29	100

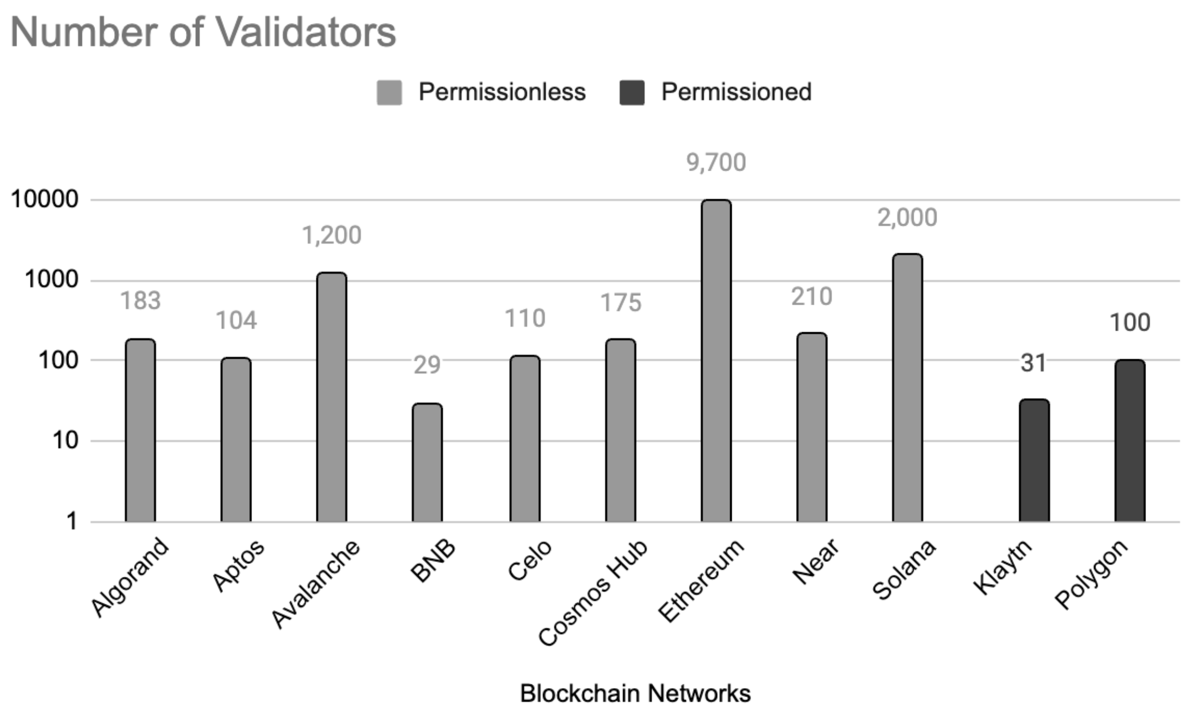
	Celo	110	200
	Cosmos Hub	175	300
	Ethereum	9,700 (number of clients)***	100,000
	Near	213	400
	Solana	2,000	10,000
Permissioned	Klaytn	31	Permission required
	Polygon	100	Permission required

* A / B - A: policy of a corresponding network as of Mar 2023. B: technical maximum number as of Mar 2023. Technical maximum number is based on proprietary analysis.

** Algorand does not disclose the total number of validators.

*** Ethereum has over 500,000 validators, but since a single client can run multiple validators, the number of clients is indicated instead of the number of validators.

Source: Staking Rewards , TheCelo, Chainparrot, Avalanche Explorer, NEAR Explorer, Algorand Developer Portal, Aptos explorer, Polygon Scan, cosmos chain explorer, Solana Beach, Klaytn Scope, Ethereum Node Tracker, BscScan



The difference in the number of validators between permissionless and permissioned blockchains is summarized in *[Table 1]*. It also depicts that the number of validators varies among open blockchains. This is due to different factors such as conditions for validator participation and the maximum limit of validators.

For example, BNB Chain is a permissionless blockchain, but it limits the maximum number of validators to 29. Like BNB Chain, many open blockchains use a strategy of limiting the maximum number of validators to increase reliability, even if it means restricting some openness.

For blockchains with multiple validators running with a single client, such as Ethereum, it is important to consider whether such multiple validators should be considered as multiple objects or one object when assessing their openness. For the purposes of this article, all validators running on a single client are considered one validator because if a client is down for some reason, all validators connected to the client may shut down simultaneously. Therefore, this article indicates the number of Ethereum clients instead of the number of its validators.

2) *Capital Requirement for Participation*

The capital required to participate has a significant impact on the openness of a blockchain. The lower the initial capital cost, the lower the barrier to entry, giving more users the opportunity to participate as validators, which increases openness. However, lower initial capital requirements can also increase the risk of a malicious act. One of the key ways to prohibit malicious behavior is slashing, but a lack of capital to slash can weaken the effectiveness of the restriction and allow malicious actors to try an attack with a lower opportunity cost.

[Table 2] Minimum staking requirements by blockchain network as of end of March 2023

Blockchain Network	Staking Requirement	USD Equivalent
Algorand	0.1 ALGO	0.1
Solana	0.01 SOL*	0.2
Cosmos Hub	0.1 ATOM	1
Celo	10,000 CELO	6,000
Polygon	10,000 MATIC	11,000
Avalanche	2,000 AVAX	36,000
Near	25,200 Near	50,400
Ethereum	32 ETH	57,600
Aptos	10,000 APT	130,000
Klaytn	5,000,000 KLAY	1,150,000
BNB	10,000 BNB	3,300,000

* Solana does not set the minimum staking quantity but spends gas fees in its consensus process, which is approximately 1.1 SOL per day.

[Table 2] shows that each blockchain network has a different minimum capital requirement to serve as a validator, which provides some insight into the openness levels of blockchain networks.

BNB Chain has a relatively high minimum capital requirement, which suggests that it values trust toward selected operators more than openness compared to other blockchains. Neither Cosmos Hub nor Algorand has a minimum staking requirement, so they can be considered more open in terms of minimum staking requirements.

Solana has no minimum capital requirement to participate as a validator, but it has a unique structure that should consider gas fees incurred from its consensus process. With this strategy, Solana has removed the barrier to entry of having to initially stake a large amount of capital.

[Table 3] Minimum capital to be qualified as a validator as of the end of March 2023

Limit in Number of Validators	Blockchain Network	Minimum Staking Requirement	Validator's Minimum Staking Quantity	USD Equivalent
No limit	Algorand	0.1 ALGO	0.1 ALGO	0.1
	Avalanche	2,000 AVAX	2,000 AVAX	36,000
	Ethereum	32 ETH	32 ETH	57,600
	Solana	0.1 SOL*	10,000 SOL	230,000
Limited Maximum Number of Validators	Near	25,200 Near	25,200 Near	50,400
	Polygon	1 MATIC	58,000 MATIC	66,700
	Celo	10,000 CELO	1,350,000 CELO	837,000
	Cosmos Hub	0.1 ATOM	82,000 ATOM	984,000
	Klaytn	5,000,000 KLAY	5,000,000 KLAY	1,150,000
	Aptos	10,000 APT	1,010,000 APT	13,130,000
	BNB	10,000 BNB	182,500 BNB	60,225,000

* Solana does not set the minimum staking quantity but spends gas fees in its consensus process, which is approximately 1.1 SOL per day.

The amount of capital staked as a collateral by validators with the smallest capital among the validators participating in each network is summarized in *[Table 3]*. This suggests an idea of how much capital is required to participate as a validator.

To become a validator on the blockchain networks such as BNB Chain and Aptos, one is required to rank in the top validators, which requires much more capital than the minimum staking requirement. In other words, you need to stake a much larger amount of capital than the minimum staking requirement to act as a validator. Ordinary users find it difficult to become validators on the blockchain networks with such large capital requirements, hence they may need help from a foundation or other organizations.

Blockchain networks like Avalanche, Ethereum, and Solana do not limit the number of validators, so anyone can join as a validator as long as they meet a minimum staking requirement. These networks have a large number of validators with a relatively small staking amount. This allows more users to serve as validators and helps increase the openness of the networks.

Ethereum has set both the minimum and maximum staking amount equally at 32 ETH. Ethereum has a large number of validators because well-funded groups run multiple validators, each of whom is staking 32 ETH.

3) Capital Concentration

The openness of a blockchain network is related to the distribution of staked capital. Particularly if stakes are concentrated on a few validators of a blockchain network where a consensus is made in proportion to staked capital, a particular validator may have too much influence over the consensus process. This reduces the openness of the network and could lead to network centralization. The more evenly staked capital is distributed, the more balanced power exists among validators, and we can say that the blockchain network is highly open.

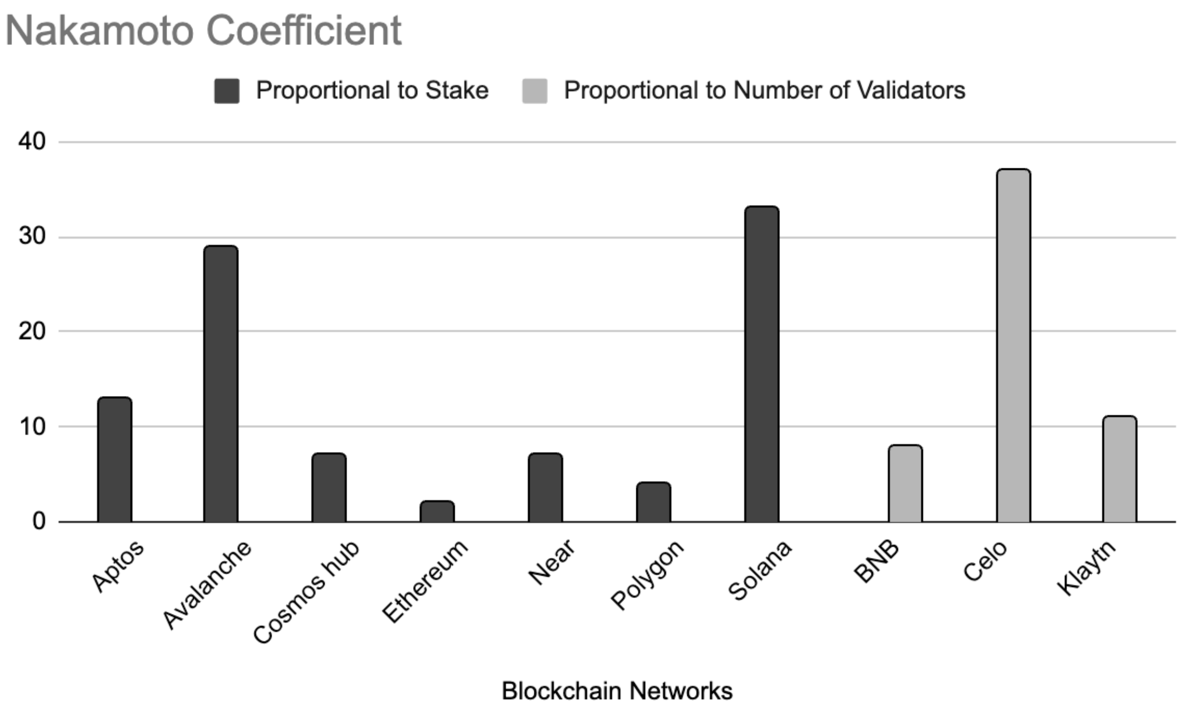
For blockchain networks that use a consensus approach proportional to the number of validators, the influence is more evenly distributed among validators, and more validators are needed to reach a consensus. Therefore, these networks are relatively more open in terms of concentration.

[Table 4] Number of validators with significant influence on consensus by blockchain network

Consensus Method	Blockchain Network	Number of Validators	Nakamoto Coefficient* (Number of nodes required to stop a chain)	Number of Validators Needed to Consensus
Proportional to stake	Algorand	183 (estimated)****	?	?
	Aptos	104	13	27
	Avalanche	1,200	29	80
	Cosmos hub	175	7	27
	Ethereum	9,700 (Clients) **	2	3,200 (Estimated)***
	Near	210	7	28
	Polygon	100	4	12

	Solana	2,000	33	132
Proportional to number of validators	BNB	29	8	20
	Celo	110	37	74
	Klaytn	31	11	21

* Quoted from Nakamoto Coefficients and included independent analysis on some networks.
** Ethereum has over 500,000 validators, but since a single client can run multiple validators, the number of clients is indicated instead of the number of validators. When calculating a Nakamoto coefficient, a group running multiple clients is counted as one.
*** Estimated to be less than ⅓ of the total number of clients because two groups hold more than ⅓ of the stakes
**** Algorand does not disclose the total number of validators.



[Table 4] demonstrates that a blockchain network using a consensus method proportional to the number of validators has a relatively lower Nakamoto coefficient than that of a network using a consensus method proportional to the number of validators. When a small number of validators have a large stake in a consensus scheme proportional to their stake, they exercise a large influence on the network, and any problem with their behavior can compromise the network stability. For example, a considerable amount of stake in Ethereum is in staking pools like Lido, which appears that more than ⅓ of the capital is concentrated on a few groups. On the other hand, blockchains that use a consensus approach proportional to the number of validators can provide a relatively higher level of decentralization with a smaller number of validators because all validators have an equal amount of voting power.

When we look at the number of validators required to achieve consensus, it does not vary much. While Solana has over 2,000 validators, the number of validators needed to reach a consensus is around 130, or 7% of the total. While a network which reaches a consensus proportional to the stake seems to have a large number of participating validators, the network can operate with the consensus of a small number of validators. However, Ethereum would need a sufficiently large number of clients for consensus.

4) Operational Costs

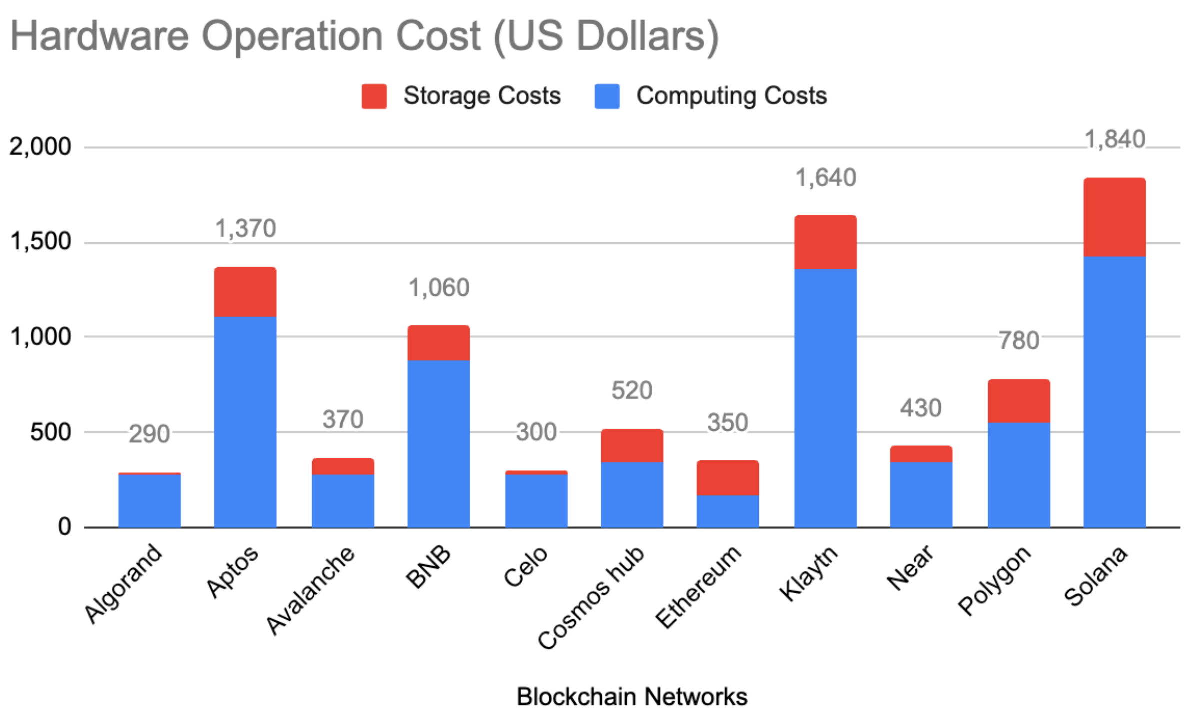
The cost of running validators can have a significant impact on the openness of a network. Lower operating costs can increase openness by lowering barriers to participation. Higher operating costs can discourage participation by making it more expensive to retain validators. In addition, to offset operating costs, validators may face increased pressure to cash out the tokens they are rewarded with. This leads to an increased supply of the tokens, which can affect their price.

[Table 5] Validator minimum specifications and monthly hardware costs (unit: USD)*

Blockchain Network	Compute Spec.	Storage Size	Computing Cost	Storage Cost	Total Cost
Algorand	8 vCPU (AWS c5.2xlarge)	100GB SSD	280	10	290
Aptos	AWS c6i.8xlarge	2TB SSD (io2)	1,110	260	1,370
Avalanche	8 vCPU (AWS c5.2xlarge)	1TB SSD	280	90	370
BNB	AWS M5zn.3xlarge	2TB SSD	880	180	1,060
Celo	8 vCPU (AWS c5.2xlarge)	256GB SSD	280	20	300
Cosmos hub	32GB RAM (m5.2xlarge)	2TB SSD	340	180	520
Ethereum	4 vCPU (AWS m6i.xlarge)	2TB SSD	170	180	350
Klaytn	AWS m6i.8xlarge	3TB SSD	1,360	280	1,640
Near	AWS m5.2xlarge	1TB SSD	340	90	430
Polygon	AWS c5.4xlarge	2.5TB SSD	550	230	780
Solana**	GCP n2-standard-32	2TB SSD (NVMe)	1,430	410	1,840

* Hardware costs include the cost of one validator node but do not include network transmission costs.
** Solana incurs additional cost for the consensus process for operation in addition to the hardware costs.

[Table 5] summarizes the monthly hardware costs based on AWS EC2 instances according to validator minimum specifications of different blockchain networks. The hardware specifications are quoted from each network's homepage. In this table, hardware specifications for validator operations vary by a blockchain network, so do the monthly hardware costs. This would enable a rough comparison of the operating costs to participate as a validator on each network.



As high-performance blockchain networks are optimized for high throughput and performance, their operating costs are relatively high. They require more CPU cores and memory and have a relatively high number of transactions per block, which increases the block size hence requires more storage space. As a result, the total operating costs go up. The chart above shows that networks categorized as a high performance blockchain such as Aptos, Klaytn, and Solana have relatively high operating costs. This indicates that high-performance blockchains may be relatively weak in terms of openness. In addition, high-performance blockchains in general have short block times and process many transactions per block, which means that a lot of data needs to be transferred and synchronized among validators in a short amount of time. Thus, the network transmission costs are also likely to be relatively higher.

If so, we can estimate how much upfront capital is needed to cover operating costs with the rewards for running a validator. If these costs are low and the rewards are sufficient, this could be an incentive to participate as a validator. Of course, this estimate is based on the reward level and a native token price at the moment, which can change at any time.

[Table 6] Initial investment required to cover the cost of running validators as of March 2023 (unit: USD)*

Blockchain Network	APR (est.)	Annual Operating Costs** (est.)	Initial Investment Costs for BEP*** (est.)	Expected Profit from $1 Million Investment (est.)
Algorand	5.6%	16,000	280,000	40,000
Aptos	7.0%	29,000	410,000	41,000
Avalanche	8.5%	17,000	200,000	68,000
BNB****	2.5%	25,000	990,000	300
Celo	4.2%	16,000	380,000	26,000
Cosmos Hub	21.4%	19,000	90,000	195,000
Ethereum	4.6%	17,000	360,000	29,000
Klaytn	13.5%	32,000	240,000	103,000
Near	9.5%	18,000	185,000	78,000
Polygon	4.8%	22,000	450,000	26,000
Solana	7.5%	49,000*****	655,000	26,000

* Estimates may vary.
** Included the cost of running 1 node and operating expenses equivalent to $1,000/month; costs for proxy nodes et al are not included.
*** Minimum staking limit was not applied.
**** BNB Chain does not offer rewards for block generation and validation, but offers rewards with transaction gas fees from a block. Reward levels may vary by validator.
***** The cost involving the network consensus process is included in Solana operating costs (approximately 400 SOL/year).

The estimated initial investment costs and annual reward rate for operating each network validator is summarized in *[Table 6]*. In this table, a single consensus node is considered a validator, and the costs of proxy nodes required for node operations are excluded. Some networks such as Klaytn require a proxy node to be installed to participate in running a validator, but since this table calculates the cost of operating with a single node, it may differ from the actual operating costs, and the annual reward levels may also vary.

Cosmos Hub and Klaytn, for instance, offer over 10% APR while other chains offer lower rewards. In terms of upfront investment, hundreds of thousands of dollars of capital should be staked on most chains to expect profits over the costs of running validators.

In the case of Ethereum, the amount that can be staked per validator is fixed (32 ETH), profits exceeding the operating costs can be expected only from running multiple validators on a single client.

5) Network Stability from an Economic Perspective

It is generally believed that Proof-of-Stake (PoS) blockchains require a higher cost for a double-spend attack than Proof-of-Work (PoW) blockchains due to the higher cost of staking. To commit a double-spend attack on a PoS blockchain, an attacker is expected to acquire over the majority of the staked native tokens, which is largely costly. In addition, a blockchain with a high staking ratio can be considered a relatively secure network, as it becomes more difficult for an attacker to obtain the native tokens needed to launch an attack.

The value of a network can be considered proportional to the circulating amount of its native tokens. This is because the higher the circulation, the more active the network is considered to be. But if a permissionless blockchain has a low staking ratio to the circulating supply, an attacker could potentially attack the network by purchasing a large number of tokens in circulation. For instance, on a Proof-of-Stake blockchain that achieves consensus proportional to the stake, a double-spend attack becomes possible if an attacker acquires ⅔ of the total staked amount needed for consensus. On the other hand, a blockchain network that uses consensus proportional to the number of validators may require less than ⅔ of the total staked amount because consensus can be made when reaching ⅔ of the number of validators sorted by ascending staking amount. Therefore, an attacker may be able to launch an attack at a relatively low cost.

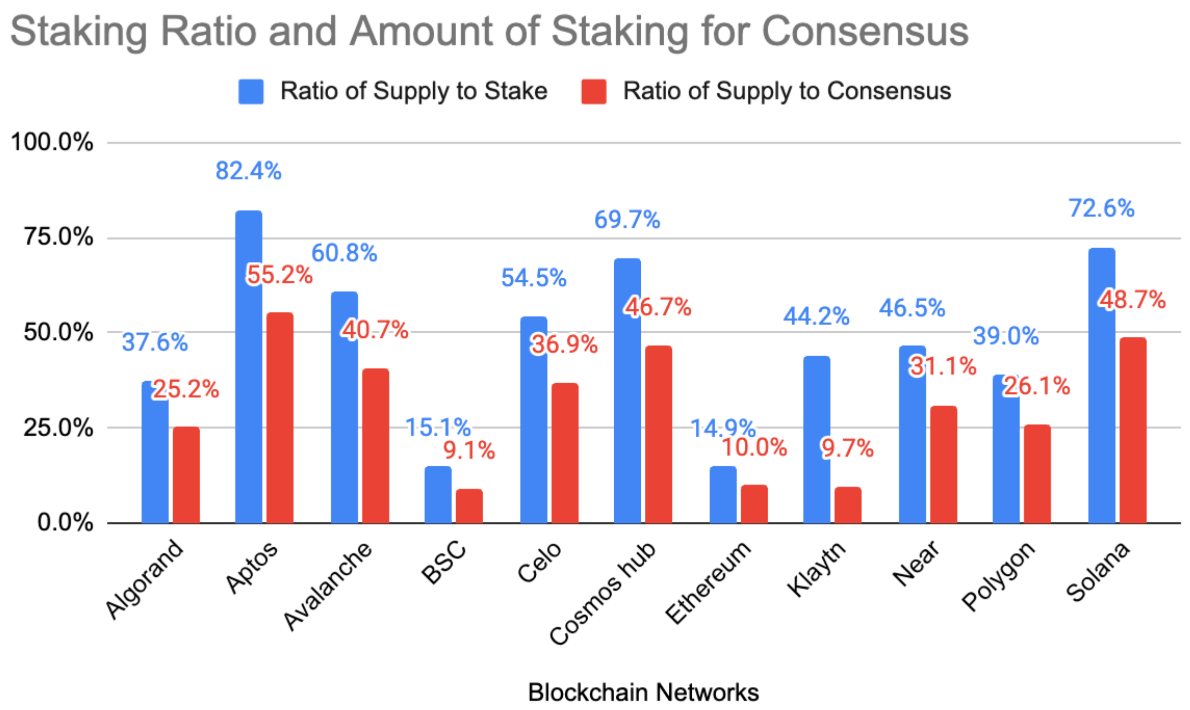
To compare network resistance to attacks, we calculated the required staking ratio to the tradable quantity for consensus by each network as described in *[Table 7]*. As the definition of tradable quantity slightly differs by network, we have defined it as the quantity that can be secured through normal transactions, which is total supply or circulating supply in here. And the quantity already minted but designated as a reserve or burnt is excluded from the tradable quantity.

[Table 7] Staking quantity for consensus out of the total circulating supply as of Apr 21 2023

Blockchain Network	Total Quantity	Total Quantity Staked	Staking Ratio	Min. Staking Quantity for Consensus / Total Circulating Supply
Algorand*	7,230,202,491	2,719,284,958	37.6%	25.2%
Aptos**	1,030,430,527	848,799,394	82.4%	55.2%
Avalanche**	422,765,487	256,902,450	60.8%	40.7%

BSC	155,864,769	23,571,835	15.1%	9.1%
Celo	494,976,084	269,794,726	54.5%	36.9%
Cosmos hub**	339,703,187	236,814,410	69.7%	46.7%
Ethereum	120,428,889	17,915,419	14.9%	10.0%
Klaytn	3,087,221,664	1,364,046,125	44.2%	9.7%
Near	1,131,342,100	525,738,078	46.5%	31.1%
Polygon	9,219,469,069	3,591,201,401	39.0%	26.1%
Solana**	545,758,273	396,316,007	72.6%	48.7%

* Algorand has two different concepts of staking, one for consensus and one for governance. Here we have defined it as the amount of staking for governance.
** Aptos, Avalanche, Cosmos Hub, and Solana defined total supply as the total amount in circulation because their staking includes the amount of uncirculated supply; the other chains were based on circulating supply.



[Table 7] shows each network's total circulating supply and the minimum staking amount for consensus divided by the total circulating supply. If a network has a large circulating supply of its native tokens and small staking amount, an attacker could make a large profit from a successful attack. In this case, a double-spend attack can be attempted even at the risk of enormous costs to attack. From this perspective, blockchains with a high staking ratio such as Aptos, Cosmos Hub, and Solana can be considered relatively secure against double-spend attacks.

As described, on a network with consensus proportional to the number of validators, the amount of native tokens needed for consensus may be less than ⅔ of the amount staked. As Algorand, BNB Chain, and Klaytn need a relatively small quantity of native tokens for consensus, an attacker can attempt an attack to seize a network such as a double-spend attack if acquiring nearly 10% of the circulating supply. However, committing such an attack would be based on the assumption that the attacker can acquire a sufficient number of validators; otherwise, such an attack would be deemed impossible.

Celo blockchain uses a consensus method proportional to the number of validators but needs a relatively large amount of native tokens for consensus, which means staking amount is relatively evenly distributed among validators. This makes the Celo network relatively resistant to attacks from an economic standpoint.

Moving on, let's analyze how much capital an attacker would actually need to disrupt a blockchain network. This will help estimate how much capital is needed for an attack and assess the resistance of a blockchain network to an attack.

Assuming that the attacker is unable to take the amount staked, the attacker then would need to purchase and stake the number of native tokens from the market for an attack, which would be at least 50% of the current staking amount according to the proportional consensus method. This is because as soon as the attacker stakes half of the current staking amount, the attacker's stake becomes ⅓ of the total staking amount. Therefore, if we know the price of the native token and the amount staked, one could roughly estimate the amount of capital an attacker would require to attack the target blockchain network.

[Table 8] Quantity of native tokens and capital required to attack a network as of April 21 2023

Type	Blockchain Network	Current Circulating Supply	Current Amount Staked	Ratio of Coins Required for an Attack to the Circulating Supply *	USD Equivalent**
Proportional to Stake	Algorand	7,230,202,491	2,719,284,958	?***	?***
	Aptos	1,030,430,527	848,799,394	40.8%	4,200,000,000
	Avalanche	422,765,487	256,902,450	30.7%	2,210,000,000
	Cosmos hub	155,864,769	236,814,410	77.0%	1,320,000,000
	Ethereum	120,428,889	17,915,419	8.3%	18,600,000,000
	Near	1,131,342,100	525,738,078	23.0%	520,000,000
	Polygon	9,219,469,069	3,591,201,401	19.5%	1,800,000,000
	Solana	545,758,273	396,316,007	36.6%	4,400,000,000
Proportional	BNB	155,864,769	23,571,835	2.5%	1,320,000,000

to the number of validators	Celo	494,976,084	269,794,726	18.4%	54,600,000
	Klaytn	3,087,221,664	1,364,046,125	2.6%	20,000,000

* To stop a chain whose consensus is proportional to stake, the additional staking amount acquired by an attacker must be over ⅓ of the total staking amount, which can be expressed as at least 50% of the current staking amount. To stop a chain whose consensus is proportional to the number of validators, the additional number of validators acquired by an attacker must be at least ⅓ of the total number of validators, which can be expressed as over 50% of the current number of validators. The number of native tokens required to attack the latter chain was calculated by multiplying the staking amount of the least staked validator on the network by the number of validators required for the attack.
** The amount multiplying the price of one native token by its quantity needed for an attack. An attacker should pay a higher price than this to acquire the required stake.
*** Algorand does not disclose the actual number of validators.

[Table 8] demonstrates a rough idea of how economically attack-resistant each blockchain network is. It indicates that an attacker would need a very large amount of capital to disrupt a blockchain network which is proportional to stake, which confirms that Proof-of-Stake based blockchain networks have a high level of attack resistance. In the case of Ethereum, the cost of an attack was estimated to be at least $18 billion, making it the most resistant blockchain among those analyzed.

On the other hand, networks with their consensus which is proportional to the number of validators have relatively lower level of attack resistance. This is because the quantity required for an attack is proportional to the least staked validator. Therefore, these networks need to either limit the maximum number of validators or increase the minimum staking amount to improve attack resistance, thereby properly maintaining their accessibility to participation, stability, and reliability.

The actual cost of a network attack can vary depending on a variety of factors, including market conditions and price fluctuations, so the analysis results should be considered a rough indicator.

3. Summary: Comparison of Openness Levels

[Table 9] A relative level of openness among blockchain networks (minimum 1, maximum 5)

Blockchain Network	Number of Validators (5)	Initial Capital Cost (5)	Nakamoto Coefficient (5)	Staking Ratio (5)	Operating Costs (5)	Total Score (25)
Algorand	3 (est.)*	5	3 (est.)*	3	5	19 (est.)*
Aptos	3	1	2	5	2	13
Avalanche	4	5	3	4	5	21
BNB	1	1	1	1	3	7
Celo	3	3	3	3	5	17
Cosmos Hub	3	3	1	4	4	15

Ethereum	5	4	1	2	5	17
Klaytn	1	3	2	1	2	9
Near	3	4	1	3	5	16
Polygon	2	4	1	3	3	13
Solana	5	4	3	4	1	17

* Algorand does not disclose the actual number of validators.

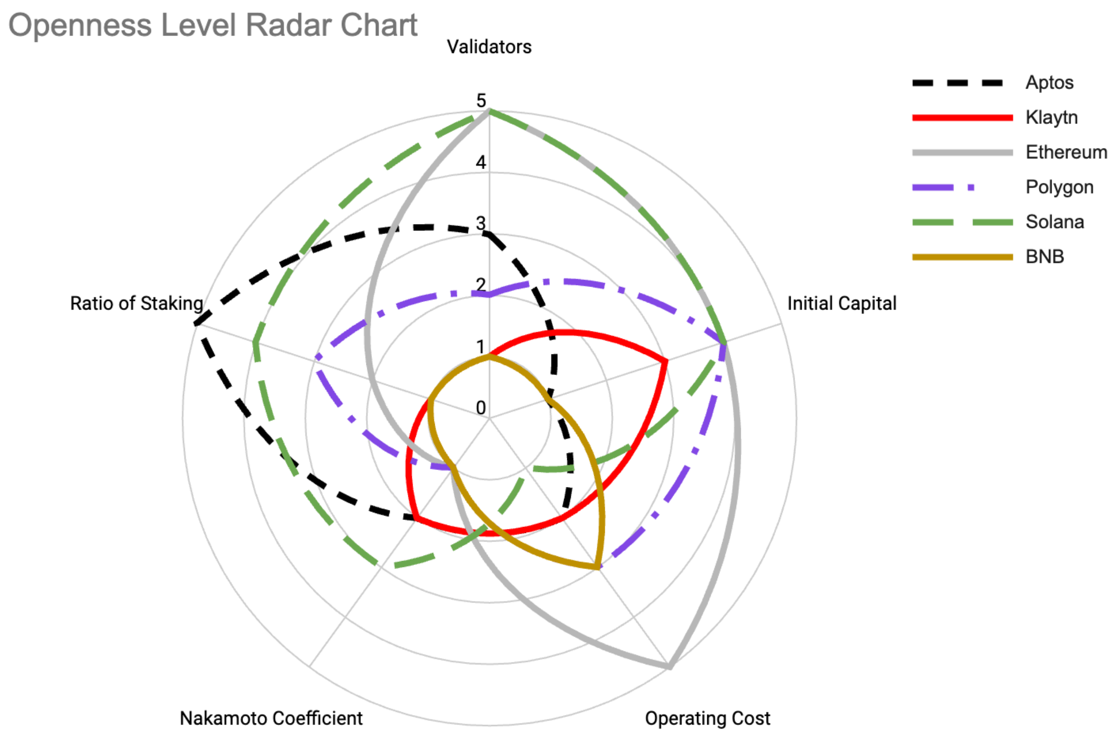
The scores of the relative openness levels among the eleven blockchain networks we analyzed is summarized in *[Table 9]*, where each score closer to 5 indicates a higher level of openness while a score closer to 1 indicates a lower level of openness.

Solana and Avalanche networks were assessed to be highly open, with relatively high scores in the number of validators, initial capital cost, and capital concentration. These factors were combined to contribute to increasing their openness.

As Algorand does not disclose the exact number of validators, the exact result is not available, but it is assumed to be highly open based on a combination of data sources.

While Ethereum scored high in several metrics, it scored low in the areas of capital concentration and network stability, which means that there are some limits to the openness of the Ethereum network.

Aptos and BNB Chain scored low in initial capital cost and decentralization, and their total scores were also relatively low. Given the fact that both Klaytn and Polygon have been permissioned blockchains, their openness scores do not mean much, but if they transition into a permissionless blockchain, they are likely to be less open.



The radar chart above visualizes the openness levels of six blockchain networks out of the 11 blockchain networks compared in this study. We can see relatively highly open Ethereum and Solana take up a larger area, while BNB Chain and Klaytn occupy a relatively small area. This chart helps compare and assess the openness levels of the networks at a glance.

4. Conclusion

In this article, we compared the openness levels of different Proof-of-Stake (PoS) blockchain networks and came up with the following insightful results.

- Proof-of-stake networks can be categorized by methods: proportional to staking vs. proportional to the number of validators.
- Networks with proportional staking have a relatively large number of validators and are relatively highly stable with high potential for capital concentration.
- Networks with consensus proportional to the number of validators are relatively highly open in terms of capital concentration but can be vulnerable to network attacks if there are large variations in the amount staked.
- Some blockchain networks have very high initial capital requirements, making it difficult to participate as a validator without foundation support.

- High-performance blockchains require high hardware specifications, resulting in relatively high operating costs.
- Algorand, Avalanche, Celo, and Solana demonstrate a high level of openness.
- Cosmos Hub, Ethereum, and NEAR Protocol are moderately open.
- Ethereum scored very high on many metrics, including the number of validators, initial capital, and operating costs, but scored low on capital concentration and staking ratio.
- The openness of permissionless networks that require an extremely large initial capital is found to be not significantly different from permissioned networks.

The analysis results above can help understand how openness and stability of blockchain networks affect each other and find out which strategy to use to improve the openness of a permissionless network.

Also, so as to transform a permissioned blockchain network into an effective permissionless blockchain, the following points should be considered.

- Choose a suitable consensus method for a network between a method proportional to stake and a method proportional to the number of validators
- Properly set the number of validators, initial capital cost, and operating costs
- Determine the level of capital concentration and staking ratio to circulating supply to maintain network reliability

Designing a methodology to meet the openness level while keeping network reliability based on the above will help the process of converting a permissioned network into a network architecture with a more permissionless setting. The research team at Klaytn Foundation would hope the findings from this comparative analysis contribute to the blockchain network segment and blockchain industry as a whole when it comes to designing and implementing a permissionless blockchain network and ecosystem.