The Limits to Blockchain? Scaling vs. Decentralization

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Discussion Paper

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Abstract: This discussion paper examines a possible limitation to the advancement of blockchain: the intrinsic tradeoff between scaling to a larger size, and the need to maintain a decentralized and distributed architecture. The scaling vs. decentralization trade-off, the paper argues, may impose a long-term limitation on the growth of blockchain-based technologies including cryptocurrencies.

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The Limits to Blockchain? Scaling vs. Decentralization

The sheer novelty of blockchain-based technology and the accompanying investor and researcher interest in the field,[3] lead observers at times to infer that the possibilities of blockchain are "endless," figuratively speaking. The sheer optimism involving the wide dissemination of blockchain (and cryptocurrencies such as Bitcoin) construct a narrative that suggests large expanses of opportunity and creativity await just beyond the horizon. While part of this enthusiasm may well be justified, the purpose of this discussion paper is to question whether the possibilities really are "endless," if an inherent limitation doesn't exist in blockchain design, premised substantially on the trade-off between **scaling and decentralization.**[4]

To propose this argument, it helps to revisit the underlying architecture of blockchain as it is typically understood. Blockchain draws upon *cryptoanarchist* principles to formulate a decentralized, distributed ledger. This distribution of free and autonomous participants across a network, reinforcing and validating each other's transactions, allows for a system that is at least "nominally" trustless, but it is premised on the cooperative nature of members of the network, working to validate transactions to grow the chain of blocks (as code). This decentralization allows for network stability, because the disruption of one node (participant) does not compromise the overall integrity of the distributed architecture.

[3] see also discussions in Decourt et al., 2017; Chohan 2017a, 2017b, 2017c, 2017d, 2017e, 2017f, 2017g, 2017h, 2017i, 2017j, 2017k, 2017l, 2017m, 2017n, 2017o, 2017p, 2017q, 2017r, 2017s, 2017t, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f, 2018g, 2018h, 2018i, 2018j, 2018k, 2018l, 2019a, 2019b, 2019c, 2019d, 2019e, 2019f, 2019g, 2019h, 2019i

[4] Vitalik Buterin of Etherum has in fact framed the problem of distributed networks as a trilemma: security, scalability, and decentralization

On the other hand, decentralized distribution of the blockchain also means that it is intrinsically difficult to scale. Without scale, the blockchain system cannot have many **real-world applications.** In order to find adoption amongst a wider set of fields and industries, blockchain must be scalable.

Whereas many startups and other initiatives have made the claims of being able to resolve the scalability issue in blockchain, as of this writing (February 2019), none have been able to square the circle. In distributed systems which have a *shared state,*[5] a CAP theorem exists which situates the problem in three dimensions: consistency, availability and partition tolerance. Consistency in the distributed database refers to the consistent receipt of the most recent update (or otherwise an error message). Availability refers to receipt of a timely response to user queries. Partition tolerance refers to the system's sustainability if the network is divided. With respect to the CAP theorem, there is a trilemma in that only any two out these three properties can hold.

As such, to square the circle, a solution must divide the state (with partition tolerance) into various parts while still maintaining the homogeneity of interactions and adhering to security expectations. By this account, any participant (whether a user account or smart contract) must be able to transact with any other entity, regardless of the relative post-compartmentalization locations.

The challenge, therefore, is being framed in the practitioner blockchain space as one of compartmentalizing and splitting the state. One proposed solution is *sharding*, which aims to split the state into shards which are distributed among groups of nodes. If a transaction is localized entirely within a shard, then its processing would

[5] The term "State" refers to the data on a distributed ledger

be akin to the typical blockchain architecture. However, recompilation problems can arise if the transaction is spread across shards. Another proposed solution is *direct acyclic graphs*,[6] which frames the process as one not of a set of blocks on a chain, but rather as leaves out of multiple branches. Other solutions have also been proposed, but have yet to arrive at a full solution to the issue of scaling vs. decentralization. It would be considered a breakthrough in blockchain technology, necessary to its wider adoption in the world, and necessary to its rise from the fringes of its cryptoanarchist redoubt, to see a squaring of the circle of scaling vs. decentralization.

[6] This model was pioneered and popularized by IOTA.

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