

**AUG
2019**



ETHEREUM AT THE CROSSROADS: The Istanbul hard fork and its implications

Executive summary

The Ethereum community is divided on the best way to handle the imminent launch of Ethereum 2.0. The most likely scenario will see Ethereum and Ethereum 2.0 run as two separate but connected blockchains, each with its own token. An alternative scenario would see Ethereum incorporated as a shard of Ethereum 2.0. The situation has some similarities to the contentious Bitcoin Segwit2x debates of 2017.

Ethereum's mining and developer communities have serious concerns. Miners remain unconvinced that the proposed move from proof-of-work to proof-of-stake is viable and are concerned that their value to network block producers will be reduced. Meanwhile, the Ethereum developer community is troubled by the prospect of having to redeploy existing Ethereum projects to the new chain.

Meanwhile, exchanges, wallet providers and Ethereum users are watching warily from the sidelines, excited at the prospect of the long-awaited scaling solutions, but wary of the possibility of another Ethereum hard fork. The hard fork has the potential to create a situation that results in three Ethereum chains, three Ethereum tokens, and a confusing brand split. Against this highly charged backdrop, the pressure is on Ethereum developers to provide a solution that meets the needs of all stakeholders. Can they deliver?

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Introduction

Background to Ethereum

Ethereum is a blockchain network that allows developers to deploy decentralized applications. Like **Bitcoin**, Ethereum is a public blockchain network. Bitcoin exists primarily as a peer-to-peer electronic cash payment network and uses its base blockchain to track and record ownership of the bitcoin digital currency. The Ethereum blockchain, however, focuses on running programming code, powered by smart contracts, for decentralized applications.

A '**smart contract**' is a piece of code that facilitates the exchange of value (in the form of currency, property, network stake, etc). When deployed on a blockchain, a smart contract can be thought of as a self-operating computer program that automatically executes when specific preset conditions are met.

The Ethereum project was proposed by Vitalik Buterin in 2013, with an ICO crowdsale occurring in 2014. Other co-founders include Anthony Di Iorio, Charles Hoskinson, Mihai Alisie, Amir Chetrit, Joseph Lubin, Gavin Wood, and Jeffrey Wilke. The ICO raised nearly US\$16 million, with each token selling for US\$0.31. The ETH ICO would eventually prove extremely profitable for early investors, with the ETH token hitting an all-time high of US\$1420.65 on 13th January 2018. The mainnet went live in July 2015 with 72 million pre-mined coins, which account for 67.7% of the current circulating supply.

To date, Ethereum protocol upgrade milestones have included; Olympic in May 2015, Frontier in July 2015, Homestead in March 2016, Metropolis Part 1: Byzantium in October 2017, and Metropolis Part 2: Constantinople in February 2019.

Ethereum timeline: A brief history of Ethereum updates

- 2013:** **First ever ICO, Mastercoin**
(now called Omni) built on Bitcoin protocol.
- 2013, October:** **Vitalik conceives of the Ethereum concept**
While working on the Mastercoin project.
- 2013, December:** **First contributors**
Charles Hoskinson, Gavin Wood approach Vitalik to contribute.
- 2014, January:** **North American Bitcoin Conference**
Ethereum team meet in person for the first time. Vitalik showcases Ethereum to the world for first time - to rapturous reception.
- 2014, February:** **Core Ethereum team move to Zug, Switzerland**
Establish Ethereum Foundation.
- 2014, June:** **Charles Hoskinson leaves team**
Due to change of tack to be non-profit venture.
- 2014, August:** **The uncle mechanism created**
To allow Ethereum's blockchain to have a shorter block time and higher capacity while mitigating centralization risks.
- 2015, May:** **Testnet, Olympic, launched**
- 2015, 30 July:** **Genesis block created**
With first live release of Ethereum, Ver 1 Frontier.
- 2015, September:** **Ethereum "Ice Age" programmed**
To increase block difficulty exponentially to incentivise miners to move from PoW to PoS.
- 2016, March:** **Ver 2, Homestead, released.**
Marks the exit from a beta product to a stable release. Homestead is introduced automatically at block number 1,150,000.
- 2016, April:** **Decentralised Autonomous Organisation (DAO) launched**
Raised over \$150m by end of May.
- 2016, June:** **Bug in DAO code exploited and attacked**
\$50m investor funds taken. Decision to hard fork the Ethereum network to refund the DAO holders. Hard fork schisms users - some decide to stay on the original chain, continuing as Ethereum Classic.
- 2017, October:** **Ver 3.0, Metropolis phase 1:**
Byzantium.
- 2018, January:** **Ethereum trades at all time high of USD\$1,420.65**
- 2018, Oct Delay:** **Ver 3.1, Metropolis phase 2:**
Constantinople hardfork to introduce Casper Hybrid.
- 2019, Jan Delay:** **Ver 3.1, Metropolis phase 2:**
Move to Casper Hybrid dropped.
- 2019, February:** **Ver 3.1, Metropolis phase 2:**
"Double hard fork" of Constantinople and St. Petersburg.
- 2019, May:** **Hard deadline to accept proposals for " Ver 4, Istanbul"**
- 2019, July:** **Soft deadline for major client implementations**
- 2019, August:** **Projected date for testnet-hardfork (Ropsten, Görli, or ad-hoc testnet)**
- 2019, October:** **Projected date for mainnet-hardfork ("Istanbul")**
- 2020-21(Projected):** **Ver. 5, Serenity**
The final phase of Ethereum 2.0 leading to implementation of Casper, Proof-of-stake and the Beacon Chain.

The evolving ICO model

Ethereum allows developers to build multiple operations into its code - opening the door to a wide range of decentralized applications. One of the most popular ways to utilize the Ethereum platform has been as a channel for token issuance using the framework set by the Ethereum foundation in the [ERC-20 protocol standard](#). The ERC-20 framework lets developers issue their own tokens, and raise funds by selling these tokens via an [Initial Coin Offering \(ICO\)](#).

An ICO is similar to the [crowdfunding model](#). Backers receive newly created tokens in exchange for value transfer mediums such as ETH or BTC. The ICO ecosystem raised billions of US dollars during an extended boom period that lasted through most of 2017. Projects like EOS, OmiseGo, and Tezos raised sizable market caps purely through public fundraising ICO sales.

The ability for projects to create and issue tokens and raise capital is rapidly evolving, however. The ERC20 Ethereum based ICO model has fallen out of favor due to regulatory uncertainty and a perception that many ICO projects were of dubious quality, and have failed to deliver.

ICOs are giving way to IEOs (Initial Exchange Offerings) and [STOs \(Security Token Offerings\)](#). These new models offer several advantages over ICOs, for both issuers and investors. However, we are currently in a transition period as the industry moves towards building out the infrastructure and regulatory framework required to support the highly anticipated STO model.

In the meantime, several platform blockchains are competing to offer developers alternatives to Ethereum for Dapp deployment and token issuance. These include [NEM](#), [EOS](#), [Tezos](#), [Waves](#), and [NEO](#) - with each protocol promising 'improvement' over Ethereum's development process by increasing the base layer efficiencies in transaction throughput, execution costs, and dev tools.

Additionally, projects such as Polkadot, [Cardano](#), and [Zilliqa](#) plan to launch new platform blockchains in the next 1-2 years, creating further token issuance options.

In this fast-evolving environment, token issuers are open to alternative platforms to Ethereum and in some cases, reissuing already launched tokens on new chains with different feature sets.

Ethereum is at a crossroads: Istanbul and Serenity

Heading into the latter part of 2019, Ethereum finds itself at a crossroads. In its current state, it has failed to provide working solutions for enterprise customers. Despite an easy to understand 'world computer that powers the decentralized internet' narrative, real-world applications and market-ready enterprise-grade solutions powered by Ethereum are few and far between.

Due to the twin threats of a multitude of competitors and the growing impatience of a developer/client base that expects Ethereum to enable real-world solutions, the project is scheduled to make two major network updates in the next six months. The first of these, Istanbul, is a hard fork set to occur in October 2019 that will complete the Metropolis stage of Ethereum development.

The second and far more ambitious update, Ethereum Serenity (or Ethereum 2.0) is scheduled to begin in January 2020. The Serenity update will launch an entirely new blockchain with fresh core features like database sharding and a proof-of-stake consensus.

For token projects and Dapps already hosted on Ethereum, the project's current near-term roadmap is either a reason for optimism or anxiety. Both network updates propose to increase Ethereum's efficiency, allowing it to handle more transactions in shorter time frames, with more security while retaining the core values of decentralization and robust consensus.

However, Ethereum is a project with a future vision that is based on multiple moving parts. Some of the proposed updates within Istanbul and Serenity overlap and conflict with each other, and Ethereum developers and stakeholders continue to aggressively debate the effectiveness of individual proposals within each update.

A further complication is the fact that Ethereum has a chequered history related to [pushing dates back on project deadlines](#). These factors make it difficult to get a clear understanding of what the Ethereum ecosystem will look like at this time next year.

Some details are clear, however. Ethereum will conduct the Istanbul hard fork in October before Serenity begins rolling out, and it is expected that the post-update chain will operate alongside the new Ethereum chain (Ethereum 2.0) for at least the next 5-10 years, independently as Ethereum 1.0. These circumstances mean the Ethereum ecosystem will operate with 2 chains, new and old (1.0 and 2.0), for an extended transitional period.

This report assesses the future state and development progress of the October 2019 Ethereum 1.0 Istanbul hard fork. It considers the improvement proposals already approved (but not yet implemented or tested), as well as the major discussion points and their implications. We also focus on Istanbul's proposed hashing switch from Ethash to ProgPoW, a fundamental change that will affect numerous stakeholders across the Ethereum and Dapp building ecosystems.

Diving into the Istanbul hard fork

Ethereum Investment Proposals and suggested fixes for ETH 1.0

Ethereum is scheduled for its next major update – Istanbul – in mid-October. The backward-incompatible hard fork will complete the second half of the Metropolis stage in Ethereum’s development cycle.

The Istanbul hard fork currently has **28 possible Ethereum Improvement Proposals (EIPs)** packaged within it. It is one of the most ambitious and significant backward-incompatible Ethereum forks. Major changes include a change to the blockchain’s mining algorithm, its code execution, and its data storage process.

The changes within Istanbul have been designed to increase the capacity of the Ethereum blockchain and ensure a high level of network decentralization in the short-to-medium term. Presently it is difficult to assess the true potential of the Ethereum platform. Hardcoded limits on computations per block mean that Ethereum can handle about 15 transactions per second across its network, which compares unfavorably to the 45,000 transactions per second offered by payment processor VISA.

Ethereum’s inherently slower rate of execution is because it is designed to be a platform that allows for more flexible and complex smart contracts, however, these design choices have translated into long wait times and a frustrating user experience. Additionally, Ethereum transaction fees are variable (non-deterministic) and users are often charged **unexpectedly high fees** for attempting to execute more complex operations, or due to their own inexperience interacting with smart contracts.

The fundamental network fixes within both Istanbul and ETH 2.0 are designed to make Ethereum cheaper, faster and more scalable for developers and end-users, without sacrificing the core design philosophies of decentralization and the flexibility to build anything.

Ethereum Istanbul development schedule

Date	Update
1st January 2019	projected date for mainnet-hardfork ("Constantinople")
17th May 2019	hard deadline to accept proposals for "Istanbul"
19th July 2019	soft deadline for major client implementations
14th July 2019	projected date for testnet-hard fork (Ropsten, Görli, or ad-hoc testnet)
16th October 2019	projected date for mainnet-hardfork ("Istanbul")

Source: Official Ethereum Github

Some EIPs within Istanbul such as [1108](#), which involves re-pricing the elliptic curve arithmetic pre-compiles that Ethereum uses, have already been approved by the core dev team. The update has the potential to assist several scaling and privacy solutions building on the platform by making small adjustments to network gas fees.

Approved Ethereum Invest Proposals (EIPs)- Istanbul Hard Fork

EIP	Title	Simple Summary
EIP 1057	ProgPoW, a Programmatic Proof-of-work	A new proof-of-work algorithm to replace Ethash that utilizes almost all parts of commodity GPUs.
EIP 1072	Generalized Account Versioning Scheme	Introduce Account Versioning for smart contracts so upgrading the VM or introducing new VMs is easier.
EIP 1108	Reduce alt_bn128 precompile gas costs	The elliptic curve arithmetic precompiles are currently overpriced. Repricing the precompiles will assist privacy and scaling solutions on Ethereum.

Source:

https://docs.google.com/spreadsheets/d/1Mgo7mJ6b6wimUwafsMo1I-b44uec28E_Hq8EQ7YdeEM/edit#gid=0

A proposal within Istanbul that immediately stands out is EIP 1057, a change to Ethereum's proof-of-work mining algorithm that will replace Ethash with the newly created ProgPoW. Earlier this year [funding for ProgPoW hardware security audits](#) was approved with 94% favoring votes from coin holders and 100% from miners. However, the successful coin vote only had a voter turnout of ~3%.

ProgPoW is designed to allow for broader participation within Ethereum mining by reducing the efficiency gap between GPU and ASIC miners.

Progressive proof-of-work and how mining Ether is set to change: GPUs, ASICs, and hashrate

One of the value propositions of Ethereum for miners is that it is ASIC chip resistant and requires only general-purpose (GPU) chips for mining. ASIC chips are a bespoke chip designed for the task of mining a particular cryptocurrency. This results in more competition for the rewards and drives the network hashrate and mining difficulty exponentially higher. The consequences of a network integrating ASIC mining is that GPUs become obsolete - and power overheads for miners increase.

Ethereum currently uses the Ethash hashing algorithm to encrypt data and secure transactions on the Ethereum blockchain in a similar fashion to Bitcoin, although there are some quantitative differences. For example, Ethereum blocks are added to its blockchain every 15 seconds while Bitcoin blocks are added every 10 minutes.

Ethash was designed to be incompatible with the ASICs that are used to mine other PoW cryptocurrencies such as Bitcoin. Ethash is deliberately memory intensive and optimized for GPU miners. However, as hardware evolves, developers are incentivized to develop ASIC miners capable of mining Ethash.

ASIC chip makers Innosilicon and Bitmain both currently have three ASIC miners available for the Ethash algorithm, while a new ASIC mining chip from a third mining company, Linzhi, is being built. If implemented, ProgPoW will make any current Ethash ASICs unable to mine the Ethereum chain. Prospective Ethash ASICs miners may choose to mine the Ethereum Classic (ETC) chain, which also uses the Ethash algorithm.

Ethereum historically secured its network through less powerful but more distributed GPU miners, however, the network's growing operations and the constrained hardware used by miners has created concerns as to whether Ethereum can scale long term. Given these scaling challenges, the core developers behind Ethereum have suggested a number of fixes to solve the scalability challenge.

A switch to a proof-of-stake consensus model seems inevitable as part of the launch of the Ethereum 2.0 Serenity beacon chain that is scheduled for January 2020. This may reduce decentralization, however, it would ease electricity requirements and create new value for ETH as a programmable store of value. The development and implementation of ProgPoW into Ethereum 1.0 will run concurrently alongside the launch of the Ethereum 2.0 beacon chain launch.

"Ethereum 2.0 (Serenity) won't be fully rolled out for another 2-3 years with Phase 0 and Phase 1 due within 1-2 years and Phase 2 due sometime in 2022. Ethereum 2.0 is being deployed as a separate blockchain so it does not supersede ETH 1.0 which means the chain needs to be sustainable for another 5-10 years."

Source: [Ethhub.io](https://ethhub.io)

The transition from ETH 1.0 to 2.0

There are several paths ETH 1.0 could take to maintain operations for the next 5-10 years to accommodate those developers, who for whatever reason, are not equipped to migrate immediately. Ethhub.io hosts a useful summary of the [possible migration strategies for making the shift from ETH 1.0 to ETH 2.0](#).

One option is that ETH 1.0 could run as a separate chain (one-way bridge) from ETH 2.0. It would have a native Ether 1.0 token with its own unique value and Dapp ecosystem. ETH 2.0 would run as a separate chain, with a separate token and ecosystem. Users would have an option to switch over at any time. This option would mean the new chain would launch with a new token. ETH 1.0 chain participants will be able to lock their Ether up in a contract and will be credited with that same amount of Ether on the Beacon Chain in ETH 2.0.

A less contentious option may be to integrate ETH 1.0 underneath and secure it by using the ETH 2.0 proof-of-stake consensus which will launch as part of Serenity in January 2020 (two-way bridge).

There are implications for either migration route. If a one-way bridge is established, current ETH holders will double their tokens by receiving new Beacon Ether (BETH) tokens as a result of the new chain launching. However, for backers of ETH 2.0, there are clear risks associated with migrating to the new chain as early adopters. If the new Beacon chain is not popular or Ethereum 1.0 has a resurgence, then transitioning to a new chain may become redundant. With a one way bridge, there are lock-up risks associated with transitioning to the new chain and this may stifle the initial growth of the Beacon chain.

If a two-way bridge is set up and the Beacon chain launches with ETH 1.0 built into it using a modified consensus model, this would mean that the two chains would coordinate around a single native currency, the existing ETH token. But choosing this option would likely slow down the shipping and iterating of ETH 2.0. Porting existing ETH 1.0 Smart contracts with a two-way bridge will add code complexity to the migration process. Ethereum foundation researcher Danny Ryan [explained](#);

"The more we encumber the 1.0 consensus with 2.0, the more we tie the development and fork processes which would likely slow down the shipping/iterating on 2.0."

However, the two-way model would allow for easier deposit flows between chains with less lock up-risk and immediately incentivize ETH 1.0 developers to experiment with building solutions for the new chain.

One-Way Bridge

Pros	Cons
Security, User deposits go up with a new token created and matched 1-for-1 with ETH	High Lock up risks for at least 1-5 years
Less complicated initial release	Futures market speculation and exposure
Forks going forward can be chain specific	Community fragmentation

Two-Way Bridge

Pros	Cons
Less lock-up/Holding risk, more likely to observe users increasing deposits	Chance that entire stake could be negatively affected by Serenity launch.
Would mean that ecosystem would continue with the single existing ETH token but issuance would have to be adjusted	Will involve additional code challenges in early stages
If ETH 2.0 runs into challenges, can coins can be brought back to ETH 1.0.	With lockup risk now less, it is suggested that there will be 'games' played on early code.

Based on a table originally found in:

<https://docs.ethhub.io/Ethereum-roadmap/Ethereum-2.0/eth-1.0-to-2.0-migration/>

Governance challenges & managing stakeholders

In this context, the timing of the major updates suggested within Istanbul make more sense. The two chain strategy to ease the transition between Metropolis and Serenity may work for developers who are not willing to make the disruptive jump to a new chain. Reasons for developer reluctance to shift might be real-world factors such as client demand and preset roadmap goals.

Some observers remain unconvinced as to why the Ethereum foundation is pushing for a major transition to ProgPoW, just a few months before another update that will significantly affect miner performance and incentives (proof-of-stake, Beacon chain). The ProgPoW has been assessed negatively by community figureheads such as [Ameen Soleimani](#) and [Martin Koppelman](#) who see it as a distraction from Ethereum's primary goal of transitioning to a proof-of-stake network. The low turnout for the coin holders vote to determine whether security audits for ProgPoW should begin and be funded by the Ethereum Foundation suggests apathy for the progress of the EIP from the ETH token holding community.

A key factor to consider is who the hard fork will benefit and the practical stakeholder incentives built into EIP 1057.

Complicating matters is the fact that major stakeholders are affected by this decision. US chip-maker Nvidia, for example, will suffer a revenue hit if the current GPU mined PoW model used by Ethereum transitions to a less power-intensive proof-of-stake model or begins to implement more off-chain scaling models as suggested by proposals within the ETH .1x updates.

Nvidia has been a direct beneficiary of the growth of the Ethereum network, as it has created new demand for Nvidia GPUs to be used for mining purposes. Similarly, during periods when Ethereum suffered from negative sentiment, lagging fundamentals, and bearish prices in mid-to-late 2018, Nvidia's stock price also suffered.

ETH vs Nvidia price comparison

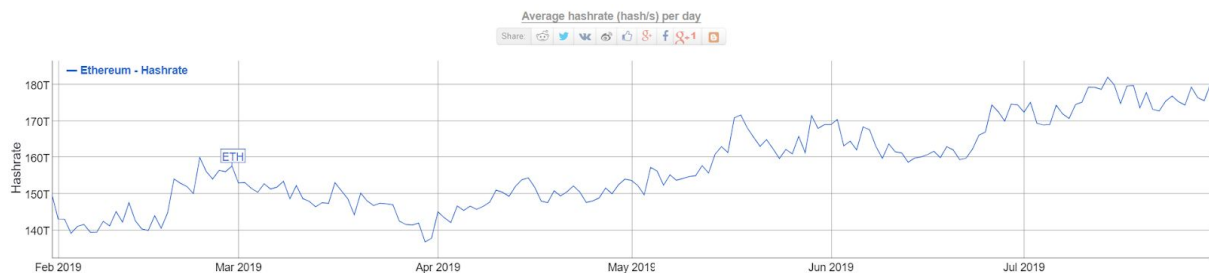
Prices in USD across the last 3 years



ETH daily time weighted spot price (BNC Ethereum Liquid Index API) and NVIDIA Corporation (NVDA) NasdaqGS Real time price. End-of-day price comparison. NasdaqGS data collected from [Yahoo Finance](#).

Following accusations of **favoritism** towards Nvidia earlier in 2019, the team behind the ProgPoW update did **reveal that they were working with Nvidia**, and another major GPU chip maker, AMD, on the update. Email reviews for ProgPoW have been conducted between the Ethereum Foundation, Ethereum core devs, and engineers from Nvidia and AMD - with engineers from the chip makers apparently providing approvals for specific changes suggested to block ProgPoW from becoming ASIC minable by rigs from Bitmain and Linzhi.

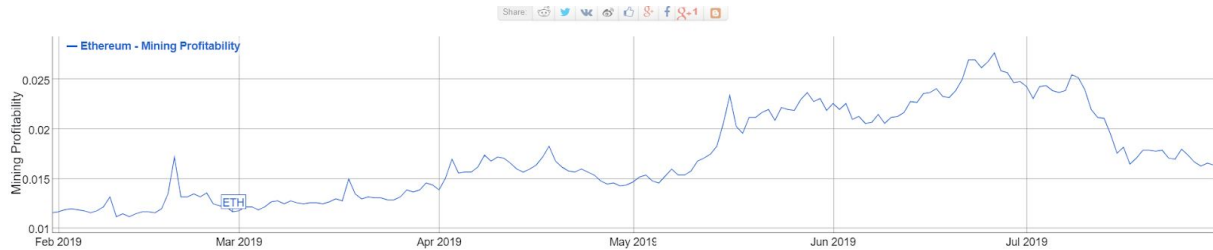
The new ProgPoW hashing algorithm proposes to reduce the computational efficiency between existing Ethereum ASICs and Ethereum GPU miners from 2x to 1.2x with ProgPoW pre-tuned to optimize performance for the most common hardware utilized by current miners. Additionally, during a ProgPoW team review, an AMD engineer stated that in theory it may be possible for an ASIC to be built for ProgPoW but it would require the builder to have GPU-specific knowledge, specifically around memory controllers. Development for ProgPoW appears to be progressing steadily and should delay a potential invasion of ASICs to the Ethereum chain, however, it remains a short term band-aid before a switch by most of the network to Ethereum 2.0 and a less processing power intensive method of securing the network.



Source: [Bitinfocharts.com](#)



Ethereum’s hash rate has steadily risen over the last year and has not been heavily affected by the development of Ethash capable ASIC miners. Other supply factors like the thirdening (Ethereum block rewards falling from 3 ETH and 2 ETH) and the reset of the **difficulty bomb**, have also not had an extreme impact on price.



Source: Bitinfocharts.com

However, falling recent price falls for ETH have affected sentiment surrounding the short term willingness of GPU miners to stay on in the face of falling mining profits. Since June 26, the price of ETH has fallen ~39% in USD terms. If mining profitability continues to dip driven by external factors, there is a chance unprofitable GPUs may switch off and there will be a push towards more efficient ProgPoW mining if the bearish price trend continues.

Conclusion: Istanbul is a cautious, necessary approach

Discussions surrounding the implementation of the Istanbul hard fork have divided the Ethereum community. The fork makes base layer improvements to the current ETH 1.0 blockchain that will increase capacity and make it cheaper and faster to use. It also addresses concerns over the network’s mining structure and state of decentralization.

ETH 2.0 Serenity will eventually arrive and current Ethereum holders will have to make the transition to the Beacon chain network. However, this transition is likely to be a long and drawn-out process with the new chain only expected to become fully usable by 2023/2024. The perspective that Istanbul and other ETH 1.0 base layer improvements are distractions that take time and focus away from ETH 2.0, is valid. However, the reality is that ETH 1.0 will have to support a large portion of its existing user base for at least the next five years.

A robust and improving ETH 1.0 chain running alongside ETH 2.0 will ease the transition for developers and stakeholders already deeply attached to the current version of the Ethereum blockchain.

Current ecosystem builders and managers should be able to ease their transition to the new proof-of-stake infrastructure, without immediately re-configuring already functioning Dapps and smart contracts. This process will be easier if ETH 1.0 is integrated to ETH 2.0 as a two-way bridge. This option would remove token lock-up risks and incentivize immediate building on the new ETH 2.0 chain.

John Dudley, the CEO of Vulcanize and an influential Ethereum community figure, suggested that the crux of Ethereum’s current governance and decision making challenges boils down to **“the World Computer chickens coming home to roost”**. Ethereum has accumulated a sizable market cap of ~US\$22,533,383,523 and an entire ecosystem of developers, who have already signed paying clients.

Much of this invested capital (human and financial) has been driven to Ethereum because of a belief in the 'World Computer' narrative. Market sentiment suggests that as Ethereum has failed to deliver on its early promise, exposed stakeholders are now losing patience - putting Ethereum core developers under pressure to deliver immediate solutions. To meet the needs of currently deployed Dapp builders and clients, changes to the base layer ETH 1.0 have to be made - and quickly.

At face value, making a major update to an existing product a few months before it is scheduled to be replaced with a new product, may appear strange. However, circumstances have put Ethereum developers in a position where they will have to manage and optimize the performance of two blockchains for at least the next five years.

Unfortunately, the nature of the changes within Istanbul has created political issues and governance challenges. Managers of the Ethereum ecosystem such as the Ethereum Foundation and the [Ethereum Cat Herders](#) development team have had to manage the interests of some stakeholders who are focused on the incoming Ethereum 2.0 solution suite, versus others who for entirely understandable reasons don't want to see the end of ETH 1.0.

Colloquially put, Ethereum has found itself between a rock and a hard place and the rollouts it has scheduled reflect the realpolitik of being unable to please everybody all-the-time - but nonetheless should ensure the blockchain's survival for the foreseeable future.

Sources and further reading on Ethereum:

Introductory reading

- Ethereum.org's resource hub- <https://www.ethereum.org/learn/>
- 101 content and background- <https://blockgeeks.com/guides/ethereum/>
- Updated roadmap and ongoing development details- <https://docs.ethhub.io/ethereum-roadmap/ethereum-1.x/>

Analysis and Opinions

- Recent fundamental and technical analysis of ETH, Josh Olszewicz- <https://bravenewcoin.com/insights/ethereum-price-analysis-mainnet-turns-four-years-old>
- Economically Linking Ethereum 1.0 & 2.0, Bryant Eisenbach- <https://medium.com/@fubuloubu/economically-linking-ethereum-1-0-2-0-e5af0fec02ed>
- Exploring Elliptic Curve Pairings, Vitalik Buterin- <https://medium.com/@VitalikButerin/exploring-elliptic-curve-pairings-c73c1864e627>
- Kicking Off Our Review of ProgPoW, Liz Steininger (Least Authority) - <https://medium.com/least-authority/https-medium-com-least-authority-kicking-off-our-review-of-progpow-be1368ae9a50>
- 13 Questions about Ethereum's Movement to ProgPow, John Scott Stevens (Altcoin magazine)- <https://medium.com/altcoin-magazine/13-questions-about-ethereums-movement-to-progpow-e17e0a6d88b8>
- The Challenges of Building Ethereum Infrastructure, Jameson Lopp- <https://blog.lope.net/the-challenges-of-building-ethereum-infrastructure/>
- Vulcanize CEO Rick Dudley: Ethereum's roadmap isn't ambitious enough, Adriana Hamacher (Decrypt media) - <https://decrypt.co/6136/vulcanize-rick-dudley-ethereum-roadmap-makerdao-polkadot>
- Why There is No "Ethereum Killer", Eric Olszewski- <https://medium.com/@eolszewski/why-there-is-no-ethereum-killer-cf99b821a6b0>

Author Bio

Aditya Das



Aditya is a market analyst & digital asset researcher, with a focus on fundamental analysis and factors affecting the inherent value of digital assets. His analysis and opinions have been featured in MarketWatch, Reuters, The Globe and Mail, and Coin Telegraph.

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