STANDARD KEPLER

RESEARCH

FOUNDATION

EOS: An Introduction

TECHNOLOGY REPORT | 2 JANUARY 2019 (V1.00)

1. EXECUTIVE SUMMARY

The following foundation technology report will examine the past, current, and expected future state of the platform protocol EOS. Await our future supplementary EOS technology commentary to further explore Standard Kepler's opinions on EOS.

The introduction of Ethereum in 2013 facilitated the development of smart contract platforms, yet the crypto community quickly identified the weaknesses of the associated Proof-of-Work algorithm. These weaknesses are closely linked to the scalability trilemma and rising transaction fees, with the Ethereum network being considered secure and decentralized, yet insufficiently scalable. Block.one has attempted to address this scalability trilemma by establishing EOS, a smart contract platform prioritizing scalability and usability for developers when deploying decentralized applications (dApps).

Following in the footsteps of Daniel Larimer's previous projects of Bitshares and Steem, EOS adopts Delegated Proof-of-Stake (DPoS) as its consensus algorithm. The goal of DPoS is to enable high transaction throughput at low latency, and ultimately achieve unlimited scaling to process millions of transactions per second. The architectural design of EOS hence sacrifices a degree of de-centralization. with only 21 block producers being elected to validate transactions. Zero transaction fees is a core feature of EOS, with block producers instead being compensated via token inflation for block creation. EOS further proposes several notable features, including unique resource allocation and governance models.

Widely considered an "Ethereum Killer", EOS raised US$ 4bn during its one-year token sale, the largest token sale to date. The mass adoption of a smart contract platform hinges on the platform's scalability, and we believe EOS has the potential to be the first major competitor of Ethereum. However, EOS is still at an early stage of development with limited use cases, and its success will depend on the platform's ability to achieve sustainable usage, to scale and grow, and to build and implement the many ambitious components of the platform that are currently in a planning stage.

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2. EOS: INTRODUCTION

2.1 BACKGROUND

The concept of Blockchain was first introduced with the advent of Bitcoin in 2008. Bitcoin was the result of advances in a number of technologies, including in distributed ledger technology and cryptography. These advances made possible the recording of transactions on decentralized public ledgers. Bitcoin was the first application of what we today consider "Blockchain 1.0" technology. Over time developers started extending the foundation laid by Bitcoin so as to construct distributed platforms capable of handling executable code: smart contracts. This led to the introduction of Ethereum (also known as "Blockchain 2.0") by Vitalik Buterin, the first blockchain enabling developers to deploy decentralized applications (dApps). As developers started to deploy dApps it became apparent that Ethereum struggles to handle bulk transaction volumes, a result of its limited scalability, high latency, and low transaction throughput.

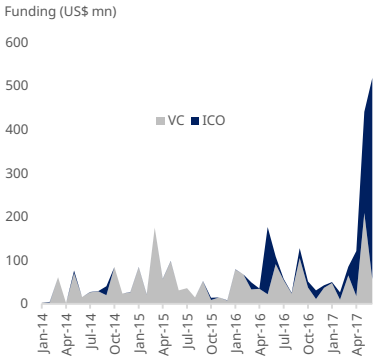
The shortcomings of Ethereum has led to the rise of EOS, a compelling candidate for the title of "Blockchain 3.0" with promises of significant enhancements to both scalability and usability. EOS' founder Daniel Larimer attempted to address the scalability problems of Ethereum by adopting Delegated-Proof-Of-Stake (DPoS) as consensus mechanism in EOS. Prior to being implemented in EOS, DPoS was first adopted in two application-specific blockchain projects also led by Larimer – Bitshares (a decentralized exchange) and Steem (a social media platform). These two projects proved successful in enhancing transaction throughput, and at easing the scalability problems related to Ethereum. Larimer then joined Block.one (a Cayman Islands company) in April 2017 as Chief Technology Officer (CTO), and Block.one announced the project of EOS at Consensus in May 2017, a blockchain powered by EOSIO software with the goal of enabling the horizontal and vertical scaling of dApps.

The cryptocurrency market experienced rapid growth in 2017, with Bitcoin's market dominance first dropping below 50% in May of 2017. The total market capitalization of cryptocurrencies first exceeded US$ 100bn in Q2 2017, a 4x quarterly increase. ICOs proved to be the leading method of fundraising for the blockchain sector in 2017 and 2018, with contributed funds exceeding that of venture capital by 3x in Q2 2017 (*see exhibit 1*). In May 2017, crypto industrial events such as Ethreal, Consensus and Token Summit focused the crypto community's attention on the challenges of scalability for smart contract platforms. Announced at Consensus in May 2017, EOS generated ample hype among investors with its promises of near unlimited scalability, and it commenced fundraising via an ICO on 26 June 2017. With a promising proposed path towards scalability, proven team, and unprecedented hype in the ICO market, EOS eventually raised a total of US$ 4bn, the largest amount of funds raised via a token sale to date. Despite its recent establishment in 2017, EOS is currently the 5th largest cryptocurrency in terms of market capitalization, with a market cap of US$ 5.34bn (as of 10 October 2018).

"Software code is an imperfect approximation of the needs of a community."

- Daniel Larimer,
Founder of EOS

Exhibit 1: Monthly Blockchain Funding via VCs and ICOs



Source: Coindesk, Standard Kepler Research

2.2 PRICE TREND

EOS launched its token sale on 26 June 2017, with its price at one point reaching US$ 5.4 in early July under the booming ICO market (*see exhibit 2*). The price of EOS started its downward trend from late July to October 2017 following the regulatory decision that DAO tokens (*see exhibit 3*) are securities by the U.S. Securities and Exchanges Commission (SEC), and the shutdown of crypto exchanges OKCoin and Huobi in China.

EOS' price rebounded following the introduction of CryptoKitties on the Ethereum blockchain (*see exhibit 4*), and the release of EOSIO Dawn 2.0. The price of EOS kept rallying following the Bitcoin futures launch by CME Group, and the formation of EOS VC. EOS' price exhibited another downward trend from late January to mid-March 2018 following the hack of crypto exchange Coincheck, and once reached US$ 5.3 when Google and Twitter announced their banning of crypto related advertising.

The price of EOS started to bounce back with the release of EOSIO Dawn 3.0 and hit an all-time high (ATH) of US$ 22.9 in anticipation of the release of EOSIO Dawn 4.0. Despite the launch of the EOS blockchain and completion of EOS' US$ 4bn ICO in June, EOS' price once again entered a downward trend due to a tightened regulatory environment, concerns surrounding the EOS governance model, and the overall negative market sentiment. EOS is priced at US$ 2.4 as of 18 December 2018. A detailed pricing curve of EOS/US$ and key market events can be viewed in *exhibit 5*.

Exhibit 2: EOS' US$ 4bn ICO

EOS was originally an ERC20 token built on the Ethereum blockchain, being initially launched at a price of EOS 1 = US$ 0.99 (ETH 0.00327) in the EOS token sale. EOS' ICO ended on 1 June 2018 with US$ 4bn raised, replacing the US$ 1.7bn Telegram private pre-sale as the largest ICO to date.

90% of the EOS tokens were distributed via public sale. Of these 90%, 20% were released during the first five days of the EOS ICO (26 June – 1 July 2017), and the remaining 70% were evenly distributed into 350 consecutive 23 hour periods of 2mn EOS tokens starting 1 July 2017. The remaining 10% of EOS tokens were reserved by Block.one for EOS ecosystem development.

Exhibit 3: DAO Token

The DAO (decentralized autonomous organization) project was crowdfunded via a token sale in May 2016.

Exhibit 4: CryptoKitties

CryptoKitties is an Ethereum blockchain-based virtual game that allows its players to purchase, collect, and breed virtual cats.

Exhibit 5: EOS/US$ and Key Market Events

Note: See Next Page for Key
Source: Standard Kepler Research

EOS Market Events

1. EOS launched its ICO
2. Release of EOSIO Dawn 1.0
3. Release of EOSIO Dawn 2.0
4. **i.** Richard Jung joined Block.one as Head of Korea
   ii. Formation of EOS VC
5. Block.one announced joint venture of US$ 325mn EOSIO Ecosystem Fund with Galaxy Digital LP
6. **i.** EOSIO updated Stack Exchange Proposal
   ii. Block.one announced US$ 100mn JV with FinLab AG to support EOSIO projects in Europe
7. **i.** Release of EOSIO Dawn 3.0
   ii. Block.one announced US$ 200mn JV fund, EOS Global, with blockchain veterans Michael Cao and Winnie Liu
8. Release of EOSIO Dawn 4.0 on 7 May 2018
9. **i.** Release of the EOS blockchain
   ii. EOS ICO reached US$ 4bn milestone
   iii. Block.one launched US$ 50mn EOSIO Fund with SVK Crypto
10. Activation of the EOS blockchain as 15% voting threshold was reached
11. **i.** EOS RAM price reached all-time high of EOS 919/MB
    ii. Michael Alexander joined Block.one as CEO of EOS VC
12. Block.one closed strategic investment round led by Peter Thiel and Bitmain

Crypto Market Events

1. The SEC classified DAO tokens as securities
2. Crypto exchanges OKCoin and Huobi announced shutdowns of their Chinese operations
3. CryptoKitties led to congestion of the Ethereum network
4. CME Group launched Bitcoin futures
5. Hacking incident of Japanese exchange Coincheck
6. Twitter, Google announced bans on crypto ads
7. Bloomberg launched Bloomberg Galaxy Crypto Index with Galaxy Capital Digital Management
8. SEC announced Ethereum is not a security
9. Facebook reversed the ban on crypto ads
10. The U.S. SEC rejected BTC ETF application by the Winklevoss Twins
11. The U.S. federal judge's decision on U.S. Securities Law is applicable to crypto fraud allegations
12. Google announced reversal of crypto ads ban starting October

Exhibit 6: EOS VC Partnership Program

During the Korean EOSIO meetup of 13 January 2018, Block.one announced the formation of its venture capital arm: EOS VC. Block.one made a formal commitment to deploy over US$ 1bn in strategic partnerships with leading venture capital firms for ecosystem development of EOS. EOS VC has thus far announced five strategic partnerships since its establishment.

Tomorrowbc

- Joint formation of US$ 50mn EOSIO Fund
- Date: 16 Jan 2018
- Purpose: Exclusive investment in opportunities utilizing EOSIO software

GALAXY

- Joint venture of US$ 325mn EOSIO fund
- Date: 23 Jan 2018
- Purpose: Development of EOSIO ecosystem

FIN LAB

- Joint venture of US$ 100mn fund
- Date: 21 Mar 2018
- Purpose: Focus on EOSIO projects in Europe

Michael Cao & Winnie Liu

- Joint venture of US$ 200mn fund with Michael Cao & Winnie Liu of EOS Global
- Date: 6 Apr 2018
- Purpose: Focus on EOSIO projects in Asia

SVKCrypto

- Joint formation of US$ 50mn EOSIO fund
- Date: 2 Jun 2018
- Purpose: Support dApps in social media, data ownership & control, tech platform, supply chain logistics built on the EOS blockchain

3. EOS: CONSENSUS MECHANISM

Developed under an open-source MIT license, the EOSIO software serves as the operating system of the EOS blockchain. The EOSIO software utilizes Delegated Proof-of-Stake (DPoS) as decentralized consensus algorithm, so as to pursue the vision of an unlimited scaling potential able to handle millions of transactions per second, and to eliminate transaction fees for end users.

3.1 DELEGATED PROOF-OF-STAKE

As the consensus algorithm of EOS, Delegated Proof-of-Stake (DPoS) was invented by Daniel Larimer in 2013. Utilized alongside Graphene technology (*see exhibit 7*), DPoS was adopted in Larimer's previous projects of Steem and Bitshares.

It is worth noting that tokens utilizing DPoS currently process the highest quantity of transactions on Blockchain on both a daily and weekly basis. Despite the relatively recent activation of the EOS blockchain in June 2018, it already processes 0.69mn transactions on a weekly average, and is ranked third in terms of total transactions processed on blockchain (as of 10 October 2018) (*see exhibit 8*). As pioneers in utilizing DPoS, Bitshares and Steem have both proven to be more scalable than Bitcoin and Ethereum with more transactions processed on blockchain.

There are two key components of the EOS DPoS consensus algorithm: the election of block producers (BPs), and scheduled block creation.

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Exhibit 7: Graphene Technology

Developed by Cryptonomex, Graphene technology is an open source toolkit for real-time blockchains, primarily written in C++. Graphene based systems go beyond mere "checkbook" style payments to offer a broad range of financial services distinguished by transparency and inherent incorruptibility.

Exhibit 8: Ranking – Most Transactions Processed on Blockchain

#	Token	Consensus Algorithm	Daily avg of Tx on Blockchain	Weekly avg of Tx on Blockchain
1	Bitshares	DPoS	1,932,628	1,635,504
2	Steem	DPoS	841,845	838,414
3	EOS	DPoS	1,621,183	683,637
4	Bitcoin	PoW	610,334	573,347
5	Ethereum	PoW (Turning into PoS)	519,480	526,624

Data as of 10 October 2018.
Source: Blocktivity.info

3.1.1 Election of Block Producers

Under the DPoS algorithm of EOS, 21 individual entities are elected as BPs by token holders of the EOS blockchain. Token holders can become voters by staking their EOS tokens to the EOS blockchain, and they are also able to delegate or proxy their voting power to other EOS accounts.

As of 10 October 2018, 395mn votes (39.50% of total) have been staked to the EOS blockchain and the top 10 BPs with the largest number of votes are shown in *exhibit 9*.

Voting mechanism: Each staked EOS native token can be used to vote for up to 30 different block producer candidates, where each token can represent 1 vote per BP, or 30 votes on different BPs. The votes are weighted on a pro-rata basis from the total number of staked tokens, and the 21 BP candidates receiving the largest number of votes become active BPs.

Block.one adopts a continuous voting mechanism on the EOS blockchain, with votes being recalculated approximately every 2 minutes. Voters can change their votes without restriction, yet tokens will be locked up for 3 days after being un-staked.

Exhibit 9: Top 10 BPs with Largest Number of Votes

#	Entity	Location	No. of Votes	% of Vote	Daily Reward
1	Eosnewyorkio	US	100,307,166	2.16%	806 EOS
2	Eoscannonchn	China	95,897,563	2.07%	785 EOS
3	Eoslaomaocom	Japan	94,324,958	2.03%	777 EOS
4	Starteosiobp	China	93,292,259	2.01%	772 EOS
5	Eoshuobipool	China	91,857,320	1.98%	765 EOS
6	Zbeosbp11111	China	91,712,081	1.98%	765 EOS
7	Eos42freedom	UK	90,160,172	1.94%	757 EOS
8	Eosfishrocks	Hong Kong	90,155,132	1.94%	757 EOS
9	Jedaaaaaaaaa	Japan	89,355,553	1.93%	753 EOS
10	Eosflytomars	Japan	88,153,042	1.90%	747 EOS

Data as of 10 October 2018.
Source: Eostracker.io

Exhibit 10: Activation of the EOS Blockchain

According to the EOS MainNet Launch Group (EMLG), there were 4 phases towards the 14 June 2018 activation of the EOS blockchain.

Phase 1: Verify Snapshot & Boot
The EMLG produced a final snapshot of the frozen ERC-20 EOS tokens using the official snapshot tool. Once the snapshot was verified, the Appointed Block Producers (ABP) were temporarily set up by the EMLG to ensure the network was stable and booted properly throughout the verification and voting process. There were no block rewards given to ABPs at this stage.

Phase 2: Testing
At this stage, the EMLG cloned the network and conducted own in-depth acceptance testing within a 48 hour testing period. If a major bug was detected during the testing, the EMLG could reset the testing period allowing for the testing of proposed bug fixes. The EOS blockchain was opened for third-party verification after the boot process was completed by the ABP, and token balances were verified.

Phase 3: Enable
The EMLG released a statement that the network was now available to the general token holder community. Voters could start voting following the guidelines from the community voting portal, and could safely import their private keys after at least 5 BPs had publish the same statement declaring the safety for other users of doing so.

Phase 4: Activation
Once 15% of total tokens were staked to vote on block producers, the EOS blockchain was activated with normal functions available. At this time, the ABPs were replaced by the elected block producers. The EOS blockchain was officially activated when the 15% vote threshold was reached on 14 June 2018.

Source: EOS MainNet Launch Group (EMLG)

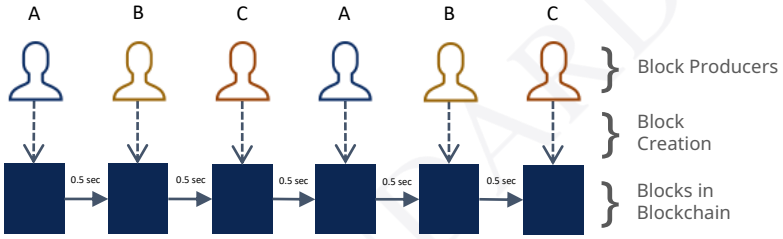
3.1.2 Scheduled Block Creation

Under the DPoS algorithm of EOS, 21 BPs produce a block every 0.5 seconds in a pre-determined order. It is invalid for BPs to produce a block other than in its scheduled time slot. The schedule for block creation must be agreed by more than a two-thirds majority of BPs (i.e. 15 or more BPs), and blocks are produced in rounds of 252 blocks (21 BPs producing 12 blocks each) as shown in *exhibit 11*.

The scheduling algorithm of DPoS provides transparency to the public on the status of block creation. For instance, the existence of a minority chain can be observed based on the frequency of missed blocks. A node can detect a minority chain accurately in 6 seconds in the event of two consecutively missed blocks. This detection provides a warning signal of an unstable network and longer confirmation times. EOS currently does not automatically remove BPs who fail to create blocks. Rather, BP removal is a manual process. This is possible either by an individual BP removing itself (common in the event of temporary technical failures), or by 15 BPs reaching consensus on removing a BP. The latter has not yet occurred, but is an option available to BPs.

On the contrary, a block is deemed irreversible if signatures are received from more than a two-thirds majority of active BPs.

Exhibit 11: Block Creation Schedule of EOS BPs



Blocks created each round: 21 BP x 12 Blocks = 252 Blocks
Each round of block creation takes 0.5 sec x 252 blocks ~ 2.1mins

Source: EOS technical whitepaper, Standard Kepler Research

Exhibit 12: The "Deferred Transactions Bug" Incident

The EOS blockchain was activated on 14 June 2018, but the transactions on EOS MainNet were frozen and paused two days later due to a technical issue whereby the application programming interfaces (APIs) for multiple block producers were not responding. Following an international conference call between block producers and standby nodes, all standby block producers stopped their nodes and performed information backup to diagnose the problem.

The root cause of the incident was identified as a bug related to the handling of deferred transactions. According to issue 4158 of EOS on Github, the EOSIO software was designed to pause the EOS blockchain in the event of a bug being detected, so as to prevent a hard fork. When all BPs reached consensus on detecting this deferred transactions bug they paused block creation.

As a measure to resume the operation of the EOS blockchain, Block.one released a patch tagged 1.0.5. that addressed the "deferred transactions bug", and the EOS blockchain resumed its operations five hours after the incident.

Exhibit 13: The EOS Network Monitor During the "Deferred Transaction Bug" Incident

The red color indicates a "no API response" from a block producer.

Source: EOS Network Monitor.io

3.2 DPOS VERSUS PROOF-OF-WORK

3.2.1 Enhanced Scalability With Significant Savings in Energy Consumption

As the consensus algorithm adopted in Bitcoin, Proof-of-Work (PoW) has received widespread criticism for its limited blockchain scalability due to high associated energy consumption costs. In particular, it is the growing energy consumption of PoW mining that has brought the sustainability of PoW into question. According to Digiconomist, Bitcoin's current (as of 10 October 2018) estimated annual electricity consumption equals 73.12 TWh, a 7.4x increase compared to February 2017 (*see exhibit 14*) and Bitcoin's annualized estimated global mining cost amounts to US$ 3.66bn. If Bitcoin was a nation, it would be the world's 39th largest consumer of electricity, with a consumption similar to that of Austria. Rising electricity costs further poses a high entry barrier for Bitcoin miners, potentially contributing to increased centralization among existing miners.

Mining and physical mining hardware is indispensable to the operating of PoW blockchains, and several major Bitcoin mining pools are located in regions susceptible to unpredictable natural forces. The Sichuan province of China is one such region, offering not only low energy prices, but also periodically adverse weather conditions. The floods on 27 June 2018 severely impacted the operations of mining pools, leading to a loss of "tens of thousands" of mining devices. DPoS removes the reliance on physical mining hardware, with network power instead being measured in votes received, leading to significant operational energy cost savings in DPoS.

3.2.2 Mitigating the Risk of 51% Attacks

Under PoW, Bitcoin could be susceptible to 51% attacks (*see exhibit 15*) if centralized Bitcoin mining pools were to collude and acquire more than half of the network's mining power, resulting in a insufficiently decentralized network vulnerable to double-spending attacks.

Compared to PoW, it is less feasible to launch a 51% attack under the DPoS algorithm because of the costs involved in acquiring a 51% stake of the network. Even if a user owned a 51% stake of the EOS blockchain, there is low incentive to launch a 51% attack as doing so would result in a loss of all wealth staked on the network once the attack is launched.

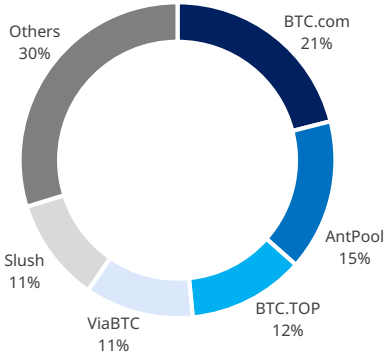
Exhibit 14: Bitcoin's Current Estimated Annual Electricity Consumption (TWh)

Data as of 10 October 2018
Source: Digiconomist

Exhibit 15: 51% Attacks

A 51% attack refers to a potential attack on a blockchain in the event that an organization can control more than 50% of the network's mining hashrate, making it possible for the organization to ultimately control the network and launch double-spending transactions.

Exhibit 16: Yearly Average Distribution of Bitcoin Mining Pools



Data as of 10 October 2018
Source: Blocktrail.com

3.3 DPOS VERSUS PROOF-OF-STAKE

3.3.1 Promoting Fairness and Democracy

Under the Proof-of-Stake (PoS) consensus algorithm the power of decision making rests with wealthy network users. This creates a conflict of interest between decision makers and other users on the blockchain, since decisions on governance and policies tend to favour the decision makers themselves.

The DPoS consensus algorithm under EOS is designed to create a more democratic and decentralized network for token holders. Under DPoS in EOS, 21 block producers are elected for decision making and block creation, with their power being a result of the votes they receive, rather than the stake they hold in the network. The continuous approval voting system is designed to promote fairness on the EOS blockchain, whereby "bad actors" can be voted out for malicious behavior. BPs are thus discouraged from inappropriate behaviour under the threat of losing income and reputation.

3.3.2 Low Risk of Spawning Multiple Chains During a Hard Fork

Under PoS, miners compete against each other to capture the block rewards for mining. Multiple chains are possible when miners publish blocks at the same time.

For EOS' DPoS consensus algorithm, the block creation schedule is pre-defined before BPs commence the block creation process. Each BP can only create one within its assigned timeslot. Instead of competition, BPs are envisioned to cooperate with each other to ensure the smooth operation of the EOS blockchain.

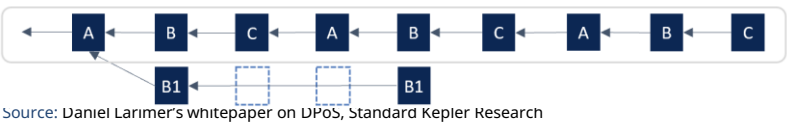
3.3.3 Solution to the "Nothing-at-Stake" Problem

The PoS consensus algorithm is exposed to the problem of "nothing-at-stake" (*see exhibit 17*), whereby in the case of a fork the validator will validate every fork, and collect transaction fees on whichever is the winning fork. Validators staking on every fork leads to disruption of consensus at minimum, and can leave the network more vulnerable to double spending attacks.

Blockchains utilizing PoS have attempted to address the "Nothing-at-Stake" problem. For example, Ethereum's proposed Casper update suggests that validators will be penalized by losing a portion or all of their security deposits if they are found validating multiple forks.

The block creation schedule of EOS DPoS is designed to mitigate the risk of multiple chains during a hard fork. If a BP intentionally creates extra blocks during its assigned timeslot (*see exhibit 18 when the BP "B" intentionally creates block "B1"*), the BP will be voted out and consensus always remains on the longest chain.

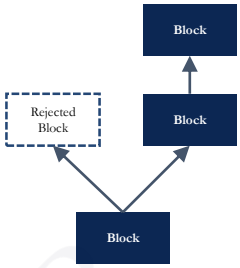
Exhibit 18: Consensus is Always on the Longest Chain



Source: Daniel Larimer's whitepaper on DPoS, Standard Kepler Research

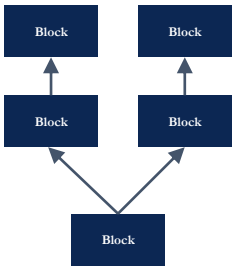
Exhibit 17: Nothing-at-Stake Problem

Proof-of-Work



If a miner split its hash power between two chains, the chance of successfully mining a block will be much lower.

Proof-of-Stake



Under PoS, there is no additional cost for validators to validate transactions on multiple forks in order to capture maximum profits. This leaves the blockchain vulnerable as validators may perform double spending attacks when they validate on multiple forks.

3.4 SUMMARY: CONSENSUS UNDER EOS

Daniel Larimer adopted DPoS as consensus algorithm on the EOS blockchain following the previous successful implementation of DPoS in Bitshares and Steem. Under EOS' DPoS, 21 block producers produce a block every 0.5 seconds in a pre-determined order, and this pre-determined block creation schedule mitigates the risk of spawning multiple chains during hard forks. Block.one adopts a continuous voting mechanism on the EOS blockchain, with votes being recalculated approximately every 2 minutes. This means misbehaving block producers can be voted out to mitigate "nothing-at-stake" problems. DPoS further mitigates the risk of 51% attacks as it is very costly to acquire 51% of the total stake of EOS tokens.

DPoS is a crucial component in EOS' plan to achieve sufficient scalability, as is further explored in chapter 5: EOS Scalability.

4. EOS: NOTABLE FEATURES

EOS introduces a number of notable features. Some of these have been trialled and tested by other sectors, applications, and blockchains, such as the concept of IPFS. Others are truly unique to EOS, and see their first large scale implementation on the EOS blockchain, such as the EOS resource allocation model, and the achieving of zero transaction fees. This chapter outlines key features of EOS that we deem notable. Note that some of the following features are not yet implemented, yet we consider them part of the vision that is EOS.

TABLE OF CONTENTS: NOTABLE FEATURES

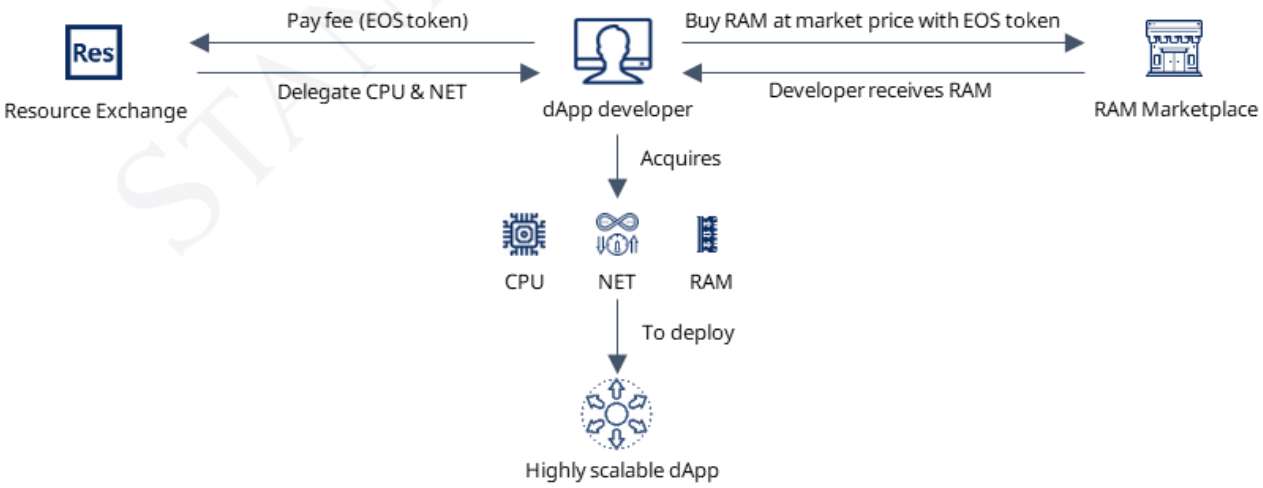
4.1 THE EOS TOKEN MODEL

The project of EOS was announced during Consensus in May 2017. While Block.one has never announced an official definition of EOS the EOS token currently represents the eligibility for users and developers to utilize the resources of the EOS blockchain, developers need to hold EOS tokens to build and run dApps.

4.1.1 The EOS Resource Allocation Model

EOS adopts an as-of-now relatively unique approach to resource allocation, whereby resource allocation is determined via an "ownership" model. The EOSIO software allows each user account to consume a percentage of the available capacity of resources (e.g. bandwidth, CPU and RAM) proportional to the amount of EOS tokens held in a 3-day staking contract. For instance, developers who own 1% of the total stake of the EOS blockchain are entitled to access 1% of total network bandwidth (NET) and storage. An overview of EOS' resource allocation model can be seen in *exhibit 19*.

Exhibit 19: Overview of EOS' Resource Allocation Model



Note: The resource exchange is proposed, and as of November 2018 not implemented.
Source: EOSIO Medium, Standard Kepler Research

4.1.2 Resource Renting Under EOS *(Proposed)*

In August 2018 a proposal for establishing EOS resource renting and rent distribution was presented by Daniel Larimer. The REX is currently feature complete and in a release candidate state, currently being tested on the Jungle testnet.

The EOS Resource Exchange: Under the proposal, a Resource Exchange (REX) would be set up on the EOS blockchain where EOS holders can lend their tokens to the exchange in return for REX tokens. These REX tokens are measured at the current book value of REX, and REX tokens can at any time be exchanged to EOS at book value. Token holders would receive fees as interest when lending EOS tokens to the REX. These fees compensate token holders for the loss of liquidity of their EOS tokens, and will increase the book value of REX. It is further proposed that the REX will generate fees from the renting out of other EOSIO resources.

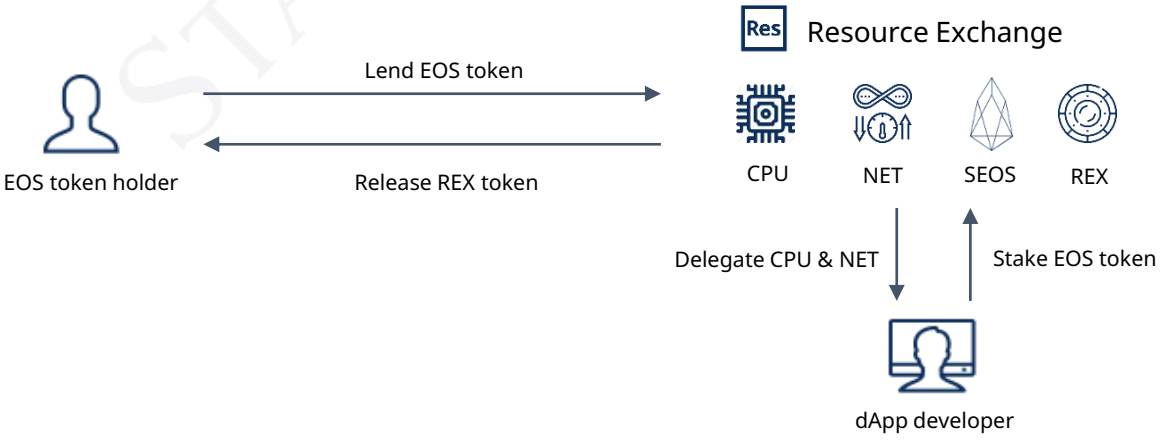
EOS, SEOS, and REX: A number of staked EOS tokens (SEOS) will be created for every EOS token contributed to the REX, so as to provide price transparency for the renting of EOS tokens. Larimer suggests the initial number of SEOS per EOS is 1:1, and that traders can buy and sell SEOS for EOS with a trading fee of 0.5%. SEOS can be converted into delegated EOS for renting either CPU or NET resources for 30 days if it is not sold back to the Bancor Relay. At the end of 30 days, the SEOS is returned to the Bancor Relay connector with a 3 day delay, and is subsequently resold to other renters.

To facilitate the trading of SEOS, the amount of SEOS is inflated at the implied interest rate of the current EOS/SEOS price for 30 days rental, which will increase the number of SEOS required to delegate 1 EOS. The inflation of SEOS serves as an effective interest rate paid to the REX holders who lends their EOS to the REX. The trading market of SEOS/EOS will enable speculators to set the interest rate for 30 day of delegated CPU or NET, which helps to inform the network of the proper rental rates. Higher rental rate drives demand to purchase and hold EOS, which will effectively lower EOS price and network usage costs.

"We believe that this proposal will lower the cost of using the EOS network and decouple cost of CPU and NET use from capital appreciation/loss of EOS. It will make EOS usable by people who do not want to have high exposure to EOS price volatility and it will create incentives to participate in the governance of the EOS network. Not adopting a resource rental model will likely limit the use of EOS to those who are also willing to speculate on EOS price."

- Daniel Larimer,
Founder EOS, on the proposed resource renting & allocation update

Exhibit 20: Proposed Resource Rental & Allocation Model



Source: EOSIO Medium, Standard Kepler Research

4.1.3 Significance: Enabling Zero Transaction Fees

It is worth noting that users do not need to pay transaction fees to utilize the network resources of EOS. Instead, the quantity of resources available to users on the EOS blockchain is determined by the number of EOS tokens staked by said users. This makes the costs of deploying dApps on the EOS blockchain more predictable to developers. The advantages of zero transaction fees are further explored in *section 4.4*.

The proposed REX can theoretically facilitate more efficient resource allocation where holders of EOS tokens can rent out or delegate their tokens (which represent resources capacity on the EOS blockchain such as NET, CPU and RAM) to developers building promising dApps. This proposal aims to lower the costs of using network and CPU resources on the EOS blockchain.

BPs are responsible for acknowledging the delegation or rental of tokens, and for allocating the network's resources to developers accordingly.

4.2 EOS RAM: FREE MARKET RESOURCE ALLOCATION

On the EOS blockchain, RAM is a precious resource for smart contract developers as they use RAM to open user accounts and host dApps. RAM is needed to store critical account information such as keys, balances and contract states.

To achieve a more efficient RAM allocation on the EOS blockchain, Block.one decided to provide financial incentives for users to free up their RAM by using a market-based allocation approach introduced in EOSIO Dawn 4.0. This approach allows buying and selling of RAM at prevailing market prices, which provides liquidity in the EOS RAM market and transparency of RAM prices. RAM is not transferrable and a 1% fee is charged on trades in order to minimize speculation on the EOS RAM market.

The market-based approach of EOS is supported by the Bancor algorithm (*see exhibit 21*) under which the price of RAM increases as the quantity of unallocated RAM on the market decreases. This has the side effect of encouraging hoarding of RAM, which led to the skyrocketing EOS RAM price incident in early July.

4.2.1 Supply of RAM

The supply of RAM is determined by the elected block producers in the EOS community, with the supply being dependent on the hardware of BPs. The total supply of EOS RAM is configured as 78.81GB (as of 10 October 2018). While 46.4GB of these 78.81GB have been purchased, actual usage is currently less than 3%.

4.2.2 Significance: Affordable Network Resources Key to Adoption

On 3 July 2018, the price of EOS RAM skyrocketed to EOS 919/1MB RAM, a 5.1x 24h price increase. The setting of the Bancor (see exhibit 21) connector weight (set at 0.05% instead of 50%, thus allowing heavy slippage of trades) and ram hoarding (whereby developers hedge the risk of future shortages of RAM by hoarding RAM now) are largely held accountable for the incident. The RAM price eventually corrected itself on 4 July 2018, and has remained stable since.

The skyrocketing EOS RAM price incident is significant, as it highlights the importance of affordable network resources in enabling the deployment of dApps and associated novel business models. A high or volatile RAM price can dampen the incentive of developers to deploy dApps on EOS, it may drive developers to other platform protocols, or incentivize EOS dApp developers to shift expenses back onto users. Whether developers can deploy large scale dApps sustainably on EOS still remains to be seen.

Measures to mitigate price volatility of EOS RAM can be explored in *exhibit 22*. The skyrocketing RAM price incident was originally covered in our Weekly Analysis titled "Ram Prices Skyrocket in EOS Dawn Resource Allocation Model".

Exhibit 21: Bancor Algorithm

The Bancor Algorithm facilitates automatic price determination and is an autonomous liquidity mechanism for tokens on smart contract blockchains.

The Bancor connector weight measure the price sensitivity of RAM against its trading orders on the EOS blockchain, with a higher weight indicating greater liquidity and price stability.

Exhibit 22: Measures to Mitigate Price Volatility of EOS RAM

i. Increase RAM supply: Following an update from Block.one, block producers can now specify a sustainable growth rate for the supply of RAM. Under the EOSIO system contract, the action "setramrate" is added where block producers can set RAM supply (in bytes) increases per block. For every RAM transaction, the amount of new RAM is calculated and added to the RAM supply. The RAM price will then be based on the new supply.

The price volatility of RAM can also be reduced by adjusting the Bancor connector weight up from 0.05% to 50%. This can reduce the slippage on large trades and makes the pricing of RAM more predictable.

ii. Lower the memory usage on user accounts: Block.one has performed audits on the actual RAM usage per account and concluded that new account creation only requires 512 bytes, compared to the original setting of 3Kb RAM usage per account. Block.one will this setting to 1.5KB of RAM per account, a 50% decrease to the amount of RAM required for user account creation.

iii. Free accounts with Block.one's iOS wallet: A free iOS hardware wallet using Apple's Secure Enclave is being built by Block.one, and a free EOS account will be attached to this account, lowering the cost for users to open an EOS account. This EOS wallet will be compatible with dApps that support Block.one's wallet API.

4.3 EOSIO STORAGE *(PROPOSED)*

EOSIO storage is a proposed decentralized file storage system. As a service provided by block producers, EOSIO storage is built on the Inter-Planetary File System (IPFS) and the EOSIO software, and provides users with the ability to permanently store and host files on an IPFS network accessible by any web browser.

4.3.1 Inter-Planetary File System

IPFS (*see exhibit 23*) provides a peer-to-peer (P2P) network layer (*see exhibit 24*) that allows computers to discover and share files based on their deterministic names.

On the EOS blockchain, a user can create a link to an IPFS file by signing a transaction that is broadcasted to the blockchain. As defined by the EOSIO Storage Software, the standardized REST Application Programming Interfaces (APIs)(*see exhibit 25*) serve as the platform for users to upload files to block producers. The block producer will announce receiving the file by broadcasting the uploaded transaction on the blockchain after verifying the size and IPFS name of the received file. The received file will then be replicated over an IPFS network by other block producers. The role of IPFS under EOSIO software can be seen in *exhibit 26.*

Exhibit 23: Inter-Planetary File System

IPFS is an emerging standard for storing content addressable files, with all files stored using IPFS being given names derived from the hash of their content. Under IPFS, the same file has the same file name on every computer, and the contents of the file can only be edited if the file name is changed.

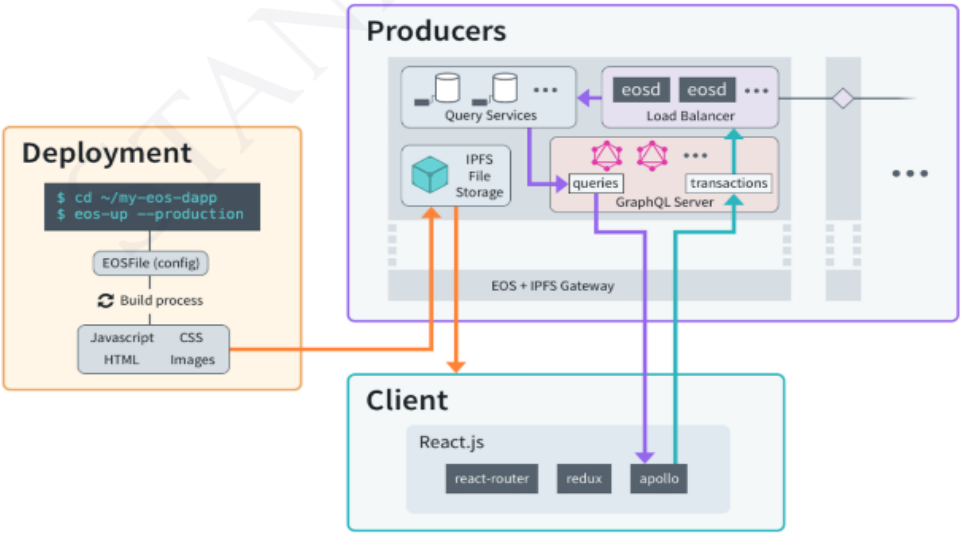
Exhibit 24: Peer-to-Peer Networks (P2P)

P2P networking is a distributed application architecture that partitions tasks or workloads between peers, and peers are equally privileged participants in the application. BitTorrent is a well known communication protocol for P2P file sharing.

Exhibit 25: REST APIs

Representational State Transfer (REST) Application Programming Interfaces (APIs). Under REST APIs, transactions are divided into small modules where each module contains a particular underlying part of the transaction. REST APIs are commonly used in cloud services, with Amazon Simple Storage Service being one well known example.

Exhibit 26: The Role of IPFS under EOSIO software



Source: EOSIO Medium

4.3.2 Storage Supply

On the EOS blockchain, the total storage capacity available is determined by the voting results of BPs, and all BPs are expected to offer storage capacity at the median value of producer votes. BPs are responsible to publish their available capacity for computation, NET and state. This is visible to the token holders and BPs are incentivised to increase their resource capacity in order to acquire more votes from token holders, so as to become of top 21 BPs.

4.3.3 Storage Costs

Storage costs exist so as to compensate BPs for their provision of storage to the network. Token holders who wish to store files on the EOSIO storage will thus be required to stake tokens. Said tokens can only be un-staked or sold once any corresponding uploaded files have been deleted. Holders who request permanent storage will stake their tokens permanently, which essentially means burning said tokens.

The value of the token will appreciate when the rate of new storage requests is locking up tokens faster than the inflation rate of the token. An increasing rate of new storage requests encourages BPs to expand storage supply as the tokens paid to them increase in value.

4.3.4 Significance: Linking Smart Contracts to Data Files

Storing data in a blockchain's transaction log or blockchain state is not a viable solution for decentralized bulk data storage, as blockchains 1) rely on decentralization for security, 2) periodically truncate data, and 3) replicate data across the whole network.

IPFS is a solution to this problem, whereby only the IPFS name of a file is stored on the blockchain. IPFS storage makes it possible to ensure that smart contracts are pointing to specific and incorruptible files since it is impossible to modify an IPFS file without also changing the file's name.

IPFS does not however ensure the availability of said file, it only serves to verify the integrity of the file, so as to support the linking of smart contracts and data files.

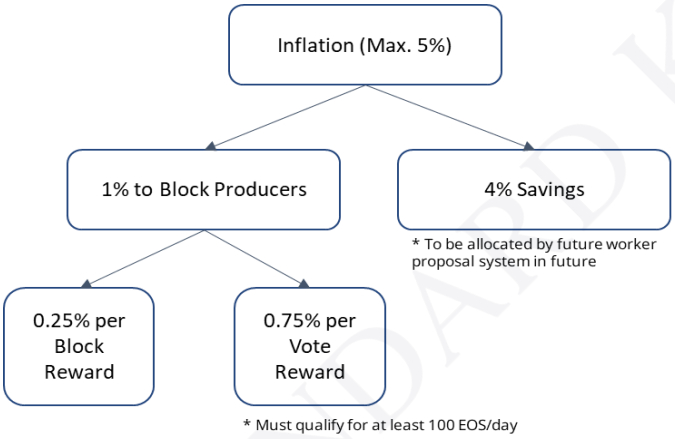
4.4 ZERO TRANSACTION FEES

Transaction fees have been a major source of income for miners on the Bitcoin and Ethereum blockchains, yet high transaction fees have hindered user adoption on these blockchains. The vision of EOS is to eliminate the need for users to pay transaction fees on the EOS blockchain. This is achieved via the EOS reward allocation model, through which BPs are compensated for their block creation efforts not via transaction fees, but instead via block rewards and vote rewards.

4.4.1 Compensating Block Producers via Inflation

With transaction fees not being included as part of block rewards, block producers on the EOS blockchain are instead compensated for their block creation efforts via inflation in the EOS token supply. The rate of inflation is hard-coded by Block.one at a maximum of 5%, with the actual rate being determined by vote by the users of the EOS blockchain.

Exhibit 27: Inflation Allocation by Block.One



Source: EOSIO Dawn 4.0

As illustrated in *exhibit 27*, the inflated token supply of EOS is split between i) savings, that will be allocated by a future worker proposal system and ii) rewards to block producers.

A maximum of 4% of the inflated token supply of EOS are set aside for the proposed worker proposal system, a system in which users can submit proposals for how to best facilitate and promote the development of the EOS ecosystem. Proposals will receive EOS tokens in proportion to the quantity of votes received from token holders. The worker proposal system will be implemented in WASM (*see exhibit 28*) without a fork.

A maximum of 0.25% of the inflated token supply of EOS are allocated to "per block" rewards for top 21 BPs, distributed as compensation for block creation efforts. These "per block" rewards are distributed proportionally to the number of blocks produced by each BP. Correspondingly, a maximum of 0.75% of the inflated token supply are allocated for voting rewards distributed to BPs proportionally to the number of votes received by each BP. BPs can claim their share of per-vote rewards at most once-per-day, given that they are qualified for at least 100 tokens per day. This minimum requirement is important so as to prevent wealthy block producers from attempting to earn interest by voting on themselves when they have no intention of creating new blocks.

Via the above architecture of inflation, block creation rewards, and vote rewards, transaction fees are made obsolete for purposes of compensating block producers on the EOS blockchain.

4.4.2 Significance: Transaction Fees Hinder User Adoption

In the case of Ethereum, users are required to pay transaction fees for any transactions made on the blockchain. Transaction fees exist to provide incentives for miners to mine blocks, with transactions associated with higher transaction fees being more likely to be selected from the transaction mempool (see *exhibit 29*) to be included in mined blocks. The existence of transaction fees further prevents the spamming of transactions on the blockchain, which can contribute to network congestion.

However, the existence of transaction fees is a significant inconvenience to users on the blockchain as any dApp service or function, regardless its importance, requires the payment of transaction fees. Looking at Ethereum as an example, users need to own ether in order to cover the transaction fee for the purpose of merely transferring an ERC20 token on the Ethereum blockchain.

Transactions fees will be further increase when a blockchain utilizing transaction fees suffers from network congestion due to its limited scalability. For example, the transaction fee on the Ethereum blockchain has kept increasing since July 2017, at one point reaching ETH 5862.5 (see *exhibit 30*). This is a barrier to entry for potential Ethereum users, and is likely to hinder long term user adoption.

On the EOS blockchain, it is free for users to conduct transactions and to interact with dApps. This is more similar to the way in which users interact with the internet, and we expect it will be significantly easier for users to transit from using traditional centralized web applications to EOS dApps, as opposed to making the same transition to ETH dApps.

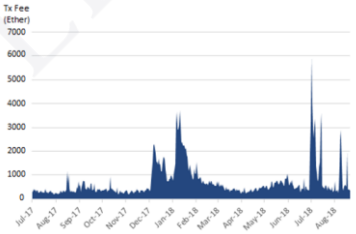
Exhibit 28: WebAssembly (WASM)

WASM is a code generated by compilers, in a binary format, which allows for the execution of C, C++, and Rust in browsers with a performance close to that of native code.

Exhibit 29: Mempool

The set of all transactions in the network that are pending verification and to be included in a block.

Exhibit 30: Transaction Fees in the Ethereum Network Since July 2017



Source: Etherscan.io

4.5 EOS: GOVERNANCE

EOS is an early pioneer in on-chain governance with its governance framework being based on the EOS Constitution. Dispute resolution is settled by the arbitrators in the EOS Core Arbitration Forum, and BPs are responsible for executing the decisions of arbitrators.

4.5.1 Governing Framework: The EOS Constitution

The EOS Constitution refers to the binding contract or the peer-to-peer terms of service agreement signed by EOS users, which is powered by the EOSIO software. Every transaction broadcasted on the network must include the hash of the EOS Constitution as part of the signature, which explicitly binds signers to the contract.

The following are the functions of the EOS Constitution:

- To define user obligations which cannot be enforced by code;
- To establish jurisdiction and choice of law with other mutually acceptable rules to facilitate dispute resolution;
- To define the human-readable intent of the source code protocol, which can identify the difference between a bug and errored features; and
- To provide guidelines on bug fixing to the community.

Exhibit 31: Proposed New EOS Constitution

To address current governance challenges on the EOS blockchain, Block.one has proposed the following improvements to EOS governance (known as the Proposal for EOS Constitution v2.0).

Ricardian Smart Contracts: Ricardian smart contracts are used to document the intent of parties and provide evidence of intent in the event of bugs. A properly written Ricardian contract should be entirely enforceable by code. Such an enforcement process is objective with all parties exercising complete autonomy within the limits of the intent of the code. Ricardian contracts operating as intended can neither be frozen nor modified by elected block producers.

"Intent of Code" is Law: Block.one has proposed the use of Ricardian contracts where rulings will be based on the "Intent of Code". The "Intent of Code" is law where the intent is documented by code, Ricardian contract, user interfaces and actual use. Decision making becomes more objective and predictable when the intent of parties is coded onto the EOS blockchain, as the enforcement is entirely based on the Ricardian contracts and disputes can be addressed by fixing the code. The Ricardian contract is deemed accepted when the transaction is coded into EOS blockchain.

Amendments to the EOS Constitution: The constitution can be amended by a vote of the EOS token holders, given that a minimum 15% of votes are staked, and the "Yes" votes exceed the "No" votes by more than 10%, sustained for 30 continuous days within a 120 day period.

4.5.2 Governing Parties: Block Producers

BPs are responsible for providing technical assistance, managing and participating in the governance process of the EOS blockchain, and to aid in other duties such as dispute resolution.

Governing responsibilities of block producers:

- Ensure users follow the EOS Constitution;
- Account freezing;
- Handling of misbehaving contracts;
- Issuing take-down notices of files;
- Hard & soft forks
  e.g. fees in account creation and parameters such as block size, rate-limited capacity; and
- Implementing EOS governance processes such as the ECAF blacklist.

Bug fixing on the EOS blockchain: There are two ways to fix the bugs on the EOS blockchain without affecting other existing EOS applications. Referenced from the DAO attack (*see exhibit 33*) in Ethereum, if DAO is implemented on the EOS blockchain, the application can be frozen after agreement by 15 out of 21 BPs. The application is frozen for bug fixing and applying new updates, which can prevent buggy contracts to disrupt other applications on the EOS blockchain. This lowers the possibility of a disruptive hard fork.

Another way to fix the buggy smart contract on the EOS blockchain is to amend the coding of smart contract. This needs to be agreed by 15 out of 21 BPs. The users can vote out the BPs and replace with the ones supporting the community consensus.

Exhibit 32: Other Responsibilities of BPs

Technical
- Block creation
- File hosting
- Server back-up
- Seed node

Managerial
- Internal control
- Communication with other BPs
- Marketing campaign for BP election
- Operational/financial transparency

Possible Extra Duties
- Account recovery and creation
- Oracles
- Price feeds
- Dispute resolution
- Education
- Community building

Exhibit 33: DAO Attack

The DAO is a digital autonomous organization built on the Ethereum blockchain. On 17 June 2016, 3.6mn Ether were stolen and this led to the Ethereum community split into Ethereum and Ethereum Classic.

4.5.3 Governing Parties: EOS Core Arbitration Forum (ECAF)

ECAF is an independent and self-governing body that has no affiliation with Block.one. This body is created to serve the EOS community via rule administration, by providing customary support to arbitrators, and by handling case administration. ECAF is responsible for dispute resolution on the EOS blockchain, and the types of disputes that fall under ECAF's jurisdiction are listed below.

Disputes Covered in the ECAF:

- Classical disputes – the owner of an asset claims damages and demands remedies;
- Requests for emergency intervention to fix bugs and account freezing;
- Data requests regarding the EOS blockchain from interested parties; and
- Legal process requests from foreign courts.

Arbitrators in the ECAF are responsible for the handling of disputes related to the EOS blockchain. Disciplinary cases and appeals are heard in the arbitral tribunal, and one arbitrator is appointed by default per case. An arbitrator can in exceptional circumstances appoint two additional arbitrators to handle a case. The chosen arbitrator(s) must be independent, and must refuse handling cases where conflicts of interest exist. It is worth noting that the ECAF is not responsible for the handling of cases related to EOS ERC20 crowdsale tokens *(see exhibit 34*).

Primary Responsibilities of Arbitrators:

- Accepting new claims;
- Choosing the appropriate communication method for the case and parties;
- Joining additional parties or dismissing current parties;
- Consolidating or dividing arbitrations; and
- Approving settlement proposals from parties.

Possible Remedies Taken by Arbitrators:

- Revoking tokens;
- Issuing tokens and/or monetary rewards related to cases;
- Freezing accounts;
- Temporary or permanently excluding a member from the EOS community;
- Ruling on findings of fact; and
- Recommending changes to the EOS Constitution.

Exhibit 34: ECAF and EOS ERC20

It is worth noting that the ECAF will not handle claims related to EOS ERC20 crowd sale tokens, since EOS ERC20 tokens operated under the laws of the Cayman Islands. The ECAF will furthermore not offer related mediation services. Claims related to lost private keys are not accepted by the ECAF.

Exhibit 35: The Account Freezing Controversy

On 17 June 2018, shortly after the activation of the EOS blockchain, block producer EOS42 discovered that any EOS accounts compromised by the registration process through phishing scams could be unlocked. The accounts suffered from phishing scams were unable to vote, and they received fake private keys which did not match to their assigned address. This could lead to user's funds being stolen. As a result, BPs subsequently filed a submission to the ECAF for a ruling on this issue.

However, the ECAF could not pass the ruling as a validated arbitrator since the EOSIO constitutions was not yet ratified by token holders. As a result, block producers decided to freeze 7 suspicious accounts after an unanimous vote, whereby the transactions related to the frozen accounts would not be processed.

The controversy of account freezing continued on 22 June, when the block producers of EOS were ordered to refuse processing transactions of 27 accounts after they received an emergency order from the ECAF. However, the ECAF initially did not provide a reason for the decision, which lead token holders to cast doubts on ECAF's decision making capabilities.

The credibility of ECAF's orders was further limited on 24 June, when an apparent hoax ECAF order caused further confusion among users on the EOS blockchain. Following the uncertainty of ECAF's orders, EOS New York decided to ignore ECAF decisions until the authenticity of ECAF's orders could be clearly identified.

4.5.4 Significance: Make or Break for On-Chain Governance

Node operators, developers, and users of any blockchain must be properly governed in order for said blockchain to properly function. Core developers have to decide what software to release, and when to release it. Nodes have to decide what software to use, and when to use it. Ethereum core developer Vlad Zamfir has presented five possible scenarios for the future of blockchain governance:

- **Autonomous blockchains:** The blockchain is allowed to run undisturbed. Minimal coordination costs, but no responsibility is taken for harm caused by the use of the blockchain.
- **Blockchain governance capture:** Governance is captured by a corporation, state, developer, or cartel. The blockchain will benefit from the maturity, flexibility, and legitimacy of the capturing entity. However, the capturing entity may govern in a way deemed "unfair" to most stakeholders.
- **Internet censorship as blockchain governance:** Jurisdictions outlaw and censor access to un-regulated blockchains. Governments can retain control, say for capital control purposes, but this comes at a freedom cost to the general public.
- **Governance via public international law or diplomacy:** Public blockchains are governed by international institutions from the legal tradition. It is thus possible to actively govern global blockchains that are accessible to the global public, while avoiding a lot of the downside of autonomous blockchains. However, reaching multilateral agreement on governing regulations may prove a gargantuan challenge.
- **International private cooperation:** A global blockchain governance system open for participation by the public. This is arguably how we do internet governance today. However, agreeing on and executing decisions may prove difficult.

The extreme case of autonomous blockchains presents a certain danger to the general public, while the governance of a captured blockchain would likely serve the interest of a small group of stakeholders. Some would argue that decentralization is a chance to try new governance systems, and EOS sets out to prove that an alternative form of governance is possible, in the form of a hybrid on-chain governance model.

Block.one plans to minimize human intervention in the governance process on the EOS blockchain. Disputes are settled off-chain by appointed arbitrators in the ECAF, yet decisions are executed on-chain by block producers. EOS still has some way to go in balancing this hybrid system, as made apparent by the repeated challenges to the legitimacy of the ECAF.

Block.one has been pursuing further on-chain governance measures following the account freezing controversy in June 2018. The use of Ricardian smart contracts has been proposed to document the intent of parties in the form of code, and make dispute resolution based on this code. The success of this governance system remains to be seen, and the global blockchain community now looks to EOS as a case study for the potential of on-chain governance.

"As another general rule, there is naturally a 'power law' distribution, where a majority of blockchains have relatively small communities relative to a small number of blockchains with relatively large communities.

This 'power law' rule means that even though it is very possible to fork, there will only ever be a small number of forks that are ultimately successful enough to be considered a 'major blockchain'. As a result, the blockchain governance regimes of a small number of major blockchains will determine governance outcomes for the entire blockchain space.

These outcomes are high stakes outcomes for anyone participating in the space, and for people whose lives might be impacted by blockchain technology in the future. This is why we need to be concerned about the blockchain governance of every major public blockchain (existing or merely aspiring)."

- Ethereum core developer Vlad Zamfir on blockchain governance

4.6 SUMMARY: NOTABLE FEATURES OF EOS

EOS' resource allocation model is critical as it allows users to access network resources without paying transaction fees, in addition to making EOSIO less vulnerable to DDOS attacks. Transaction fees have proven to be a significant barrier to scalable adoption of the Ethereum network, and avoiding transaction fees may allow users to interact with the EOS blockchain in a fashion more similar to how users typically interact with the internet. EOS furthermore aims to improve the efficiency of its transaction fee free resource allocation via the proposed resource lending and distribution model.

RAM resources are also provided via a noteworthy free market model to developers for purposes of opening user accounts and hosting dApps. The skyrocketing EOS RAM price incident highlights the importance of affordable network resources in enabling the deployment of dApps and associated novel business models. A proposal is also in place for the launch of EOS storage, which will add an IPFS network for distributed storage of bulk data, making possible the verification of bulk data integrity, and linking between smart contracts and IPFS files.

Lastly, node operators, developers, and users must be properly governed in order for a blockchain to function properly. Two extreme opposite approaches to governance are autonomous blockchains on the one hand, and full off-chain governance in the form of censorship or governance capture by off-chain entities. EOS sets out to prove that a hybrid approach is possible, whereby disputes are settled off-chain by appointed arbitrators in the ECAF, yet decisions are executed on-chain by block producers. The blockchain community now looks to EOS as a case study for the potential of on-chain governance.

5. EOS: SCALABILITY

5.1 INTRODUCTION TO SCALABILITY

Scalability refers to a blockchain's ability to handle large quantities of transactions. Scalability is essential for the mainstream adoption of a blockchain, as a highly scalable smart contract platform enables dApps with large quantities of users and bulk trading volumes. The key metric commonly used to measure scalability is transactions per second (TPS), which is the maximum rate at which a blockchain can confirm transactions. The TPS processed by a blockchain is fundamentally determined by two components: block size and block time.

Comparing block size and block time to a train station, the block size can be thought of as the size of departing trains, and the block time can be thought of as the frequency of departures from said station. Increasing either one will result in an increase to the total number of passengers able to depart from the station per unit time (TPS). The station platform can further represent the transaction pool (mempool), where passengers (transactions) wait to be included in the next train (block).

5.1.1 Block Size

Block size determines the maximum quantity of transactions that can be contained per block. While a larger block size makes it possible to contain more transactions in each block, it will also result in higher latency as it will take longer to propagate the larger block to the network. For example, once a block on the Bitcoin blockchain reaches a size of 20kb, each additional kb results in an additional 80ms required to propagate the block to the network. Pruning the size of each individual transaction (transaction size) is one way to include more transactions in a block without increasing the block size.

5.1.2 Block Time

Block time refers to the average block creation time. In other words, how long does it take for a miner or block producer to create a block. The pace of block creation (block time) is non-fixed on Proof-of-Work blockchains, but adjusted via the mining difficulty. The pace of block creation is fixed on Delegated Proof-of-Stake blockchains.

A shorter block time enhances the scalability of a blockchain as the frequency of transaction processing is higher. However, a shorter block time also means there are more blocks to propagate (synchronize) across the network. This in turn leads to higher bandwidth requirements, and possibly slower network communications. A shorter block time also leads to a higher rate of uncle block.

EOS is designed to handle a relatively short block time of 0.5 sec, which is possible due to the use of graphene technology and by limiting the number of block producers to 21. This makes possible block synchronization to the majority of users in a shorter time by minimizing the block size during block propagation.

TABLE OF CONTENTS: SCALABILITY

5.2 LIMITED SCALABILITY OF EXISTING PLATFORMS

Databases face an inherent trade-off between speed (scalability) via centralization, and security via decentralization. All decentralized systems inherently face challenges of limited scalability, platform protocols more so than many other blockchain protocols.

Limited scalability has been a major concern for existing platform blockchains, including Ethereum, the scalability of which has been increasingly questioned following the "CryptoKitties Incident", and the introduction of transaction-fee mining by crypto exchanges such as F Coin.

5.2.1 CryptoKitties Incident

One of the most popular dApps on the Ethereum blockchain is CryptoKitties, in which users can own a decentralized digital pet, and the provenance of this pet (CryptoKitty) is recorded on the Ethereum blockchain. The popularity of CryptoKitties led to significant congestion of the Ethereum network, and according to Etherscan the number of pending transactions (in other words, passengers waiting on the platform) on the Ethereum network rose shortly after the introduction of CryptoKitties. This can be viewed as an indicator of Ethereum's limited ability to scale, making it more costly and difficult for developers to deploy dApps.

5.2.2 Transaction-Fee Mining Model

The trans-fee mining model was initiated by F Coin. Under F Coin, when users pay transaction fees in Bitcoin or Ethereum, the platform will compensate users FT (F Coin's native token) and the value of FT is equivalent to the transaction fees paid. In addition, F Coin stated that for the daily transaction fees received in Bitcoin and Ethereum, 80% of the transaction fees (in terms of Bitcoin) will be reimbursed to users who hold FT continuously throughout the day. This led to congestion of the Ethereum network, with the Ethereum average transaction fee reaching an all-time high of US$ 5.53, raising concerns in the crypto community on how Ethereum can handle large amounts of transactions at low costs.

To learn more about Trans-fee mining, see our Weekly Analysis titled "Trans-fee Mining May Prove Yet Another Unsustainable Model".

5.3: HOW DOES EOS SCALE?

EOS can be described as a hybrid system, that introduces elements of centralization for the sake of improving scalability. Most of EOS' potential value, and future success, rests with its ability to build a truly scalable public blockchain. EOS' path to scalability is as such an area worthy of closer examination.

EOS aims to achieve the ability to confirm millions of transactions per second. DPoS and Graphene technology, alongside the proposed introduction of sidechains and supporting inter-blockchain communication technologies, are critical components in this vision to achieve sufficient horizontal scaling of dApps on the EOS blockchain.

5.3.1 Delegated Proof of Stake

Compared to PoW, DPoS only assigns a specific number of block producers (BPs) to validate blocks. Consensus can as such be reached faster, which enables the setting of shorter block times. DPoS has previously been adopted by Daniel Larimer in Bitshares and Steem with the goal of enhancing scalability. In the case of Bitshares, 27 witnesses are elected and every witness produces a block every 3 seconds. In the case of Steem Larimer attempted to shorten the consensus time, and subsequently arrived at 21 witnesses, each producing a block every 3 seconds. Both Bitshares and Steem are proven to be relatively scalable, and they process the largest quantity of transactions among public blockchains as of 10 October 2018.

In EOS, Larimer is attempting to further enhance scalability by shortening the block time. Under EOS' DPoS consensus algorithm, 21 BPs are elected to validate blocks with each BP creating a block every 0.5 seconds.

5.3.2 Graphene Technology

Written in C++, Graphene technology is an open source protocol for block propagation. Its original release is managed by Cryptonomex, also founded by Daniel Larimer. Graphene technology was also adopted in Bitshares and Steem, both having achieved speeds of 3000 transactions per second, before being adopted on the EOS blockchain.

Graphene technology reduces the size of block announcements to 2kB for Graphene blocks, compared to 1MB for Bitcoin blocks. This reduction in the size of block announcements opens up network bandwidth for a higher transaction rate and lowers the latency of block propagation, which reduces orphan block generation and allows for the setting of a shorter block time.

Using Graphene technology to reduce the block announcement size is similar to compressing a file on a computer, which in turn allows for faster transfer of said file.

5.3.3 Sidechains *(Proposed)*

Block.one has proposed the horizontal scaling of the EOS blockchain via the launch of sidechains and supporting inter-blockchain communication infrastructure.

A sidechain is a blockchain running in parallel with the main blockchain. The sidechain can extend functionality through interoperable blockchain networks and allow for the transfer and synchronization of tokens between the two chains. Block.one believes the transition from single-threaded to multi-threaded execution requires launching a new chain (sidechain) with multi-threaded support run by the same BPs staking the same native tokens. This provides the sidechain with the flexibility to tweak its design as necessary to support multi-threaded operations without risking an in-place upgrade to the live chain.

Returning to the train station metaphor, where block size is represented by the size of trains and block time is represented by the frequency of departures, adding sidechains can be thought of as the addition of parallel train tracks with separate platforms to the train station. These separate tracks can be different from the main track, and can each carry a different type of train. Introducing sidechains can reduce congestion on the main track, and reduce the waiting time for passengers (transactions) on station platforms.

Exhibit 36: Advantages and Drawbacks of Sidechains

Advantages

i. Allow interaction of cryptocurrencies: Developers can perform beta testing of software updates on sidechains before actual implementation on the main chain. For example, the issuance and ownership tracking of shares in traditional banking can be tested in sidechains before launching said shares to the main chain.

Drawbacks

i. Substantial initial investment required: The operation of sidechains requires sufficient miners to ensure the safety of the network.

ii. Corruptibility risk for federation: A federation is a group serving as intermediary between the main chain and sidechains, which adds an extra layer between them. This layer can be a potential point of weakness vulnerable to bribing.

5.3.4 Inter-Blockchain Communication (IBC) *(Proposed)*

IBC facilitates transactions and token transfers between blockchains. This interoperability between blockchains is made possible by the combination of a number of technologies and concepts, including merkle proofs of light client validation, the achieving of low latency, proof of completeness, SegWit and context-free actions.

Merkle proofs (*see exhibit 37*) are essential in IBC as they ensure the completeness and sequence of blocks can be easily traced. The implementation of IBC enables parallel execution of blockchains, a key component in EOS' attempt to achieve sufficient scalability.

Again returning to the train station metaphor, IBC can be thought of as the supporting infrastructure, such as switches and transfer stations, that allow the efficient and accurate transfer of passengers from one train to another. The following are all critical components of IBC:

Merkle Proofs of Light Client Validation (LCV): LCV (*see exhibit 38*) enable users to generate merkle proofs using a lighter data set. The objective is to ensure users can easily obtain the state of a blockchain. On the EOS blockchain v1.3.0, Block.one has introduced trusted producer light validation, which shortens the block propagation delay and enables a shorter block time.

Segregated Witness (SegWit): SegWit represents significant savings in disk usage and syncing time. Under SegWit, transaction signatures are no longer relevant after the transaction is recorded on the blockchain. Once the transaction is immutable, the current state can still be derived even if the signature data is pruned. SegWit applies to merkle proofs used for IBC. On the EOS blockchain, once the proof is accepted and irreversibly coded into the blockchain the transaction signature is no longer needed to derive the current state of the blockchain. The savings on merkle proofs lead to smaller transaction sizes, with size savings that are 32x greater than savings on normal signatures.

Context-free Actions: Context-free actions enable parallel execution of the vast majority of the overhead associated with inter-blockchain communication. To encourage the use of context-free actions, BPs are only charged for a fraction of CPU usage associated with context free actions. This lowers the cost of receiving or transmitting information, which leads to faster block propagation and the setting of shorter block times.

Proof of Completeness: To ensure the completeness in the transaction history, EOS assigns a sequence number to every action delivered to every account. The sequence number can prove that all intended actions for user accounts have been processed in order and ensure no transactions are omitted when performing IBC.

Low Latency of Interchain Communication: Latency refers to the time required for one account to send an action to another account, and receive a response back. EOS aims to require only 0.5 seconds for two accounts to exchange actions within a single block, which helps facilitate efficient IBC.

Exhibit 37: Merkle Proofs

Merkle trees can be used to enable proofs of user actions to light weight clients. Light weight clients are the foundation of Inter-blockchain communication, where one blockchain acts as light client of another blockchain.

Exhibit 38: Light Client

Light client is a way of interacting with a blockchain that only requires a very small amount of computation resources, keeping track of only the block headers of the chain and acquiring any needed information on transactions, states and receipts by asking for and verifying merkle proofs of relevant data on an as-needed basis.

5.4 SUMMARY: SCALABILITY

Adjusting the scalability of a blockchain is at the core an adjustment of two key parameters, the block size and block time. The key metric commonly used to measure scalability is transactions per second (TPS).

DPoS and Graphene technology are two existing key components of EOS' effort to achieve sufficient scalability. A relatively small number of block producers (21) and relatively small block announcements using graphene technology limit latency challenges. This in turn makes possible the setting of a relatively short block time (0.5 seconds). The EOS team is furthermore envisioning EOSIO as a multi-chain blockchain, supported by parallel sidechains and inter blockchain communication infrastructure.

It is clear that EOS primarily seeks to achieve scalability by solving latency challenges, subsequently making possible the setting of lower block times. Block size is purposefully kept at 1MB (same as Bitcoin), as increases to block size would lead to increased latency in block propagation. The EOS blockchain is already relatively scalable when compared to other platform protocols, having achieved an all time high of 3997 TPS. The expected future introduction of sidechains may also allow for multifold increases in the number of transactions that can be processed per second.

6. EOS: SMART CONTRACT DEVELOPMENT

This chapter examines the role of smart contracts on the EOS blockchain, followed by an evaluation of EOS smart contracts from both a developer's and end user's perspective, in accordance with Standard Kepler's framework for smart contract evaluation.

6.1 OVERVIEW OF SMART CONTRACTS ON EOSIO

6.1.1 Smart Contracts

A smart contract is a computer protocol stored on the blockchain, the code of which represents a set of pre-defined rules formalizing the rights and obligations between parties. Once a pre-defined rule is met, the smart contract will be executed automatically on the blockchain. The execution process of smart contracts is decentralized, as it does not require trusted intermediaries. Once a smart contract is executed transactions are trackable and immutable, preserving the immutability of the blockchain.

6.1.2 EOSIO Smart Contracts

An EOSIO smart contract is the software registered on the EOS blockchain. The code in the smart contract defines the interface such as actions, parameters and data structures. The code is then compiled into canonical bytecode format for the nodes to retrieve and execute. The blockchain stores the transactions of the contract, and each contract must be accompanied by a Ricardian contract that defines legally binding terms and conditions of the contract.

As of 10 October 2018, the latest version of the EOS blockchain is v1.3.0. It is Block.one's stated goal to provide an update to the EOSIO software on the second Tuesday of each month.

6.1.3 Smart Contract Evaluation

We utilize the Standard Kepler framework for smart contract evaluation to examine EOS smart contract development from the perspective of smart contract developers and end users.

Exhibit 41: Standard Kepler's Criteria for EOS Smart Contract Evaluation

Developer Perspective	End User Perspective
1. Developer Community	1. Account Management
2. Smart Contract Languages	2. Costs
3. Development Tools	3. Transaction Latency
4. Development Costs	4. Tools
	5. Account Security

TABLE OF CONTENTS: SMART CONTRACT DEVELOPMENT

Exhibit 39: Environments Supported by EOSIO Software

- Amazon 2017.09 and higher
- Centos 7
- Fedora 25 and higher (Fedora 27 recommended)
- Mint 18
- Ubuntu 16.04 (Ubuntu 16.10 recommended)
- Ubuntu 18.04 LTS
- MacOS Darwin 10.12 and higher (MacOS 10.13x recommended)

Exhibit 40: Components of EOSIO

- **Nodeos** (node+eos = nodeos), the core EOSIO node daemon that can be configured with plugins to run a node. Example uses are block producing node, validating node, and HTTP RPC API service for the chain and wallet.
- **Cleos** (cli+eos = cleos), the command line interface, used to interact with the blockchain and to manage wallets.
- **Keosd** (key+eos=keosd), the component that securely stores EOSIO keys in wallets, and signs transactions before broadcasting to the network.

6.2: SMART CONTRACT EVALUATION: DEVELOPER PERSPECTIVE

Smart contract developers deploy dApps on the EOS blockchain. We are of the opinion that EOS manages to enrich the experience of developers with its toolkits and use of C++, yet the volatile RAM price and limited RAM supply will be significant concerns to developers.

6.2.1 Developer Community

Github is the most popular platform from which it is possible to peek into the discussions and involvement of developers on the development of cryptocurrencies. For platform tokens, two rudimentary metrics that may indicate a developer's involvement is the number of Github commits and star repositories. Among platform tokens, EOS ranks 2nd in number of star repositories and 3rd in number of Github commits (*see exhibit 42*).

6.2.2 Availability of Smart Contract Languages

EOSIO software currently supports C++ as the main smart contract language, with a roadmap to support other languages such as Solidity, Python and Rust in the future.

C++: The language used to build EOS smart contracts. C++ is a common programming language known for its ability to reduce code repetition (such as generic containers, algorithms). According to the EOSIO developer portal, C++ is the most suitable language for deploying dApps with robust smart contract debugging support, resourceful libraries, and communities of outstanding developers. C++ is furthermore a low level language that enables huge flexibility for developers writing smart contracts and managing resources. Such flexibility makes C++ a powerful language able to support robust dApps deployment by experienced developers. However, the huge flexibility of C++ is a double-edged sword, as it is highly time consuming for developers to master the language. Such a steep learning curve may dampen the mass deployment of dApps on the EOS blockchain.

Solidity: The smart contract language initially adopted in Ethereum. Solidity is easier to learn for amateur developers with a background in Javascript, and is significantly less complex than C++. As such, it is easier for developers to write crowd sale contracts using Solidity. This can be a double-edged sword as amateurs tend to make mistakes, and mistakes are costly to rectify due to the immutability of blockchain. The EOS virtual machine currently does not support Solidity.

Exhibit 42: Github Stats on Platform Tokens

	No. of Github Commits	No. of Star Repository
ETH	55,406	29,311
EOS	9,982	10,902
ADA	26,353	4,018
NEO	3,150	3,252
XLM	4,668	1,918

Data as of 10 October 2018
Source: Ratingtoken.io, Standard Kepler Research

6.2.3 Availability of Developer Tools

There are four primary components in evaluating EOS developer tools: The tools available for simplifying smart contract development, the command line interface, tools available for new blockchain developers, and the availability of testnets.

EOSIO.CDT and Demux are tools available to simplify the development of EOS smart contracts. EOS uses Cleos as the command line interface and the EOS community provides two testnets for developers. To assist new blockchain developers building dApps on the EOS blockchain, Block.one provides a free-online game-based tutorial and the use of docker.

EOSIO Contract Development Toolkit (EOSIO.CDT): EOSIO.CDT is a toolchain for WASM for compiling smart contracts and generating ABI files. To support building EOSIO smart contracts, EOSIO.CDT is built around Clang (*see exhibit 43*), which means the EOSIO.CDT has the most recently available optimizations and analyses from LLVM (*see exhibit 44*).

EOSIO.CDT provides support for Gnu & C++ 11 style, which creates a more reliant way to declare smart contract and associated data structures.

It is worth noting that as of 10 October 2018 the WASM target is still at an experimental stage, and certain optimizations are still incomplete.

Demux: An open source tool to simplify smart contract development. Demux allows for the sourcing of blockchain events in order to update queryable databases for dApps on the EOS blockchain in a deterministic order. It allows developers to use traditional Mongo or Postgres SQL databases, with the data stored being verifiable by blockchains.

Developers need to resolve two problems when they retrieve data directly from the EOS blockchain. Firstly, since developers have limited options in choosing the query interface in retrieving the indexed data, they have to make an excess number of queries or store additional sorted data on the blockchain in order to build complex dApps. Furthermore, developers need more blockchain endpoint nodes to scale the query load, which increases the costs of deploying dApps on the EOS blockchain.

Demux tackles these problems by off-loading storage and queries to a developer's preferred database choice such as MongoDB or Postgres. Demux can also reduce the amount of data stored in RAM and lower the operating costs for developers (*see exhibit 45*).

Cleos: The command line interface on the EOS blockchain. For developers, one advantage of using Cleos is the resourceful inline documentation. Besides, Cleos recently supports delayed transactions, which enhances developer flexibility in deploying dApps.

Exhibit 43: Clang

Clang is an "LLVM native" C/C++/Objective-C compiler, which aims to deliver fast compiles, useful error and warning messages and to provide a platform for building great source level tools.

Exhibit 44: LLVM

The LLVM project is a collection of modular and reusable compiler and toolchain technologies. Its goal is to provide a modern, SSA-based compilation strategy capable of supporting both static and dynamic compilation of arbitrary programming languages.

Exhibit 45: How Demux Lowers Developer Costs

Under Demux, a developer's chosen database is updated via updater functions when blockchain events occur. The database can be queried by the front-end dApp through a suitable API such as REST or GraphQL, which reduces the amount of direct interaction with the blockchain needed to retrieve data. This helps developers to limit the amount of data stored in RAM, thus lowering operating costs of dApps.

Online game based tutorial – Elemental Battles: Block.one has released Elemental Battles, an on-boarding learning toolkit for new blockchain developers with basic C++ and Javascript programming knowledge. This toolkit helps acquaint developers with the basic knowledge of EOS smart contract development, the writing of simple artificial intelligence (AI) code and logic validation.

Docker: The fastest tool to build EOS blockchains for starters. There are two main methods assisting developers in building EOS blockchains, which are Autobuild Script and Docker (*see exhibit 46*). Compared to Autobuild Script, we believe that Docker enables faster set up of nodes and installation of cleos for accessing the EOS blockchain.

Availability of testnets: Developers can configure the development environment via nodeos. The most common development environment is to launch a local single-node testnet, whereas a local multi-node testnet is more beneficial for developers working on core development, such as benchmarking, optimization and experimentation. The EOS community has set up the Jungle testnet and CryptoKylin testnet for developers to perform testing of their dApps.

6.2.4 Development Costs

The volatile RAM price has been the main obstacle for developers to deploy dApps. Compared to other cryptocurrencies where the cost of deploying dApps is borne by users, EOS developers have to store RAM before deploying dApps. The RAM price can be volatile with its limited supply, partly a result of hoarding by non-developers in order to profit through speculation. This can dampen the incentive for developer to deploy dApps, and whether developers can deploy large scale dApps sustainably remains to be seen.

The security of RAM is also of concern to developers. As reflected by the unexpected RAM consumption incident in August 2018, the RAM can be consumed by malicious users, which also limits the ability for developers to deploy their dApps.

Exhibit 46: Docker

Docker is an open platform for developers and system admins to build, ship, and run distributed applications on laptops, data center VMs or in the cloud.

6.3 EOS SMART CONTRACT EVALUATION FOR END USERS

6.3.1 Account Management

The use of human readable usernames is a user friendly feature of the EOS blockchain that should not be overlooked. Compared to the Bitcoin and Ethereum blockchains, on which usernames are represented by long strings of letters and numbers, users can create 12 character long usernames on the EOS blockchain. Note that bidding is required for "premium" account names, which are usernames less than 12 characters in length or containing "." The minimum bid is 0.0001 EOS and there are no caps. Only one premium account name will be sold per day in the daily account name auction, and it will be awarded to the highest bidder.

When sending funds between accounts on the EOS blockchain, users merely need to verify the receiving account in a process similar to that employed by social media platform Twitter. A seemingly small feature such as this can have a large impact when it comes to preventing user errors and associated losses of funds. The EOS blockchain also allows users to create sub-accounts, and grant other users permission to these sub-accounts (*see Exhibit 47*).

The termination of EOS user accounts after 3 years of inactivity can be considered a disadvantage to users. Under Article XV of the EOS Constitution, if a member's account has not signed any transactions to the blockchain for 3 years the account is considered inactive and this account can be put up for auction. Proceeds from the auction are subsequently distributed to all members according to the system contract provisions in effect for such redistribution.

6.3.2 Costs of Using the EOS Blockchain

The cost of using the EOS blockchain is borne by developers. Unlike the Ethereum blockchain on which transaction fees are paid in the form of "gas", users do not need to pay transaction fees on the EOS blockchain.

High account creation costs on the EOS blockchain has been a known drawback to the EOS community. Despite BPs recently agreeing to cut the account creation cost from 4 KiB to 3 KiB, the time cost and the purchase of KiB to create EOS accounts still impose entry barriers to new users.

6.3.3 Transaction Latency

The EOS blockchain enhances the user experience with its low transaction latency of 0.5 seconds.

Exhibit 47: Creation of Sub-Accounts on the EOS Blockchain

EOS user Matthew11111 would like to create a number of sub-accounts under the suffix "sk". First he needs to bid for and win the premium account name "sk" in the daily account name auction.

After winning the auction for the account name "sk", Matthew is now able to create sub-accounts under the "sk" account name, with "sk" serving as the top level domain. Matthew subsequently creates the sub-accounts matthew.sk and tobias.sk. These sub-accounts can be up to 12 characters long.

Matthew can now create new permissions for Tobias to access this new account by assigning the account tobias111.sk to Tobias' EOS account or public key.

6.3.4 Available Tools for End Users

The tools available for end users are primarily built by the EOS community, and notably BP candidates. The tools can be divided into users accounts and wallet services, BP activity trackers, and community services (*see exhibit 48*).

Exhibit 48: Overview of Available Tools to EOS End Users

Users Account & Wallet Services
- Account activity tracker
- Account registration services
- Website wallet
- Desktop service

BP Activity Trackers
- Voting tools, guidelines and statistics tracker
- BP reward claimer

Community Services
- Airdrop tracker
- Block explorer
- Educational platform and forum
- Resource planner
- Worker proposal tracker

Source: Standard Kepler Research

EOS desktop (*see exhibit 49*) is an innovative solution that allows end user interaction with the EOS ecosystem in a fashion similar to the experience of using desktop computers. Designed by Errick Benson Peart, EOS desktop is a graphical user interface (GUI) for users to enter a fully integrated EOS network environment. User interaction with the EOS ecosystem will be significantly easier, as users can access block explorers, account details, dApps on the EOS blockchain, cryptocurrency websites and toolkits using EOS desktop.

6.3.5 Account Security

User accounts can be recovered on the EOS blockchain even in the event that a user's private keys are stolen. This can be compared to the Bitcoin and Ethereum blockchains, on which it is impossible to recover exposed accounts. Users can appoint one or more "account recovery partners" on the EOS blockchain. When a user's key is stolen, the user can reset their owner's key by using anyone's owner key that was active in the last 30 days, and obtaining the approval from their account recovery partner *(see exhibit 50)*.

Hackers cannot intervene in the approval process as the account recovery partner needs to verify the identification of the account user to reset the account user's owner's key.

Exhibit 49: EOS Desktop Features

- Play any dApp that runs the latest version of ScatterJS
- Easy access to block explorers or account managers that link with Scatter desktop, e.g. EOS toolkit, Bloks.io
- Access account in the sidebar, such as tokens, resources and recent actions
- Shortcuts to useful EOS and crypto related websites

Exhibit 50: Account Recovery Partners

The account recovery partner is the approver for users to reset their owner key. They perform identification and multi-factor authentication (phone and email) to users in the approval process. The partner cannot control the account without the help of users and have no power over daily transactions of the account. This can reduce the potential costs and legal liabilities for everyone involved.

6.4 SUMMARY: EOS SMART CONTRACTS

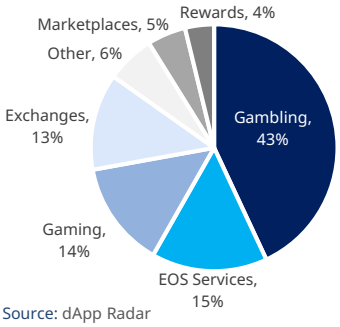
EOS notably appears to favour end user usability over developer usability. EOS is the pioneer of zero transaction fees for end users interacting with the blockchain. The costs are indeed borne by the developers of EOS dApps, who need to possess sufficient resources (such as RAM) to deploy dApps. As shown by the skyrocketing RAM price and unexpected RAM consumption incidents, unstable RAM costs and security are two of the major obstacles for sustainable development of dApps on the EOS blockchain.

For end users, we consider the inclusion of account recovery partners a truly innovative solution towards account recovery on a public chain. Furthermore, the usage of human-readable usernames on the EOS blockchain is a significant convenience for end users. One concern that may affect end user adoption is the relatively high account creation cost, compared to on other blockchains where users don't need to pay to create user accounts.

7. EOS: ECOSYSTEM

As of 10 October 2018, there are 79 dApps on the EOS blockchain. EOS dApps can be classified into 7 sectors, namely EOS services, exchanges, gambling, gaming, marketplaces, rewards, and others.

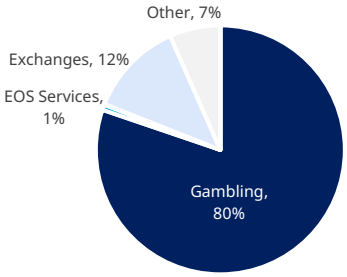
Exhibit 51: EOS dApps By Sector



Source: dApp Radar

There are 34 gambling dApps (43% of total) on the EOS blockchain. This is followed by EOS services (15%) and gaming (14%).

Exhibit 52: EOS Weekly Trading Vol. By Sector



Source: dApp Radar

The weekly trading volume of dApps is 14.62mn EOS, with 80% being derived from gambling dApps. In particular, EOSBet and BetDice produce a weekly trading vol. of 9.96mn EOS.

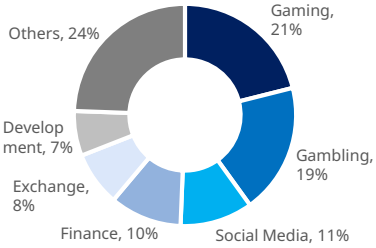
Exhibit 53: EOS Weekly Transactions Processed By Sector

Source: dApp Radar

The weekly number of transactions processed on the EOS blockchain is 6.23mn. Gambling contributes 84% of total transactions and BetDice and EOSBet themselves processed 4.46mn transactions on a weekly basis.

It is observed that gambling and gaming dApps are the main drivers of traffic on the EOS blockchain in terms of trading volume and transactions processed. As the EOS blockchain is still at an early development stage, the available dApps have less diversity than dApps on Ethereum, especially with regards to sectors such as finance and social media. We will continually expand our analysis of the EOS ecosystem as more dApps become available.

Exhibit 54: Ethereum dApps (By Sector)



Total number of Ethereum dApps:1959
Source: State of the dApps

Exhibit 55: Top 5 EOS dApps (Weekly Trading Vol.)

#	dApp	Sector	Trading Vol.
1	EOSBet	Gambling	5mn
2	BetDice	Gambling	4.96mn
3	EOSPlay Lottery & Dice	Gambling	1.40mn
4	Newdex	Exchanges	1.17mn
5	Chintai	Other	0.97mn

Trading Vol. unit expressed in EOS.
Source: Dapp Radar

Exhibit 56: Top 5 EOS dApps (Weekly Transactions Processed)

#	dApp	Sector	Transactions
1	BetDice	Gambling	2.34mn
2	EOSBet	Gambling	2.12mn
3	EOS Knights	Gaming	0.55mn
4	EOSPlay Lottery & Dice	Gambling	0.51mn
5	PRA CandyBox	Rewards	0.19mn

Source: Dapp Radar

8. EOS: CONCLUSION

Scalability is crucial for the development of platform protocols, and EOS has taken the lead in demonstrating real world scalability, ranking 3rd in terms of most activity on blockchain with an all-time high of 3997 TPS. We also deem EOS' proposed path to further scalability realistic given the expertise of the Block.one team. While EOS' ability to achieve millions of TPS remains to be seen, we have little reason to doubt that the future implementation of sidechains would not enable such a multifold improvement to scalability, assuming the implementation itself is successful.

Yet scalability is only valuable if it is accompanied by user adoption. EOS introduces a number of systems that are not only innovative, but may also promote the liquidity and functionality of the EOS token, one such example being the proposed resource allocation exchange which is currently being tested on the Jungle testnet. There are also significant improvements in place to enhance the usability of the EOS blockchain for both dApp developers, and dApp end users. However, so far we have yet to see general adoption of dApps hosted on EOS, and a majority of the current EOS transaction volume is currently driven by gambling applications. It remains to be seen if other applications will benefit from being hosted on EOS.

We furthermore spotted a number of worrying risks associated with EOS, and the future success of EOS will depend on Block.one and the EOS community's ability to successfully navigate these challenges. The following section will be continuously updated as EOS matures further.

8.1 FUTURE RISKS

8.1.1 Centralization

In addressing the issues of the scalability trilemma, we believe that EOS achieves scalability and security at the expense of decentralization. The risks of centralization stem from the strong authority of BPs. The community grows increasingly concerned that the authority granted to BPs will make EOS more centralized than intended, as BPs have demonstrated their ability to bypass the ECAF.

The danger would grow significantly more severe were EOS BPs to form into cartels. The BPs in such cartels can perform "mutual voting", which they receive the voting rewards together by voting each other. For example, the so-far unverified allegations relating to "mutual voting" among some BPs in late September 2018 can be interpreted as a possible violation of Article IV ("No Vote Buying") of the EOS Constitution. Such allegations and violations can undermine the integrity of the EOS blockchain, as well as create barriers of entry for small entities competing for BP roles.

"The great challenge facing EOS is not to reach sufficient scalability. Rather it is the sustainability of EOS that is questionable, and this challenge deserves the community's full attention."

- Johnny AuYeung,
CTO Standard Kepler

The growing storage and network requirement to host nodes on the EOS blockchain also leads to risks of centralization. As stated in EOSIO Dawn 1.0, if the EOS blockchain is to be able to achieve a million transactions per second in the future, it will have to handle 100's of megabytes of data per second per connection. While this is trivial for large data centres, it will become unaffordable for home users to operate full nodes as they don't have sufficient NET and CPU power. The number of full nodes will keep decreasing in such a scenario, and ultimately only large data centres and crypto exchanges would be eligible to compete for becoming BPs.

8.1.2 Unsustainable Deployment of dApps

One distinctive feature of EOS aimed at enriching the end-user experience is its feeless transaction model. However, the cost of deploying dApps is entirely borne by developers, and potential volatility in the EOS RAM price could disrupt sustainable deployment of dApps on the EOS blockchain. Lowering or eliminating the account creation cost and promoting a stable EOS RAM price would be beneficial to EOS' sustainable development, especially for developers.

8.1.3 Undermined and Irrelevant Governance System

Despite the early effort towards on-chain governance, the direction of EOS governance is unclear at the moment. Daniel Larimer's proposed "Intent of Code is law" has not yet been adopted, with no consensus currently reached on how to utilize the $192mn in the eosio.savings account. Investors should pay attention to the utilization of this huge savings account to monitor EOS' future development.

As illustrated by the account freezing controversy of the EOS blockchain, the legitimacy of the ECAF is also fragile, and limited. The limited legitimacy of ECAF is also reflected by its ambiguous role in the EOS governance model and arbitration procedures, which lead to EOS New York's announcement on ignoring ECAF's decisions. The poor public awareness of ECAF is also reflected by the lack of a public communications officer or budget of ECAF. A number of solutions have been proposed by Block.one to address these governance risks, including a notification system proposed by the ECAF and the establishment of the EOS Mandarin Arbitration Community (EMAC) to facilitate communication with Chinese BPs, yet the effectiveness of these measures appears to be limited because of the different communication channels adopted between China and Western countries.

8.1.4 Resource Allocation Issues

The security of EOS RAM aroused public concern with the unexpected RAM consumption incident in August 2018. To prevent user's RAM from being consumed by malicious 3rd parties, Daniel Larimer suggests using the "Intent of code" to document user intent in RAM consumption, yet this proposal has not been implemented yet. Besides, the popularity of gambling dApps on the EOS blockchain in October 2018 led to the shortage of CPU resources. The EOS community has proposed to increase target block CPU usage from 10% to 20%, yet we view this as a short term solution, and the supply of CPU ought to be increased in the long term.

8.1.5 Loss of Core Staff

EOS generated much hype among crypto investors with its $4bn ICO, as well as among high-profile investors such as Mike Novogratz and Peter Thiel. However, as EOS is still at a stage of early development, whether EOS can deliver on the expectations of investors largely depends on the retainment of core management and tech personnel at Block.one, especially Daniel Larimer. The expectations among investors and the general public are largely based on Larimer's reputation, and past achievements with DPoS projects Bitshares and Steem. The importance of this "Larimer Effect" is in itself a risk for EOS. Implications of the loss of key personnel were recently demonstrated when four Block.one employees, including John Moss, left EOS to establish StrongBlock. Larimer himself has also voiced an interest in pursuing a number of projects which may or may not be related to EOS and EOSIO.