# TRUECHAIN: HIGHLY PERFORMANT DECENTRALIZED PUBLIC LEDGER
## FIRST DRAFT
## WORK IN PROGRESS

TRUECHAIN RESEARCH TEAM
TECH@TRUECHAIN.PRO

ABSTRACT. In this paper we present the initial design of truechain consensus protocol and other technical details. Briefly, our consensus design enjoys the same consistency, liveness, transaction finality and security guarantee, a de-facto with the Hybrid Consensus. We discuss optimizations like frequency of rotating committee members and physical timestamp restrictions. We go on to propose the idea of a new virtual machine on top of Ethereum which adds permissioned-chain based transaction processing capabilities in a permissionless setting. We also use the idea of data sharding and speculative transactions, evaluation of running of smart contracts in a hybrid cloud infrastructure and usage of existing volunteer computing protocols for something we introduce as a compensation infrastructure.

In the next version of this Yellow Paper, we will address some of these properties formally along with few of the future directions listed at the end of the paper.

## 1. INTRODUCTION

With the surging popularity of cryptocurrencies, blockchain technology has caught attention from both industry and academia. One can think blockchain as a shared computing environment involving peers to join and quit freely, with the premis for a commonly agreed consensus protocol. The decentralized nature of blockchain, together with transaction transparency, autonomy, immutability, are critical to crypocurrencies, drawing the baseline for such systems. However top earlier-designed cryptocurrencies, such as Bitcoin[19] and Ethereum[11], have been widely recognised unscalable in terms of transaction rate and are not economically viable as they require severe energy consumptions and computation power.

With the demand of apps and platforms using public blockchain growing in real world, a viable protocol that enables higher transaction rate is a main focus on new systems. For example, consider a generic public chain that could host computationally intensive peer to peer gaming applications with a very large userbase. In such a chain, if it also hosts smart contracts for Initial Coin Offerings in addition to Digital Advertisement applications, we could easily expect a huge delay in transaction confirmation times.

There are other models like delegated mechanism of Proof of Stake and Permissioned Byzantine Fault Tolerant (BFT) protocols. The BFT protocol ensures safety as long as only one third of the actors in the system are intentionally/unintentionally malacious adversaries, at a time. This is a really good mechanism, however a BFT chain alone has a problem with scalability and pseudo-decentralization. The Proof of Stake protocol with a small number of validators could although facilitate high throughput, but the system in itself is highly dependent on a few stakeholders to make the decisions on inclusion and exclusion of delegates. Moreover, there is no transparency without Merkel trees and this type of system could always suffer from nothing-at-stake paradox.

In this Paper, we propose TrueChain, a Hybrid Protocol[20] which incorporates a modified form of PBFT (Practical Byzantine Fault Tolerance)[13] and POW (Proof of Work) consensus.

The POW consensus ensures incentivization and committee selection while the PBFT layer acts as a highly performant consensus with capabilities like instant finality with high throughput, transaction validation, rotating committee for fair trade economy and a compensation infrastructure to deal with non-uniform infrastructure. The nature of hybrid protocol allows it to tolerate corruptions at a maximum of about one third of peer nodes.

## 2. BACKGROUND

The core strength of this proposal lies in the recognition of the theorems proposed in the Hybrid Protocol[20] by Pass and Shi. We benefit from the fact that there is a lot of design space for further optimizations in that paper. The use of DailyBFT as committee members allows for the rotating committee feature which provides for better fairness for the consensus validating peers.

The POW nodes could benefit from incentivization infrastructure while they are also a part of the slower snailchain, helping deploy smart contracts and validations but mostly catching up with the fast chain time to time.

### 2.1. **Related Works.**

Hybrid Consensus follows a design paradigm where BFT and PoW are combined together so that it enjoys nice properties from both of the world. In general, Hybrid Consensus will utilize BFT protocols, which by default works in a permissioned setting where all the identities are known before the protocol starts, as a fast path dealing with large amount

*Date*: April 28th, 2018.

of incoming transactions, and PoW protocols with stake_in / stake_out (with random selection) acting as the barebone of the protocol which supports BFT to deal with dynamic membership and committee switching in the permissionless setting.

## 3. Consensus

Our consensus design is largely based on Hybrid Consensus by Pass and Shi [20], with several modifications and improvements in order to tailor for the application scenarios that we focus on. In this section we will assume the readers are familiar with every detail of Hybrid Consensus protocol.

3.1. **Design Overview.** In this subsection we will present an overview of our consensus protocol. In this protocol, we use the same abstract symbols and definitions in [20]. In the following part of this section, we will explain our modifications and further constructions on top of Hybrid Consensus.

Our adversary model follows the assumptions in [20] where adversaries are allowed to mildly adaptively corrupt any node, while corruptions do not take effect immediately. In the next version of Yellow Paper we will formally explain our modifications in Universal Composabililty model [12].

Note that all the pseudocodes in this Yellow Paper are simplified for the sake of easy explanations. They are not optimized for engineering.

3.2. **Recap of Hybrid Consensus Protocol.** In this subsection, we recall major components and definitions from the Hybrid Consensus protocol.

3.2.1. *Daily offchain consensus protocol.* In DailyBFT, committee members run an offchain BFT instance to decide a daily log, whereas non-members count signatures from committee members. It extends security to committee non-members and late-spawning nodes. It carries with it, a termination agreement which requires that all honest nodes agree on the same final log upon termination. In DailyBFT, committee members output signed daily log hashes to be later be consumed by the Hybrid Consensus protocol. These signed daily log hashes satisfy completeness and unforgeability.

On keygen, add public key to list of keys. On receiving a comm signal, a conditional election of the node as committee member happens. The environment opens up the committee selectively.

Here is how the subprotocol works for when the **node is a BFT member**:- A BFT virtual node is then forked. BFT virtual node here, denoted by $\mathsf{BFT_p k}$, then starts receiving the TXs (transactions). The log completion is checked and stopped if only if the stop signal has been signed off by atleast a third of the initial comm distinct public keys. During this, a continuous "Until done" check happens and once completion of gossip happens at each step, all the stop log entries are removed

Here is how the subprotocol works for when the **node is not a BFT member**:- On receival of a transaction, the message is added to history and signed by a third of the initial comm distinct public keys

The signing algorithm tags each message for the inner BFT instance with the prefix 0, and each message for the outer DailyBFT with the prefix 1 to avoid namespace collision.

3.2.2. *The mempool subprotocol.* Initializes TXs with 0 and keeps a track of incoming transactions with a Union set. On receiving a propose call, it adds the transaction to log and communciates with gossip protocol. It also supports query method to return confirmed transactions. By keeping track of transactions in a set, it purges the ones already confirmed.

3.2.3. *Main Hybrid Consensus protocol.* A newly spawned node with an implicit message routing that carries with it history of the transcripts sent and received. This interacts with the following components - Mempools, Snailchain, Preprocess, Daily Offchain Consensus, and on chain validation.

3.3. **Variant Day Length and Hybrid Committee Election.** In [20], instances of BFT committees are switched every a fixed period of time (with the snailchain as a logical clock). And new committee is formed simply by the miners of the latest *csize* number of blocks inside snailchain. In our consensus design, we want to exploit the intuition that, if the committee behaves well, we don't have to force them to switch, and therefore the overhead of switching committee could be prevented in some situtations. On the other hand, this will raise difficulty for new nodes to get elected as a committee member if the previous committee keeps good records. Therefore we still keep the design of forcibly switching the committee every fixed amount of time, but with a much lower frequency, (for example, the committee will be switched every $K$ days). On the other hand, we incoporate the idea of authenticated complaints from Thunderella [22] where the slowchain can be used as the evidence of mishavioring of BFT committee. That is, whenever a committee misbehavior is detected from the snailchain, the next day starting point (not necessarily the $K$-th day) will trigger a forced switch.

More over, we will replace the committee election criterion. In Hybrid Consensus, committee members are chosen from the miners of the most recent snailchain blocks. We decide to select committee members based on a hybrid criterion by stakes and randomness. To be more specific, we allow full nodes to propose special stake_in and stake_out transactions to temporarily freeze their token assets. And whenever a committee switch happens, we will elect $\theta \cdot \mathsf{csize}$ accounts based on their frozen stakes where $\theta \in [0, 1]$ is a manual parameter. And following the design of [14], we choose the rest $(1-\theta) \cdot \mathsf{csize}$ nodes based on the result of VRF [18] where the seed is determined by the seed used in previous committee selection, as well as the proposed randomness from recent csize blocks. Different from Algorand [14], here we don't count stake weights for this part of selection.

Notice that the nodes that is chosen by random functions will have a high probability of not being online. For this reason, given the estimated online rate $r_{on}$, since we don't want the offline nodes to take the Byzantine quota, we need to make sure $r_{on} \cdot \theta < \frac{f}{\mathsf{csize}}$. Usually we take $\theta = \frac{f}{2 r_{on} \mathsf{csize}}$. Another

potential design alternative is that we can allow offline nodes by design [21].

Note that a party in charge of overwhelming computation resources will be likely to manipulate the input of VRF, but that already goes beyond our security assumption.

3.4. **Application Specific Design.** In our consensus design, we keep aware of application specific requirbements and tailor for them under the conditions that the consisttency, liveness and security properties are not compromised.

3.4.1. *Physical Timing Restriction.* Conventional consensus design by default allows miners / committee members / leaders to re-order transactions within a small timing window. This raises a problem for some decentralized applications such as commercial exchanges where the trading fairness requires the timing order between transactions to be carefully preserved, or otherwise malicious (or, even normal rational) participants will have the incentive to re-order transactions, or even insert its own transactions, to gain extra profits. And this incentive will be magnified under high throughputs.

And what is even worse, is that such malicious re-ordering is impossible to distinguish because naturally network latency will cause re-ordering and such latencies can only be observed by the receiver itself and therefore it has the final evidence of numbers regarding network latency.

To support decentralized advertisement exchanges, we try to reduce such problems by incoporating one more restriction called sticky timestamp. More specifically, with a heuristic parameter $T_\Delta$, when proposing transactions, we require the client to put a physical timestamp $T_p$ inside the metadata of the transactio, and this physical timestamp is signed together with the other parts of the transaction. Later when validators inside BFT verify the transaction, it will do the following extra checks as shown in Algorithm 1.

At the stage of materializing logs inside BFT, the leader will sort the transaction batch according to its physical timestamps and break ties (though very unlikely) with the sequence number. Actually this step is not necessary because we can enforce the order later in the evaluation and verification. But for simplicity, we put it here.

This set of modications give us several extra properties:

(1) The order of transactions from any node $N_i$ is internally preserved according to their physical timestamps. Thus the sequence order of these transactions is strictly enforced. This will get rid of the possibility of some malicious re-ordering that involves two transcations from the same node.
(2) The order within a batch of transactions output by the BFT committee is strictly ordered by timestamps.
(3) Nodes cannot manipulate fake physical timestamps because of the timing window restriction.

One obvious disadvantage of this modificaion will be the reduction in terms of throughput due to aborting transactions when the parameter $T_\Delta$ is inappropriate for the varying network latency. Another disadvantage is that, the BFT committee members are still allowed to lie about their local time and reject certain transactions. However, committee members can reject certain transactions anyway. But honest nodes could potentially reject ignorant transactions because of their unsynchronzied clocks. This issue can be reduced by adding restrictions on the eligibilities of the BFT committee. Later we will see that to get into the committee, the nodes should present evidence of synchronized clocks.

3.5. **Computation and Data Sharding, and Speculative Transaction Execution.** In this subsection we introduce our sharding scheme.

An important modification over the original Hybrid Consensus is that we add computation and data sharding support for it. And even more, first of its kind, we design a speculative transaction processing system over shards. The idea is clear. In Hybrid Consensus, the DailyBFT instances are indexed into a determininstic sequence DailyBFT[1 ... R]. We allow multiple sequences of DailyBFT instances to exist at the same time. To be precise, we denote the $t$-th DailyBFT sequence by shard $S_t$. For simplicity, we fix the number of shards as $C$. Each DailyBFT is a normal shard. Besides $C$ normal shards, we have a primary shard $S_p$ composed of csize nodes. The job of the primary shard is to finalize the ordering of the output of normal shards as well as implementing the coordinator in distributed transaction processing systems. And the normal shards instead of directly connects with Hybrid Consensus component, it submit logs to the primary shards and then primary shards talks to Hybrid Consensus.

We don't allow any two shards (either normal or primary) to share common nodes, which can be enforced in the committee selection procedure. The election of multiple shards is similar to the election procedure described in Section 3.3.

We partition the state data (in terms of account range) uniformly into $C$ shards. This will make sure that every query to the corresponding shard will return a consistent state. Since we are going to include meta data for each data unit, we split data into units of data sectors and assign each data sector with an address. We have a mapping from data position to data sector address. For simplicity, from now on, we only discuss at the level of data sectors. Each data sector DS[addr] has metadata of rts, wts, readers, writers.

We assume the partition principle is public and given the address addr we can get its host shard by calling the function host(addr).

Notice that if we treat every normal shard (when the number of adversaries is not large) as a distributed processing unit, we can incorporate the design of logical timestamps [25] in distributed transaction processing systems [17], which will empower the processing of transactions. Here we utilized a simplified version of MaaT where we don't do auto-adjustment of other transaction's timestamps.

**Algorithm 1:** Extra Verification Regarding Physcal Timestamp

```
Data: Input Transaction TX
Result: A Boolean value that indicates whether the verification is passed
current_time ← Time.Now();
if |current_time − TX.T_p| > T_Δ then
    return false;
    // if the time skew is too large, reject TX.
var txn_history = new static dictionary of lists;
if txn_history[TX.from] == NULL then
    txn_history[TX.from] == [TX];
else
    if txn_history[TX.from][−1].T_p − TX.T_p > 0 then
        return false;
        // To make sure the transactions from the same node preserve timing order.
    else
        txn_history[TX.from].append(TX);
        return true;
```

FIGURE 1. Pseudo-Code for Extra Verification

For normal shards, it acts exactly as described in DailyBFT except the following changes to make it compatible for parallel speculative execution.

For the primary shard, it collects output from all the normal shards. Notice that, the data dependency of transactions can be easily inferred by their metadata. And a fact is that, if a transaction visits multiple remote shards, it will leave traces in all the shards involved. When a normal shard submit logs to the primary shard, it will also write to the snailchain.

When the primary shard receives (or fetch from the snailchain) a batch of txns from a shard, it will check if it has received from all the shards transactions within this batch. If after certain timeout it has not received transactions from a particular batch, it means that batch has failed. In this case, a whole committee switch will be triggered at the next day starting point. After receiving all the shards' logs, the primary shard sort the transactions based on their commit timestamps (if some transaction has earlier batch number, it will be considered as the first key in the sorting, however, if its physical timestamp violates the timestamps from many shards, we decide that batch as invalid and all the transactions inside that batch are aborted). After sorting the primary shards filters all the transactions and keep a longest non-decreasing sequence in terms of physical timestamps. Out the log to the Hybrid Consensus component as that day's log.

There are still many optimisation spaces. One certain con is that the confirmation time in this design is not instant.

## 4. SMART CONTRACTS IN VIRTUAL MACHINES

4.1. **Design Rationale.** Of all the reasons to have an Ethereum Virtual Machine (EVM) [24], one of aims is to meter the usage with a transaction fee in a Proof of Work model. Since ours is a hybrid model, we'll take the liberty of exploring this design space a little bit further. Let us consider the possibility of a hybrid cloud ecosystem.

A basic problem people have faced is the kind of crude mathematical notations followed in Ethereum's Yellow Paper [24]. We therefore hope to follow something like KEVM jellopaper [15] to list out the EVM and TVM (described in 4.2) specifications. And in future, we hope to maintain our own specifications through Truechain's github account (https://github.com/truechain).

4.1.1. *What about containers instead of VMs?* One of the blockchain frameworks out there that come as close to this idea as possible, is Hyperledger's Fabric framework [9]. If one sets out to convert Fabric's permissioned nature into permissionless, one of the foremost challenges would be to solve the chaincode issue. What this means is while it's possible to keep a chaincode/smart contract in a single container, that is not a scalable model for a public chain. Having such a model for public chain means having to run several thousand containers, per se, several thousand smart contracts on a single node (because each node maintains a copy).

There have been attempts from the community on being able to run a certain maximum containers per node. The limit currently is 100 pods per node, per se, approximately 250 containers per node, as illustrated in Kubernetes container orchestration platform [5] and Red Hat's Openshift Container Platform 3.9's Cluster Limits [7]. Even with latest storage techniques like brick multiplexing [1], the max possible value (say MAX_CONTR) of containers could not possibly reach (at least right now) 1000. This issue could further be looked up in the discussions on kubernetes issues github page [4] around workload-specific limits that usually determine the maximum

**Algorithm 2:** Sharding and Speculative Transaction Processing

```
On BecomeShard:
  Initialize all the state data sectors: lastReaderTS = −1, lastWriterTS = −1, readers = [], writers = []
With transaction TX on shard S_i:
On Initialization:
  TX.lowerBound = 0;
  TX.upperBound = +∞;
  TX.state = RUNNING;
  TX.before = [];
  TX.after = [];
  TX.ID = rand;
On Read Address(addr):
if host(addr) == S_i then
    Send readRemote(addr) to itself;
else
    Broadcast readRemote(addr, TX.id) to host(addr);
    Async wait for 2f + 1 valid signed replies within timeout T_o;
    Abort TX when the timeout ticks;
Let val, wts, IDs be the majority reply;
TX.before.append(IDs);
TX.lowerBound = max(TX.lowerBound, wts);
return val;
On Write Address(addr):
if host(addr) == S_i then
    Send writeRemote(addr) to itself;
else
    Broadcast writeRemote(addr, TX.id) to host(addr);
    Async wait for 2f + 1 valid signed replies within timeout T_o;
    Abort TX when the timeout ticks.
Let rts, IDs be the majority reply;
TX.after.append(IDs) TX.lowerBound = max(TX.lowerBound, rts);
return;
On Finish Execution: for every TX' in TX.before do
    TX.lowerBound = max(TX.lowerBound, TX'.upperBound);
for every TX' in TX.after do
    TX.upperBound = min(TX.upperBound, TX'.lowerBound);
if TX.lowerBound ¿ TX.upperBound then
    Abort TX;
Broadcast Precommit(TX.ID, ⌊(TX.lowerBound + TX.upperBound)/2⌋) to all the previous remote shards which TX has accessed;
// If TX.upperBound = ∞, we can set an arbitrary number larger than TX.lowerBound.
On receive readRemote(addr, ID):
if host(addr) == S_i then
    DS[addr].readers.append(ID);
    return DS[addr].value, DS[addr].wts, DS[addr].writers;
else
    Ignore
On receive writeRemote(addr, ID):
if host(addr) == S_i then
    DS[addr].writers.append(ID);
    Write to a local copy;
    return DS[addr].rts, DS[addr].readers;
else
    Ignore
```

FIGURE 2. Pseudo-Code for Sharding and Speculative Transaction Processing

**Algorithm 3:** Sharding and Speculative Transaction Processing (cont.)

**On receive** Precommit(ID, cts)**:**
Look up TX by ID;
**if** *Found and* cts *not in* [TX.lowerBound, TX.upperBound] **then**
    Broadcast $Abort(ID)$ to the sender's shard.;
TX.lowerBound = TX.upperBound = cts;
For every data sector $DS[addr]$ TX reads, set $DS[addr].rts = max(DS[addr].rts, cts)$;
For every data sector $DS[addr]$ TX writes, set $DS[addr].wts = max(DS[addr].wts, cts)$;
Broadcast $Commit(ID, batchCounter)$ to the sender's shard.;
// batchCounter is a number which increases by 1 whenever the shard submit a batch of log to the primary shard.
**On receive** $2f + 1$ Commit(ID, batchCounter) **from each remote shards which** $TX$ **has accessed:**
TX.lowerBound = TX.upperBound = cts;
For every data sector $DS[addr]$ TX reads, set $DS[addr].rts = max(DS[addr].rts, cts)$;
For every data sector $DS[addr]$ TX writes, set $DS[addr].wts = max(DS[addr].wts, cts)$;
Mark $TX$ committed;
Let $TX.metadata = [ShardID, batchCounter]$;
**On output log**
Sort $TX$'s based on their $cts$. Break ties by physical timestamp.

pods per node. People who wish to scale containers usually prefer horizontal scaling rather than a vertical scaleup [2, 6], as the latter significantly increases complexity of design decisions. And there's no one-size-fits-them-all rule for a cluster scale configuration as that entirely depends on the workload, which being more in our case due to its decentralized nature, isn't very convincing for taking a step towards scaling this. At this point, it becomes more of an innovation problem than a simple technical specification search. Ethereum currently has $> 1000$ smart contracts deployed. Therefore this would be nothing but a crude attempt at optimizing the container ecosystem's design space.

Now let us expand a bit on the container scenario. Given the above crisis, a possible solution is to use container in a serverless architecture. But consider a scenario where $> 2000$ contracts are online and the concurrent requests, i.e., invocation calls to chaincode (a moving window) at a time exceed MAX_CONTR value, we then face the same problem all over again. Therefore, it is only advisable to add a throttling rate limit on the max concurrent requests. This severly limits the Transactions Per Second from the consensus, by design. Engineering should not be a bottleneck to what could be achievable alternatively. Therefore, we choose to stick to EVM design, although a bit modified for our purpose.

4.2. **Truechain Virtual Machine (TVM).** A typical example in this space would be that of the Ethereum Virtual Machine (EVM) [24], which tries to follow total determinism, is completely optimized and is as simple as it gets, to make incentivization simple step to calculate. It also supports various features like off-stack storage of memory, contract delegation and inter-invocation value storage.

We would reuse the EVM specifications for the snailchain, but add a new specification for TVM in the next version of this Yellow Paper, after careful consideration of the design rationale similar to EVM, deriving the stack based architecture utilizing the Keccak-256 hashing technique and the Elliptic-curve cryptography (ECC) approach.

The Truechain infrastructure will utilize a combination of EVM and another EVM-like bytecode execution platform for launching smart contracts. We choose to use one VM for POW and another for PBFT, embedded within each full node, so they could manage invocation calls on per-need basis.

The TVM backs the DailyBFT powered chains, which interact with the following components:

- re-using some of the concepts from tendermint, like the ABCI (Application BlockChain Interface) which offers an abstraction level as means to enable a consensus engine running in one process to manage an application state running in another.
- A different consensus engine pertaining to dailyBFT chians,
- A permissioned Ethereum Virtual Machine
- An RPC gateway, which guarantees (in a partially asynchronous network) transaction finality

#TODO - formally define transition states of TVM, smart contracts deployment strategy and a way to deploy permissioned VM onto a permissionless chain.

#TODO - define parameter to switch between the POW and the full node (POW and PBFT).

## 5. Blocks, State and Transactions

# TODO - Talk about changes to blocks, world state flow, transactions and execution model

## 6. Changes to the Ethereum Blockchain Paradigm

#TODO - Talk about the genesis block

### 6.1. Incentive Design.

#TODO - talk about incentive design

### 6.2. Compensation Infrastructure.

In this section we will present a concept of composation infrastructure in order to balance the workload of BFT committee members and non-member full nodes.

Treating all shards as equivalent of each other in terms of network and CPU bandwidth could produce skewed results, with inconsistent TPS, or worse, sometimes cross timeout limits, while ordering of transaction takes place from the Primary shard. To tackle this, we propose a compensation infrastructure, that works along the lines of Berkeley Open Infrastructure for Network Computing. There has been a previous attempt in this area from Gridcoin [3] and Golem network [23].

Gridcoin's distributed processing model relies pre-approved frameworks to the like of Berkeley Open Infrastructure for Network Computing (BOINC) [8], an opensource distributed volunteer computing infrastructure, heavily utilized within cernVM[10] in turn, harnessed by the LHC@Home project [16] A framework like this has to tackle non-uniform wealth distribution over time. On the other hand, Golem is another great ongoing project with concrete incentivization scheme, which would be used as an inspiration for compensation infrastructure's incentivization methodology. However a keeping in mind, a widely known problem is that a blockchain powered volunteer computing based rewarding model could easily fall prey to interest inflation if the design lacks a decent incentive distribution scheme over time. So to speak, an increasing gap between initial stake holders minting interest due to beginner's luck (algorithmic luck) and the contributors joining late, could thence be found fighting for rewards from smaller compensation pools that further condense.

Depending on the kinds of transactions and whether we'd need decentralized storage for some of the smart contracts, we propose the use of a hybrid infrastructure that utilizes BOINC and IPFS/Swarm, along side of EVM and TVM. This would make use of Linux Containers to deal with isolation of resources and we hope to expand on this section in the next version of this yellowpaper.

## 7. Future Direction

Even after optimizations to the original Hybrid Consensus, we acknowledge various optimizations possible on top of what was proposed in this paper. There are following possibilities:

- Improving timestamp synchronization for all nodes, with no dependency on centralized NTP servers.
- Detailed incentivization techniques for compensation infrastructure, so heavy infrastructure investors don't suffer from 'left-out', 'at a loss' problem
- Sharding techniques with replica creation to minimize the transaction set rejection from the BFT committee.
- Addition of zero knowledge proof techniques for privacy.
- Hybrid infrastructure of EVM, TVM and Linux container ecosystem.
- Sections for Virtual Machine Specification, Binary Data Encoding Method, Signing Transactions, Fee Schedule and Ethash Alternative.

## 8. Conclusions

We have formally defined Hybrid Consensus protocol and its implementation along with plausible speculations in the original proposal as well as implementation specifications. In this draft of paper, we have introduced various new concepts some of which we will detail in the next version very soon. We recommend people to choose ASIC resistant hardware for deployment of the POW only versus full nodes, although more details on hardware shall follow soon.

## 9. Acknowledgements

We owe a great deal of appreciation and are thankful, to the following folks for their untiring work towards pushing the protocols for a decentralized sovereignty, for their design rationale and implementations that serverd as a solid reference architecture in our proposal above. These folks and their legacies are as mentioned below:

- Rafael Pass, Miguel Castro, Satoshi Nakamoto, Vitalik Buterin, Gavin Wood, Ethan Buchman, Andrew Miller et al for their untiring work, contributions and continuous improvisations while spearheading the glamorous Improvement Proposals forums in addition to the active participation through Reddit, Mailing lists, chat forums, white and Yellow Papers, and rest of the mediums alike.
- CNCF and Kubernetes communities for their inspiring ventures into hybrid cloud computing.

## References

[1] Container-native storage for the openshift masses. *URL https://redhatstorage.redhat.com/2017/10/05/container-native-storage-for-the-openshift-masses/*.

[2] Deploying 2048 openshift nodes on the cncf cluster. *URL https://blog.openshift.com/deploying-2048-openshift-nodes-cncf-cluster/*.

[3] Gridcoin whitepaper: The computation power of a blockchain driving science and data analysis. *URL https://www.gridcoin.us/assets/img/whitepaper.pdf*.

[4] Increase maximum pods per node [kubernetes github issue #23349]. *URL https://github.com/kubernetes/kubernetes/issues/23349*.

[5] Kubernetes: Building large clusters. *URL https://kubernetes.io/docs/admin/cluster-large/*.

[6] Kubernetes scaling and performance goals. *URL https://github.com/kubernetes/community/blob/master/sig-scalability/goals.md*.

[7] Red hat openshift container platform's cluster limits. *URL https://docs.openshift.com/container-platform/3.9/scaling_performance/cluster_limits.html*.

[8] D. P. Anderson. Boinc: A system for public-resource computing and storage. *URL https://boinc.berkeley.edu/grid_paper_04.pdf*.

[9] E. Androulaki, A. Barger, and V. e. a. Bortnikov. Hyperledger fabric: A distributed operating system for permissioned blockchains. *URL https://arxiv.org/pdf/1801.10228v1.pdf*, 2018.

[10] J. Blomer, L. Franco, A. Harutyunian, P. Mato, Y. Yao, C. Aguado Sanchez, and P. Buncic. Cernvm a virtual software appliance for lhc applications. *URL http://iopscience.iop.org/article/10.1088/1742-6596/219/4/042003/pdf*, 2017.

[11] V. Buterin. Ethereum white paper, 2014. *URL https://github.com/ethereum/wiki/wiki/White-Paper*.

[12] R. Canetti. Universally composable security: A new paradigm for cryptographic protocols. In *Foundations of Computer Science, 2001. Proceedings. 42nd IEEE Symposium on*, pages 136–145. IEEE, 2001.

[13] M. Castro, B. Liskov, et al. Practical byzantine fault tolerance. In *OSDI*, volume 99, pages 173–186, 1999.

[14] Y. Gilad, R. Hemo, S. Micali, G. Vlachos, and N. Zeldovich. Algorand: Scaling byzantine agreements for cryptocurrencies. In *Proceedings of the 26th Symposium on Operating Systems Principles*, pages 51–68. ACM, 2017.

[15] E. Hildenbrandt, M. Saxena, and X. e. a. Zhu. Kevm: A complete semantics of the ethereum virtual machine. *URL https://www.ideals.illinois.edu/handle/2142/97207*, 2017.

[16] D. e. a. Lombraa Gonzlez. Lhchome: a volunteer computing system for massive numerical simulations of beam dynamics and high energy physics events. *URL http://inspirehep.net/record/1125350/*.

[17] H. A. Mahmoud, V. Arora, F. Nawab, D. Agrawal, and A. El Abbadi. Maat: Effective and scalable coordination of distributed transactions in the cloud. *Proceedings of the VLDB Endowment*, 7(5):329–340, 2014.

[18] S. Micali, M. Rabin, and S. Vadhan. Verifiable random functions. In *Foundations of Computer Science, 1999. 40th Annual Symposium on*, pages 120–130. IEEE, 1999.

[19] S. Nakamoto. Bitcoin: A peer-to-peer electronic cash system. *URL http://bitcoin.org/bitcoin.pdf*, 2008.

[20] R. Pass and E. Shi. Hybrid consensus: Efficient consensus in the permissionless model. In *LIPIcs-Leibniz International Proceedings in Informatics*, volume 91. Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2017.

[21] R. Pass and E. Shi. The sleepy model of consensus. In *International Conference on the Theory and Application of Cryptology and Information Security*, pages 380–409. Springer, 2017.

[22] R. Pass and E. Shi. Thunderella: blockchains with optimistic instant confirmation, 2017.

[23] T. G. team. The golem project: The golem project. *URL https://golem.network/doc/Golemwhitepaper.pdf*, 2016.

[24] G. Wood. Ethereum: A secure decentralized generalized transaction ledger. *URL https://ethereum.github.io/yellowpaper/paper.pdf*, 2018.

[25] X. Yu, A. Pavlo, D. Sanchez, and S. Devadas. Tictoc: Time traveling optimistic concurrency control. In *Proceedings of the 2016 International Conference on Management of Data*, pages 1629–1642. ACM, 2016.

## APPENDIX A. TERMINOLOGY

**TrueChain Virtual Machine (TVM):** In contrast to EVM which does handles incentivization and rotating committee selection, a TVM is based on similar design principles but carries out actual consensus and voting based off of PBFT based Hybrid Consensus.