Asynchronous Consensus Algorithm

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Abstract

This document describes a new consensus algorithm which is asynchronous and uses gossip based message dissemination between nodes. The current version of the algorithm does not cover the case of a node failure or significantly delayed response. This is the subject of further research of the algorithm.

An outline of a new design for trust-less payment system is given in appendices.

1 Introduction

Consensus is a fundamental problem in distributed systems with a wide range of application. There are two types of consensus; the first is Consensus on a value, or, on the fact that an event has happened. The second is Consensus on the linear order of the events in the system. The later assumes a consensus on every value to be ordered and imposes stricter requirement of the order of these events in the system.

The Lachesis protocol \cite{3,2} aims to provide consensus on linear order of events, however, implementation of it revealed several flaws that prevented it from reaching consensus at scale. Attempts to fix these issues led to a rethink of the approach which consequently produced the algorithm as described below.

2 Acknowledgement

It is a pleasure to thank Ann Marie Vande More whose help in improving the readability of this article is greatly appreciated.

3 Basic notions

3.1 Node/peer

A node is an autonomous participant in the network of consensus (section \ref{sec:network}). Usually, it is a standalone computer, however, we consider a node to be any instance following this algorithm and having the following unique attributes within the network:

- a pair of private/public keys;
- its unique identifier;
• a network address at which this node operates following the algorithm.

Other attributes of a node:
• current Lamport time (section 3.4) on the node;
• current height number, indicating the index of the last event created by the node;
• current frame number (section 3.6);
• last finalised frame number on the node;

In the description of the internal functionality of a node, the node is called a node. In the description of node functions as they are seen from another node, the node is called a peer. Otherwise the node and the peer are synonyms throughout this article.

3.2 Peer list

The Peer List is the list of all nodes that execute this algorithm and combined into a single network ensuring each peer is aware of the existence of all other peers of that network. Unique attributes of each peer are known to every member of the network.

3.3 Consensus network

The Consensus network is a set of nodes that execute this algorithm and sharing common Peer List. In other words, they are aware of existence of each other and can communicate with each other following procedures of the algorithm. The network throughout this document means the Consensus network unless otherwise specified.

3.4 Lamport time

The Lamport time is the virtual clock of a node that follows specific rules:
1. There are two strategies to initialise it; the first is that all nodes start with the value set to 0, and the second is to initialise it with the value of 13th byte of the node’s unique identifier. The former gives a higher number of events with the very same Lamport timestamp in initial rounds of the algorithm;
2. On creation of a new event, the node increases its Lamport time by 1 before assigning timestamp to the event;
3. On synchronisation with other peer, the Lamport time is set to the maximum value of Lamport time on both peers.

The Lamport timestamp is a fixed value of the Lamport time.

3.5 Event

The Event is an atomic block of exchange between peers. The event’s creator is a peer who created that event. Each event has the following attributes:
• its unique identifier;
• creator’s unique identifier;
• creator’s height index;
• self-parent’s unique identifier and hash value;
• other-parent’s unique identifier and hash value;
• Lamport timestamp;
• transaction payload (section 3.5.1);

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4 usually it is an IP address and base port number
4 the node connection graph may not be complete until it remains connected
5 see 4 for the original idea description.
6 or any other preselected
- hash value of all attributes above\(^7\);
- array of digital signatures of the hash attribute above; one per each peer this event has been passed by;
- frame number (section 3.8);
- flag table (section 3.9).

Please note, the frame number and the flag table attributes are not passed over the network (communicated between peers); each node of the network calculates values of these attributes independently.

ACA does not require any particular hashing algorithm to be used for the hash values; the choice of such algorithm is on the implementation.

Events of the network form a Merkle-like tree\(^8\): each event references two other events as its parent events by hash values of these events; one parent event is the most recently created event of the node, this event is called self-parent, and the second is the last known even\(^9\) created by any other peer, this event is called other-parent. Leaf events (see section 3.5.2) are the base for such reference recursion. This structure ensures integrity of all events passed through the network.

If an event \(y\) is in a sub-tree of the Merkle-like tree described in the paragraph above with an event \(x\) as its root, then the event \(x\) sees the event \(y\) and the event \(y\) is visible for the event \(x\).

When a peer creates an event it signs it using its private key. When a peer receives an event following the Synchronisation Procedure (Procedure 4) it verifies all digital signatures of the event using public keys of corresponding peers and then sign it with its private key. This structure provides additional guarantee of the event integrity.

### 3.5.1 Transaction payload

The Transaction payload is an array of user transactions (which could be empty) combined with an array of internal transactions (which again could be empty).

Internal transactions are separated from user transactions because they are hidden from users and can be used for implementation of internal network operations such as to handle dynamic node participation and private/public keys change. They could also disseminate information about events failed in the consensus or any other data needed to implement any additional node/peer functionality.

### 3.5.2 Leaf event

The Leaf event is the first event of a peer. It has special status as follows:

- it is created once a peer is added to the network;
- it has empty transaction payload;
- its height index value is 0 (index is equal to creator’s height at the time of event creation);
- its Lamport timestamp is set to the initial value of the node’s Lamport time;
- its parents’ unique identifiers and hashes are set to zero;
- its Flag table contains only that leaf event itself with value of the frame number equal to the current frame number at the time of peer addition\(^{10}\).

This special status allows all leaf events to be created on each participating node independently without the need to communicate those leaf events to other participants. Every newly added peer devises leaf events of all other participants from the Peer List of the network.

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\(^7\)these attributes are called hash domain attributes.
\(^8\)see [5] for the original idea.
\(^9\)known to the node at the time of event creation.
\(^10\)at the time of network initialisation the value of the current frame is 0.
3.6 Frame number and Frame

The Frame number is a characteristic of an event which initial value is calculated in the Event Insertion Procedure (Procedure 6). Frame is a set of all messages in the network having the same frame number; and also all events of the same frame come into final ordering altogether; this means all events in a frame with a lower number precede all events in a frame with a higher number.

3.7 Root majority

The Root majority is a number indicating threshold value for the number of visible roots from the current frame for an event before that event becomes the root of a new frame. This parameter regulates approximately the number of events of the same creator in a single frame. This could be of any value strictly between 1 and n, with n being the size of the Peer List. The nearest integer to \( \frac{n+3}{3} \) could be a good initial value for it. Additional research is required to see if this parameter could be a per-node parameter (with modification of its value via internal transactions).

3.8 Root

Leaf events are roots by default; any event seeing Root majority roots of the previous frame becomes a root of a new frame.

3.9 Flag Table and Creator Flag Table

The Flag Table is a map used in the algorithm to track propagation of events between nodes. It uses unique identifiers (IDs) of visible roots as keys of the map and for each root it stores the frame number of that root. \{ event.ID : framenumber \}

The Creator flag table is a map similar to the Flag table in that both reference visible roots, but Creator flag table uses creator’s unique identifier as key of the map instead of event unique identifier. This map is used to detect the moment when a frame may be finalised on a particular node. \{ creator.ID : framenumber \}

3.10 Visibilis

An event becomes a Visibilis when the size of its creator flag table becomes equal to the number of peers in the network. Once an event becomes Visibilis on the current node, the current node executes the Frame Finalisation Procedure (Procedure 9).

3.11 Gossip List

The Gossip list stores Lamport timestamps and event unique identifiers for every peer and indicates when each peer has communicated or seen most recently as well as its last known event.

The merging of two Gossip Lists is a simple procedure that creates a new Gossip List consisting of the maximal value of Lamport timestamp and unique identifier of the most recent event for every peer out of these two lists.

4 Node procedures

The functionality of a node is defined by two main procedures A (Procedure 1) and B (Procedure 2) executing in parallel.

Procedure A periodically selects the next peer from its peer list and requests from it all events known by remote peer but unknown by the current node.
Procedure 1: Procedure A

1: loop
2: start heartbeat timer;
3: select a peer, P, following Peer Selection Procedure (Procedure 3);
4: execute Synchronisation Procedure (Procedure 4) with peer P;
5: wait until heartbeat timeout.
6: end loop

The heartbeat period in the Procedure A has no effect on reaching the consensus and can be set to an arbitrary value which throttles the frequency of communications between peers and thus controls the load on the node; it can be omitted.

Procedure B is a listener which reply to synchronisation requests from other peers.

Procedure 2: Procedure B

1: loop
2: receive a Synchronisation Request from a peer, A;
3: execute Synchronisation Reply Procedure (Procedure 5) with peer A.
4: end loop

4.1 Next Peer Selection Procedure

The selection of the next peer to communicate with in the Procedure A should aim to assist the construction of a well balanced tree of events in the network and therefore minimise the height of sub-trees spanning all nodes. It should take into account all known events and the topology of the tree they induce.

For simplicity one can take the following idealistic approach: let all peers be sorted by public key and there are $n$ peers in total, with $n > 1$. The current is the index of the node in that sorted list. If $r$ is the peer selection round number, which is an internal static variable, then here Procedure 3 to select the index of the next peer to connect.

Procedure 3: Next peer selection procedure

```
Require: initially $r \leftarrow n \gg 1$  \(\gg\) is the operation of binary shift to the right
1: next = (current + r) \(\mod n\)  \(\mod\) is modulo \(n\) operation
2: if $r > 1$ then
3: $r \leftarrow r \gg 1$
4: else
5: $r \leftarrow n \gg 1$
6: end if
7: return next
```

Another approach would be to select the next peer randomly from the peer list excluding the current node and the most recently contacted peer. This approach is closer to real byzantine-like behaviour of a node, which does not follow prescribed next peer selection procedure, rather, it leads to a less optimal peer synchronisation pattern.

4.2 Synchronisation Procedure

The Synchronisation Procedure is an active part of event propagation between nodes. As the first step, it sends the Synchronisation Request which is formed by the current Gossip List and the current Lamport time of the node.

Then, upon receiving the Synchronisation Reply which consists of the remote Gossip List, the remote Lamport time value and the bundle of events. All received events in the bundle are processed one by one in the order of the bundle by executing the Event Insertion Procedure (Procedure 6) for each event.

In the next step, the remote Gossip List is merged into the current Gossip List while the Lamport time value of the current node is set to either its current value or the remote Lamport time value, whichever is greater.

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11 any practical implementation better should allow several instances of procedure B to run in parallel, one per each remote peer connected; or create a pool of such procedures to balance load on the node.
12 not yet known by the current node
Finally, any pending user transaction, internal transaction or a non-finalised event will initiate a new event executing the Event Creation Procedure (Procedure 6).

Procedure 4 Synchronisation Procedure

| Require:     | P = remote peer selected following Procedure 3 |
| Require:     | $GossipList$ = current $Gossip List$ of the node |
| Require:     | $Lamport Time$ = current $Lamport time$ of the node |
| 1:           | send $Synchronisation Request$ to remote peer $P$; |
| 2:           | receive a $Synchronisation Reply$ $R$; |
| 3:           | for all $event \in R.bundle$ do |
| 4:           | $EventInsertionProcedure(event)$ |
| 5:           | end for; |
| 6:           | $GossipList \leftarrow \text{merge}(GossipList, R.GossipList)$ |
| 7:           | $Lamport Time \leftarrow \text{max}(Lamport Time, R.Lamport Time)$ |
| 8:           | if $\exists$ pending user or internal transaction or $\exists$ non-finalised event then |
| 9:           | $EventCreationProcedure(P)$ $\triangleright$ see section 4.5 |
| 10:          | end if |

4.3 Synchronisation Reply Procedure

The Synchronisation Reply Procedure is a passive part of event propagation between nodes and is executed upon receiving a $Synchronisation Request$ from a remote peer.

As the first step, it extracts the remote $Gossip List$ from the $Synchronisation Request$ received, compares it with the current $Gossip List$ of the node and creates a bundle of all known messages not known by the remote peer.¹³

Then it sends bundled events to the remote peer along with the current $Gossip List$ and the current $Lamport timestamp$. All three form the Synchronisation Reply.

Finally, it sets the $Lamport time$ value of the current node to either its current value or the remote $Lamport time$ value, whichever is greater.

Procedure 5 Synchronisation Reply Procedure

| Require:     | $Synchronisation Request, Req$, from a peer, $P$. |
| Require:     | $GossipList$ = current $Gossip List$ of the node. |
| Require:     | $Lamport Time$ = current $Lamport time$ of the node. |
| Ensure:      | $Synchronisation Reply, Rpl$, is sent back to the peer $P$. |
| 1:           | $Rpl.bundle \leftarrow \emptyset$ |
| 2:           | for all $event \in GossipList$ and $event \notin Req.GossipList$ do |
| 3:           | $Rpl.bundle \leftarrow Rpl.bundle + event$ |
| 4:           | end for |
| 5:           | $Rpl.GossipList \leftarrow GossipList$ |
| 6:           | $Rpl.Lamport Time \leftarrow Lamport Time$ |
| 7:           | $Lamport Time \leftarrow \text{max}(Lamport Time, Req.Lamport Time)$ |
| 8:           | send $Rpl$ to the peer $P$ |

4.4 Event Insertion Procedure

The Event Insertion Procedure is executed each time an event is inserted into the local storage of a node, either in the Synchronisation Procedure (Procedure 4), or in the Event Creation Procedure (Procedure 7). It calculates the frame number and the flag table attributes of the event, which are not transmitted over the network between peers. This procedure also checks the condition for frame finalisation on the current node and finalises the frames with that condition met.

As the first step, this procedure calculates the frame number for the inserting event and checks the condition if the event becomes root using the following rules:

- If the frame number of the other-parent event is greater than the frame number of the self-parent event then the event becomes root and its frame number is set to the frame number of other-parent event.

¹³these are events from each known peer whose Lamport timestamp greater or equal to the value from corresponding coordinate in the remote Gossip List.
• Or, if the frame number of the self-parent event is greater than the frame number of the other-parent event then the event is not the root and its frame number is set to the frame number of self-parent event.

• Otherwise, both parent events have the same frame number; and in that case:

  – the Root Flag Table is calculated using the Strict Flag Table Merging Procedure (see section 4.6) with the self-parent event frame number and the self-parent event flag table and the other-parent event flag table as parameters;

  – and then the Creator Flag Table is derived from the Root Flag Table and the self-parent event’s frame number using the Creator Table Derivation Procedure (Procedure 8).

  – Now, if the size of the Creator Flag Table is greater or equal to the value of Root Majority (see section 3.7), then the event becomes root and its frame number is set to one more than the self-parent event’s frame number.

Next, the Visibilis Flag Table is calculated using the Open Flag Table Merging Procedure (Section 4.6) with the last finalised frame number plus one, the self-parent event flag table and the other-parent event flag table as parameters. For the event detected as root in the previous step, its unique identifier and the frame number are added into the Visibilis Flag Table. After that, the Visibilis Flag Table becomes the flag table of the inserting event. At this point the event could be stored in the local database.

The final step is to check the condition for frame finalisation. To do so, the Creator Visibilis Flag Table is devised from the Visibilis Flag Table and the number of first not yet finalised frame as parameters to the Creator Table Derivation Procedure (Procedure 8). If the size of the Creator Visibilis Flag Table is equal to the size of the Peer List the procedure finds the minimal value of the frame number in the Creator Visibilis Flag Table and finalises all frames up to this number by calling the Frame Finalisation Procedure (Procedure 9) consecutively for each frame to finalise. It is important that the frame with the number equal to the minimal found is not finalised at this stage.

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**Procedure 6 Event insertion procedure**

Require: event – the event being inserted

Require: selfParent, otherParent – parent events of the event being inserted

Require: lastFinalisedFrame – the number of the last finalised frame on the node

Require: n – the size of peer list, i.e. the number of peers in the network

Ensure: frame number of the event is calculated

Ensure: flag table of the event is calculated

1: if selfParent.Frame = otherParent.Frame then

2: rootFlagTable ← strictMergeFlagTables(selfParent.Frame, selfParent.FlagTable, otherParent.FlagTable)

3: creatorRootFlagTable ← deriveCreatorTable(rootFlagTable)

4: if length(creatorRootFlagTable) ≥ rootMajority then

5: root ← True

6: frame ← selfParent.Frame + 1

7: else

8: root ← False

9: frame ← selfParent.Frame

10: end if

11: else if selfParent.Frame > otherParent.Frame then

12: root ← False

13: frame ← selfParent.Frame

14: else

15: root ← True

16: frame ← otherParent.Frame

17: end if

18: event.Frame ← frame

19: visibilisFlagTable ← openMergeFlagTables(lastFinalisedFrame+1, selfParent.FlagTable, otherParent.FlagTable)

20: if root then

21: visibilisFlagTable(event.ID) ← frame

22: end if

23: event.FlagTable ← visibilisFlagTable

24: ◦ ... store event into local database ...

25: creatorVisibilisFlagTable ← deriveCreatorTable(visibilisFlagTable)

26: if length(creatorVisibilisFlagTable) = n then

27: frameToFinaliseUpto ← minFrameInFlagTable(creatorVisibilisFlagTable)

28: for frame = lastFinalisedFrame + 1 up to frameToFinaliseUpto do

29: FrameFinalisationProcedure(frame)

30: end for

31: end if
Please note, it is important that the loop on the line 28 is not executed for the value of frameToFinaliseUpto.

Function minFrameInFlagTable() on the line 27 looks up for the smallest Frame number in the CreatorFlag Table given.

4.5 Event Creation Procedure

A new event may be created each time a node synchronises with another peer following procedure A (Procedure 1). The Event Creation Procedure calculates attributes of the new events according to the following rules:

- The creator’s unique identifier is set to the unique identifier of the current node (that is, the one that creates the event);
- The creator’s height index is set to the next index of the event created by the current peer;
- The self-parent’s hash and unique identifier are set to the hash and unique identifier of the last event created by the current node;
- The other-parent’s hash and unique identifier are set to the hash and unique identifier of the last known event of the peer just communicated following procedure A (Procedure 1);
- The Lamport timestamp of the new event is set to the next value of the node’s Lamport time;
- The transaction payload is created from pending internal and external transactions;
- The hash value is calculated as hash (control sum) of the values of all attributes above;
- The signature of the hash value above (or all attributes above) is created using node’s private key and put it into signatures array;

After all attributes above are filled, this procedure executes the Event insertion procedure (Procedure 6) for the created event, which calculates the value of the frame number and the Flag table for created event.

**Procedure 7 Event creation procedure**

| Require: peer – a remote peer as other-parent |
| Require: node – current node |
| Ensure: Attributes of the new event are filled. |

1: event ← ∅  
2: event.signatures ← ∅  
3: event.creatorID ← node.ID  
4: lastSelfEvent ← getLastEvent(node.ID)  
5: lastOtherEvent ← getLastEvent(peer.ID)  
6: node.height ← node.height + 1  
7: event.height = node.height  
8: event.selfParent.ID ← lastSelfEvent.ID  
9: event.selfParent.hash ← lastSelfEvent.hash  
10: event.otherParent.ID ← lastOtherEvent.ID  
11: event.otherParent.hash ← lastOtherEvent.hash  
12: node.lamportTime ← node.lamportTime + 1  
13: event.lamportTimestamp ← node.lamportTime  
14: event.payload ← createPayload()  
15: event.hash ← Hash(event)  
16: event.signatures ← event.signatures + node.Sign(event)  
17: EventInsertionProcedure(event)

Function getLastEvent() on the lines 4 and 5 retrieves the last known event for the peer with specified unique identifier.

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14ACA doesn’t rely on uniqueness of this value for all events created by a peer, though this property is for convenience and provides additional check for integrity of events from the same peer.

15the new event is considered created when this procedure finishes.

16node’s Lamport time is increased by 1 before assigning to the event.

17external transactions – those received from customers
Function `createPayload()` on the line 14 creates payload for the event out of pending internal and external transactions.
Function `Hash()` on the line 15 calculates hash (control sum) of the event over hash domain attributes.
Method `node.Sign()` on the line 16 creates digital signature of the event hash value or of hash domain attributes and the hash value.

### 4.6 Flag Table Merging Procedures

1. **Open procedure**
   
   Open flag table merging procedure takes two flag tables and the frame number as parameters and forms a new flag table. This contains only the entries from source flag tables whose corresponding frame number is equal to or greater than the frame number specified.

2. **Strict procedure**
   
   Strict flag table merging procedure takes two flag tables and the frame number as parameters and forms a new flag table. This contains only the entries from source flag tables whose corresponding frame number is equal to the frame number specified.

### 4.7 Creator Table Derivation Procedure

The **Creator Table Derivation Procedure** is an auxiliary procedure used in the **Event Insertion Procedure** (Procedure 6). This procedure takes a flag table as an input and produces a map which stores the creator’s unique identifiers of visible roots, and for each visible root it stores the minimal frame number.

#### Procedure 8 Creator table derivation procedure

```plaintext
Procedure 8 Creator table derivation procedure

Require: inputFlagTable – flag table
Require: minFrameNumber
1: resultCreatorTable ← {}  
2: for all pair \{eventID, frameNumber\} ∈ inputFlagTable and frameNumber ≥ minFrameNumber do
3:   event ← getEvent(eventID)
4:   creator ← event.creatorID
5:   if ∄ resultCreatorTable{creator} then
6:     resultCreatorTable{creator} ← frameNumber
7:   else if resultCreatorTable{creator} > frameNumber then
8:     resultCreatorTable{creator} ← frameNumber
9:   end if
10: end for
```

The function `getEvent()` on the line 3 retrieves an event by its unique identifier.

### 4.8 Frame Finalisation Procedure

The **Frame Finalisation Procedure** is called from the **Event Insertion Procedure** when the condition for the frame finalisation is met on the current node.

Firstly, all events in the frame are sorted according the following rules:

1. the smaller Lamport timestamp has priority;
2. to break ties above, the smaller Lamport timestamp of self (grand-)parents (recursively up to leaf events) has priority;
3. to break ties above, the smaller hash value has priority;
4. to break ties above in a rare case of hash collision, the smallest unique identifier has priority.

Then each event in the frame is finalised in the order by executing **Event Finalisation Procedure** (see Section 4.9).

18 referred as `strictMergeFlagTable()` in Procedure 6
19 referred as `openMergeFlagTable()` in Procedure 6
20 For a large number of peers in the network, this rule will require significant amount of storage access operations and thus could be omitted or relaxed to self-parent’s Lamport timestamp only due to performance reasons.
**Procedure 9 Frame Finalisation Procedure**

**Require:** Frame.events – all events in the frame.

1. Sort(Frame.events)
2. for all event ∈ Frame.events do
3.   eventFinalisationProcedure(event)
4. end for

### 4.9 Event Finalisation Procedure

The Event Finalisation Procedure is called by the Frame Finalisation Procedure for each event in the frame being finalised.

For each event, the payload is processed in the following order: 1. the external transactions are pushed to customers; 2. then internal transactions are processed; 3. and finally, the flag table is stripped off.

Thus external transactions should not depend on the execution results of internal transactions from the same event, if they do, such external transactions must be put into the next event of the creator.

### Appendices

**Rust implementation**

The ACA has been implemented in the Rust language. The implementation is available on Github: [https://github.com/Fantom-foundation/libconsensus-dag](https://github.com/Fantom-foundation/libconsensus-dag)

This implementation of ACA’s procedures relies on hashes and digital signatures as unique identifiers of events in the network, however, none of hashing and digital signature algorithms provides guarantee of being collision-free. Additional research is required to tailor modifications of the implementation to make it collision proof. Such research and application is at the discretion of the user.

**A note on Lachesis protocol and Swirlds algorithm**

The Lachesis protocol \[3, 2\] works with \(n\) nodes and connects each new event with parent events from \(k\) other nodes. Thus, a \(k\)-ary tree with \(n\) leaf vertexes must be constructed before a node would be aware of all events of the same frame from all \(n\) nodes. It is well-known that the minimal height for a tree with \(n\) leaf vertexes is \(\lceil \log_k n \rceil\).

When a root becomes clotho it sees \(\frac{2}{3}\) of roots of the previous frame, this means a tree of height at least \(\lceil \log_{\frac{2}{3}} n \rceil\) should be constructed, but this value is less than or equal to the minimal height mentioned in the paragraph above.

The atropos time selection procedure is executed straight after clotho status is confirmed (see Algorithm 1 in [2]), thus, there is a possibility that atropos time will be selected before a node sees events of the same frame from all \(n\) nodes. This means a non-zero probability that different nodes would select different atropos time (having different sets of events included into \(\frac{2}{3}\) of \(n\) peers seen be each node).

The Swirlds hashgraph consensus algorithm [1] is very similar to the Lachesis protocol, its divideRounds, decideFrame, findOrder procedures are executed after each reception of a sync, and in the same way as for the Lachesis protocol there is a non-zero probability that different nodes would select different events in the next round received and thus sorted them differently in the return of findOrder procedure because the Swirlds algorithm requires \(\frac{2}{3}\) of witness events and this is very same case of tree heights as for the Lachesis protocol.

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21 this procedure is called eventFinalisationProcedure() in Procedure 9.
22 to save storage space; though this step is optional.
23 commit 1f9ec3570c70d51c060cfc5eba8d76f938890dcb
24 one witness event per network member in each round
Both the Lachesis protocol and the Swirlds consensus algorithm have the very same
design flaw: they lack a mechanism of detecting if a particular node has received all events
of a particular round/frame from all other nodes and thus would execute voting and produce
the final event sorting prematurely. This problem will aggravate with the growth of network
size, that is, the number of participating nodes.

TxFlow: a new electronic payment system

In the seminal paper *Bitcoin: A Peer-to-peer Electronic Cash System* [6], Satoshi Na-
kamoto outlined the design of a new payment system when the trusted third party has
been replaced with the cryptographic proof and the public disclosure of all operations with
the electronic cash in order to solve the coin double-spending problem.

The events of the ACA defined in this article form Merkle-like tree (see section 3.5),
which provides the same level of the cryptographic proof as in the Bitcoin design. Making
the whole system public, one can build a distributed payment system similar to the bitcoin
network but without a need to form blocks of transactions. Below is the outline of such
system design.

**Accounts**

A peer with public and private keys (and so with an unique peer ID) represents an
account. Only owner of the private key can authorise operations on a particular account.
Note, in this schema a peer may not execute ACA procedures and do supply/receive trans-
actions over its account via another peer willing to do so.

**Transactions**

A transaction in such a system could be anything put into transactions field of the ACA
event. It could be a simple instruction to move funds from the account to another or a group
of them; it could be a program for a virtual machine to execute a smart contract. We leave
the semantic of transactions to the implementation.

Overall, the ACA guarantees the key property of the system: each node receives all
transactions in the very same order. In other words, every account receives the same flow
of all transactions in the system, and having the same starting values for all accounts each
node will have the very same state of all accounts after each transaction processed. This
property solves double spending problem in a way that, out of two transactions spending
the same funds, one would be delivered first for every participant and it would be the same
transaction for all participants. This means everyone will accept and reject the very same
transaction out of two conflicting transactions.
References

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