

CLAIMS

1. A sharding engine, SE, configured to monitor and optimise the performance of a communicatively coupled distributed ledger technology, DLT, platform,
5 the DLT platform comprising a DLT storage module configured for storing and processing DLT transactions, the DLT storage module being partitioned into one or more DLT shards according to a DLT configuration, each DLT shard being associated with a local network of transaction processing nodes configured to process and verify submitted DLT transactions according to a local consensus protocol defined by a Global Conflict
10 Resolver, GCR, module in accordance with the DLT configuration, the sharding engine comprising:

a sensor module configured to monitor a set of configuration parameters associated with the DLT platform; and

a decision and optimisation, DO, module configured to receive and process the
15 values obtained from the set of configuration parameters to determine a set of corresponding performance metrics indicative of the operational performance of the target DLT platform;

wherein the DO module is configured to compare the values of the performance metrics with corresponding target values, and wherein, when at least one of the
20 performance metrics is within a value range from at least one corresponding target value, the DO module is configured to adjust an aspect of the DLT configuration of the DLT platform to optimise its operational performance.

2. The sharding engine of claim 1, wherein the DO module is configured to adjust the DLT configuration based on at least one configuration protocol selected from
25 a configuration protocol database, the at least one configuration protocol comprising instructions, which when executed trigger an optimisation of one or more aspects of the DLT platform configuration.

3. The sharding engine of claim 2, wherein the at least one configuration protocol is selected, based on the operational performance determined for the DLT platform, from a DLT optimisation matrix comprising a plurality of different DLT
30 operational performance scenarios, each associated with one or more configuration protocols from the database.

~~4.3. The sharding engine of claim 3, wherein when the determined DLT operational performance is absent from the DLT optimisation matrix, the DO module is~~

configured to issue a notification to one or more users requesting input for adjusting the DLT configuration and/or selecting a configuration protocol.

5 5. ~~_____~~ The sharding engine of ~~any one either~~ of claims 2 ~~to 4~~ or 3, wherein the DO module is configured, based on the at least one selected configuration protocol, to adjust the DLT storage architecture:-

~~6.4. _____~~ The ~~sharding engine of claim 5~~, wherein adjusting the DLT storage architecture comprises adjusting the partitioning configuration of the DLT storage architecture by adjusting the number and structure of DLT shards involved in the processing of DLT transactions.

10 7. ~~_____~~ The sharding engine of ~~claims 5 or 6~~ claim 4, wherein adjusting the DLT storage configuration comprises grouping of DLT shards having common shard characteristics:-

~~8.5. _____~~ The ~~sharding engine of claim 7~~, wherein the common shard characteristics comprise at least one of identifying DLT shards that are involved in inter-shard DLT transactions.

 9. ~~_____~~ The sharding engine of ~~any one of claims 5 to 8~~ either of claims 4 or 5, wherein the DO module is configured, based on the selected at least one configuration protocol, to adjust the DLT storage architecture by splitting the DLT storage architecture into a plurality of hierarchically connected storage layers:-

20 ~~10. _____~~ The ~~sharding engine of claim 9~~, and wherein the hierarchically connected storage layers comprise a local storage layer, which is configured to store in a plurality of local shards the DLT transactions submitted to each of the DLT shards, and a main storage layer comprising one main shard, which is configured to store references to all DLT transactions processed by shards belonging to lower storage layers:-

25 ~~11.6. _____~~ The ~~sharding engine of claim 10~~ and, wherein the hierarchical connected storage layers comprise one or more intermediate storage layers between the local storage layer and the main storage layer, each intermediate storage layer being configured to store, in intermediate shards, inter-shard DLT transactions between two or more DLT shards and/or references to transactions processed by a group of shards
30 belonging to the local storage layer and/or one or more lower hierarchy intermediate storage layers.

~~12.7. _____~~ The sharding engine of ~~any one of claims 9 to 11~~ claim 6, wherein each shard in each of the hierarchical connected storage layers is associated with a network of transaction processing nodes for ordering and verifying submitted DLT transactions.

~~13.8.~~ The sharding engine of claim ~~127~~, wherein the DO module comprises a Global Committee Selection, GCS, module configured to select, based on a set of criteria associated with safety and liveness, a set of global transaction processing nodes from the local networks of the DLT shards to participate in the transaction processing networks associated with the shards in each hierarchically connected storage layer.

~~14.9.~~ The sharding engine of claim ~~138~~, wherein the GCS module is configured to generate a global network of transaction processing nodes for processing and verifying transactions submitted to the main shard of the main storage layer and intermediate shards of the intermediate storage layers, wherein the global network of transaction processing nodes are at least selected from the transaction processing nodes of the local network associated with each of the DLT shards.

~~15.10.~~ The sharding engine of any one of claims ~~96~~ to ~~149~~, wherein the DO module is configured to generate shards at each of the different hierarchically connected storage layers, based on the DLT transactions submitted to the DLT shards and/or the grouping of the DLT shards.

~~16.~~ The sharding engine of claims ~~96~~ to ~~1510~~, wherein the DO module comprises an Intermediate Graph Representation, IGR, module configured to convert the data structure of the DLT transaction data processed by the transaction processing nodes in each of the local shards of the local storage layer into a common IGR data structure, which acts as a common data representation format for various types of DLT platforms.

~~17.11.~~ ~~The sharding engine of claim 16~~, wherein the IGR data structure comprises a graph data structure configured to abstract the data structure of a target DLT platform to the common IGR data structure; and an authenticated data structure comprising ordered references to transactions in the graph data structures, so that operations submitted to the DLT platform by untrusted parties are verified by the corresponding networks of transaction processing nodes.

~~18.~~ The sharding engine of ~~claims 16 or 17~~ claim 11, wherein the DLT consensus module comprises a Higher Graph Representation, HGR, module configured to receive as input the IGR data structures generated by the IGR module and accordingly convert them into corresponding higher graph representations, HGR, data structures stored at corresponding intermediate shards at one or more intermediate storage layers and/or the main shard of the main storage layer of the DLT storage module.

~~19.12.~~ ~~The sharding engine of claim 18~~, wherein each HGR data structure comprises references to inter-related DLT transactions referenced in a plurality of IGR

and/or HGR data structures that are stored at a lower hierarchical storage layer of the DLT storage.

20-13. The sharding engine of claim ~~18~~ or ~~19~~ 12, wherein the HGR module comprises a graph data structure configured to aggregate multiple graph data structures into a single graph data structure, such that a DLT transaction stored in an HGR graph data structure consists of references to DLT transactions referenced in IGR and/or lower level HGR data structures; and
5 an authenticated data structure comprising ordered references to transactions in the HGR graph data structures so as to ensure correct ordering of the referenced transactions and provide a mapping between HGR and IGR referenced DLT
10 transactions.

21-14. The sharding engine of any one of the preceding claims, wherein the sharding engine comprises a reward/penalty, RP, module configured for assessing, based on the generated performance metrics, the performance of the local transaction
15 processing nodes associated with each DLT shard of the DLT platform and accordingly assign to each transaction processing node a performance score indicative of their liveness and safety.

22. The sharding engine of claim ~~21~~ 14, wherein the DO module is configured to adjust and optimise the network of transaction processing nodes associated with each
20 shard of the DLT storage based on their performance score.

~~23-15. The sharding engine of claim 22, wherein adjusting and optimising the network of transaction processing nodes comprises at least one of removing or replacing underperforming transaction processing nodes, and/or assigning and/or redistributing transaction processing nodes according to the partition configuration of the DLT.~~

24. The sharding engine of claims 2 to ~~23~~ 15, wherein the DO module comprises a shard formatter module configured to execute the instructions of the selected configuration protocols and perform required network and data layer operations associated with the DLT configuration changes made by the selected configuration
25 protocol.

25-16. The sharding engine of claim ~~24~~, wherein the shard formatter module comprises a network layer module configured to set up an overlay network for assigning identities and keys to the transaction processing nodes and managing connections between transaction processing nodes based on a membership management protocol.
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26-17. The sharding engine of claim ~~24~~ or ~~25~~ 16, wherein the shard formatter module comprises a data layer module configured to migrate data and current states of
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shards in the DLT storage module to each transaction processing node participating in the corresponding transaction processing network.

27.——The sharding engine of any one of the preceding claims, wherein sharding engine comprises a Cross-shard Collaboration, CC, module configured to execute and
5 validate inter-shard transactions involving a plurality of shards.

~~28.18.~~ 28.18. The sharding engine of claim 27, wherein the CC module is configured to select a communication protocol for transmitting transactions, states, cryptographic signatures and state transfers between shards, and a validation protocol configured to
10 validate inter-shard transactions according to the current state of the shards involved and the local and/or global consensus protocol.

~~29.19.~~ 29.19. The sharding engine of ~~claims 27 or 28~~ claim 18, wherein the CC module is communicatively coupled to a Correct Data Provider, CDP, module of the sharding engine to validate inter-shard transactions, wherein the CDP module is configured to connect to the transaction processing nodes of the transaction processing networks
15 associated with each shard in the DLT storage module to retrieve and validate, based on a set of validation procedures, the outputs and actions taken by the corresponding transaction processing nodes participating in the inter-shard transactions.

~~30.20.~~ 30.20. The sharding engine of claim ~~29~~ 19, wherein the set of validation procedures comprise at least one of :
20 validating DLT states provided by the transaction processing nodes of the global network through succinct proofs generated by means of cryptographic tools of a Cryptographic module,
detecting inconsistencies in the states provided by the transaction processing nodes by comparing the generated responses with an expected state evolution,
25 and
verify state agreement between shards involved in inter-shard transactions.

~~31.21.~~ 31.21. A method for monitoring and optimising the performance of a communicatively coupled distributed ledger technology, DLT, platform, the DLT platform comprising a DLT storage module configured for storing and processing DLT
30 transactions, the DLT storage module being partitioned into one or more DLT shards according to a DLT configuration, each DLT shard being associated with a local network of transaction processing nodes configured to process and verify submitted DLT transactions according to a local consensus protocol defined by a Global Conflict Resolver, GCR, module in accordance with the DLT configuration, the method
35 comprising:

monitoring a set of configuration parameters associated with the DLT configuration of the DLT platform;

receiving and processing the values obtained from the set of configuration parameters to determine a set of corresponding performance metrics indicative of the operational performance of a target DLT platform; and,

comparing the values of the performance metrics with corresponding target values, and wherein, when at least one of the performance metrics is within a value range from at least one corresponding target value, the DO module is configured to adjust an aspect of the DLT configuration of the DLT platform to optimise its operational performance.