ETSI GR PDL 018 V1.1.1 (2023-04)

Permissioned Distributed Ledger (PDL); Redactable Distributed Ledgers

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Permissioned Distributed Ledger (PDL).

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1 Scope

The present document describes the definition of redactable distributed ledgers, presents use cases where redactable distributed ledgers are useful, and assesses existing solutions of redactable distributed ledgers. The present document also discusses potential standardization areas for enabling, managing, and using redactable distributed ledgers.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

hashing collision: scenario where two different input messages get the same hashing value using the same hashing function

Redactable Distributed Ledger (RDL): distributed ledgers where the stored content or objects can be modified with consensus through certain redaction operations

NOTE: A survey on mechanisms for mutable blockchains is presented in [i.1].

redactable objects: objects on distributed ledgers with the redaction property

redaction: property for supporting changes to one or multiple objects on distributed ledgers

redaction operations: actions or operations to change redactable objects on distributed ledgers

NOTE: To modify, to delete, and/or to insert one or multiple redactable objects on distributed ledgers.

Trapdoor-Controlled Hash (TCH): hashing scheme with two modes:

1) collision-free one-way hashing without using a trapdoor key to map an input message to a unique hashing value, which is the typical mode in traditional collision-free hashing schemes; and
2) using a trapdoor key to cause a hashing collision (i.e. to cause the same hashing value for two different input messages)

NOTE: Chameleon hash, as described in [i.2], is an example of trapdoor-controlled hash schemes.

Trapdoor Key (TK): secret key that allows the owner of this secret key to generate a hashing collision for two different input messages

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3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

DAG	Directed Acyclic Graph
DAO	Decentralized Autonomous Organization
DLT	Distributed Ledger Technology
ETSI	European Telecommunications Standards Institute
GDPR	General Data Protection Regulation
ISG	Industry Specification Group
PDL	Permissioned Distributed Ledger
PK	Public Key
PKi	Public Key i
RDL	Redactable Distributed Ledger
TCH	Trapdoor-Controlled Hash
TK	Trapdoor Key
TXN	Transaction

4 Introduction to Redactable Distributed Ledger

4.1 Introduction

Distributed Ledger Technology (DLT) systems have been evolving.

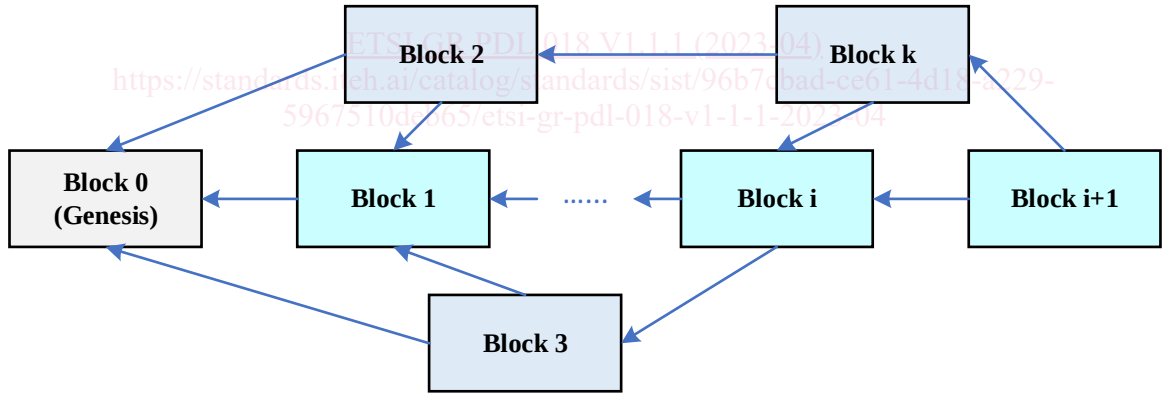
EXAMPLE 1: Distributed ledgers can be formed in different structures as illustrated in figure 4.1-1, such as blockchain (e.g. Bitcoin™, Ethereum™, Hyperledger Fabric™), block Directed Acyclic Graph (DAG) (e.g. PPHANTOM as described in [i.3]), and blockless DAG (e.g. IoTA as described in [i.4]). In general, DLT brings unique characteristics and advantages such as immutability, transparency and decentralization.

1) **Blockchain:** A linear topology with a set of chained blocks starting from the first genesis block. Each block (except the genesis block) has one and only one parent block.

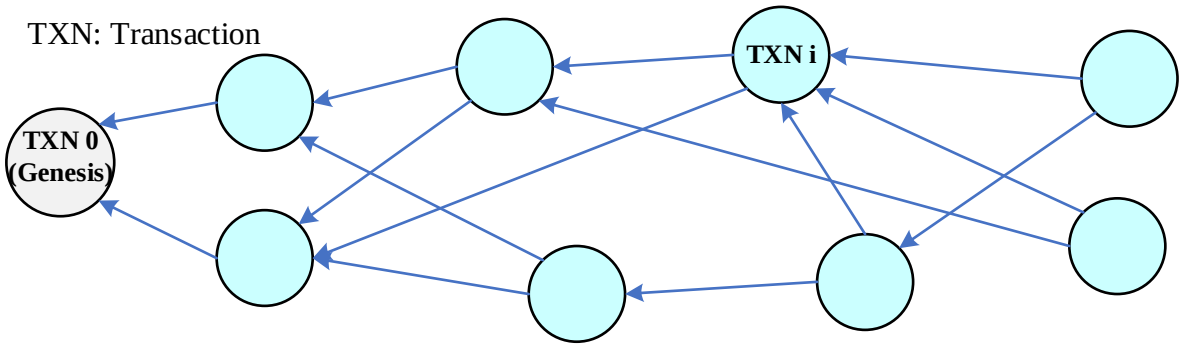
2) **Block DAG:** Blocks are organized in a DAG, where each node represents a block. Usually, each block (except the genesis block) has more than one parent blocks. Two or more blocks are connected if the corresponding two nodes are connected in the DAG.

3) **Blockless DAG:** Transactions are directly organized in a DAG, where each node represents a transaction. Usually, each transaction (except the genesis transaction) has more than one parent transactions. Two or more transactions are connected if the corresponding two nodes are connected in the DAG.

(a) Blockchain



(b) Block DAG



(c) Blockless DAG

Figure 4.1-1: Structures of Distributed Ledgers

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DLT-based solutions are usually characterized by being immutable, tamper-proof, and decentralized, making them outperform centralized counterpart systems. Such unique characteristics of DLT fit perfectly with any decentralized applications, where trust is an issue.

EXAMPLE 2: Blockchain guarantees the integrity and security of financial transactions in the economic sector by preventing double-spending frauds and protecting users' assets from being tampered with.

4.2 Limitations of Immutable Ledgers

The unique characteristics of DLT (especially immutability) could be misused and lead to potential issues. Figure 4.2-1 illustrates some potential limitations of immutable ledger structure:

1) Information published by users on distributed ledgers may become sensitive and create privacy concerns in the future, especially in public DLT systems. Such privacy-concerned information cannot be removed from distributed ledgers due to their immutability, therefore contradicting "the right to be forgotten" associated with General Data Protection Regulation (GDPR).

2) Misinformation could be added to the distributed ledgers by attackers and stay there forever.

3) Crypto criminals and hackers can inject illegal contents forbidden by national or international laws into distribute ledgers, which cannot be removed.

4) Bogus smart-contracts, and more specifically bogus Decentralized Autonomous Organization (DAO) smart-contracts, can be exploited and immutability limits the ability to rectify such problems. E.g. DAO applications, the most significant smart contract applications in the Ethereum™ platform, are another example of immutability misuse. Hackers and crypto criminals discovered logical flaws and vulnerabilities in DAO smart contracts that led to transferring over US$ 120,3 million worth of Ethereum™ coins to their accounts as reported in [i.5], which could have been avoided if such flawed smart contracts had been modified. This problem was semi-cured by hard forking Ethereum™ blockchain back in 2016 to delete the attackers' transfer transactions.

5) Finally, immutability unavoidably causes a scalability issue in maintaining the append-only and ever-growing chain-length of distributed ledgers.

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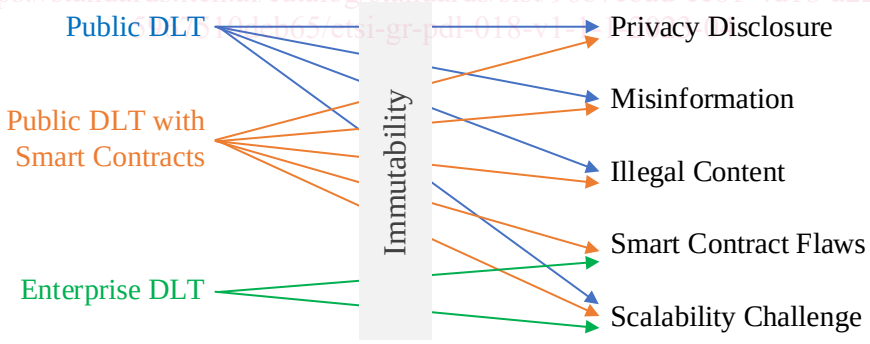

Figure 4.2-1: Potential Limitations with Immutable Distributed Ledgers

4.3 Redaction Operations

4.3.1 Introduction

Redaction operations could be different for different structures of distributed ledgers,. Even if it is possible to apply the same redaction operation on different distributed ledger structures, the complexity and implications of the redaction operation could still be different.

4.3.2 Redaction Operations for Blockchain

4.3.2.1 Types of Blockchain Redaction Operations

Redaction operations for blockchain-based distributed ledgers are: transaction-level redaction operations, single-block-level redaction operations, and multiple-block-level redaction operations.

4.3.2.2 Transaction-Level Redaction Operations

4.3.2.2.1 Changes Caused by Transaction-Level Redaction Operations

These redaction operations aim to impose changes on one or multiple existing transactions being included in an existing block and/or add new transactions. The modification of these transactions within the same block will automatically change:

1) the fingerprint (e.g. the Merkle tree root) of all transactions;
2) the content of this block; and
3) the hash value of this block.

4.3.2.2.2 Scope of Transaction-Level Redaction Operations

Transaction-level redaction operations include:

1) modification of an existing transaction, which could be any one or multiple fields of the existing transaction;
2) removal of an existing transaction from the corresponding block;
3) insertion of a new transaction to an existing block;
4) modification of more than one existing transaction from the corresponding block;
5) removal of more than one existing transactions from the corresponding block; and
6) insertion of multiple transactions to an existing block.

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4.3.2.3 Single-Block-Level Redaction Operations

These redaction operations are used to change an existing block or introduce a new block. The change of the existing block will change the hash value of the existing block. The introduction of new block needs to deal with how to maintain the hash-based blockchain structure. Single-blockchain-level redaction operations include:

1) modification of non-transaction-related fields of an existing block;
2) removal of an existing block; and
3) insertion of a new block to an existing blockchain (not to append the new block to the existing blockchain).

4.3.2.4 Multiple-Blocks-Level Redaction Operations

These redaction operations are used to introduce changes related to multiple blocks, such as:

1) removal of multiple existing consecutive blocks;
2) removal of multiple existing non-consecutive blocks, which will essentially be using "Single-Block-Level Redaction Operations";
3) insertion of multiple new blocks in a consecutive order to an existing blockchain (not to append blocks to existing blockchain); and
4) insertion of multiple new blocks in a non-consecutive order to an existing blockchain (not to append blocks to existing blockchain).

4.3.3 Redaction Operations for Block DAGs

4.3.3.1 Types of Block DAG Redaction Operations

Redaction operations for a block DAG are similar to redaction operation to a blockchain and include the following: transaction-level redaction operations, single-block-level redaction operations, and multiple-block-level redaction operations.

4.3.3.2 Transaction-Level Redaction Operations

They are the same as transaction-level redaction operations for a blockchain as descried in clause 4.3.2.2.

4.3.3.3 Single-Block-Level Redaction Operations

These redaction operations are used to change an existing block or introduce a new block. Each node on a block DAG represents an existing block. Since an existing block in a block DAG may be a child node of multiple parent nodes and/or a parent node of multiple child nodes, to change an existing block or to insert a new block needs to consider any impact and implications to its child and/or parent nodes. Blockchain-level redaction operations for a block DAG include:

1) modification of non-transaction-related fields of an existing block;
2) removal of an existing block; and
3) insertion of a new block to the existing block DAG (not to append the new block to the existing block DAG).

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4.3.3.4 Multiple-Blocks-Level Redaction Operations

These redaction operations are used to introduce changes related to multiple blocks, such as:

1) removal of multiple existing connected blocks;
2) removal of multiple existing non-connected blocks;
3) insertion of multiple new blocks in a connected sub-graph to an existing block DAG (not to append blocks to existing block DAG); and
4) insertion of multiple new blocks in a non-connected way to an existing block DAG (not to append blocks to existing block DAG).

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4.3.4 Redaction Operations for Blockless DAGs

Redaction operations for blockless DAGs are transaction-level only, since transaction is the only object unit in a blockless DAG. Each node on a blockless DAG represents an existing transaction. Since an existing transaction in a blockless DAG may be a child node of multiple parent nodes and/or a parent node of multiple child nodes, when changing an existing transaction or inserting a new transaction any impact and implications to its child nodes and/or parent nodes needs to be considered and addressed.

The following redaction operations are possible for a blockless DAG:

1) modification of an existing transaction, which could be any one or multiple fields of the existing transaction;
2) removal of an existing transaction from the current blockless DAG;
3) insertion of a new transaction to the current blockless DAG;
4) modification of multiple connected transactions from the current blockless DAG;
5) removal of multiple connected transactions from the corresponding block; and
6) insertion of multiple connected transactions to the current blockless DAG (not to append them as leaf nodes).