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ITU-T Technical Specification

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STANDARDIZATION SECTOR
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(1 AUG 2019)

ITU-T Focus Group on Application of
Distributed Ledger Technology
(FG DLT)

Technical Specification FG DLT D1.1

Distributed ledger technology terms and definitions

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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The ITU Telecommunication Standardization Advisory Group established the ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT) in May 2017.

FG DLT concluded and adopted its Deliverables on 1 August 2019.

Type	**Number**	**Title**
Technical Specification	FG DLT D1.1	DLT terms and definitions
Technical Report	FG DLT D1.2	DLT overview, concepts, ecosystem
Technical Report	FG DLT D1.3	DLT standardization landscape
Technical Report	FG DLT D2.1	DLT use cases
Technical Specification	FG DLT D3.1	DLT reference architecture
Technical Specification	FG DLT D3.3	Assessment criteria for DLT platforms
Technical Report	FG DLT D4.1	DLT regulatory framework
Technical Report	FG DLT D5.1	Outlook on DLTs

The FG DLT Deliverables are available on the ITU webpage, at https://itu.int/en/ITU-T/focusgroups/dlt/.

For more information about FG DLT and its deliverables, please contact Martin Adolph (ITU) at tsbfgdlt@itu.int.

Technical Specification FG DLT D1.1

Distributed ledger technology terms and definitions

Summary

This technical specification is a deliverable of the ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT).

It contains a baseline set of definitions of terms commonly used in the context of distributed ledger technology (DLT). The definitions provide a basic characterization of the term, and where appropriate, a note is included to provide additional clarity. The concept and rationale for some of the key terms and definitions is described in Annex A.

Keywords

DLT; distributed ledger technology; ledger; blockchain; terms; definitions

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Distributed ledger technology terms and definitions

1 Scope

This document contains a baseline set of definitions of terms commonly used in distributed ledger technology (DLT). The definitions provide a basic characterization of the term, and where appropriate, a note is included to provide additional clarity. The concept and rationale for some of the key terms and definitions is described in Annex A.

2 References

None.

3 Definitions

This clause is intentionally left blank.

4 Abbreviations and acronyms

This document uses the following abbreviations:

BaaS	Blockchain as a Service
DAO	Decentralized Autonomous Organization
DLT	Distributed Ledger Technology
PII	Personally Identifiable information

5 Conventions

This clause is intentionally left blank.

6 Terms and definitions

6.1 account: representation of an entity whose data is recorded on a distributed ledger.

6.2 address: identifier for entity(ies) performing transactions or other actions in a blockchain or distributed ledger network.

6.3 application [b-Y.2091]: a structured set of capabilities, which provide value-added functionality supported by one or more services.

6.4 asset: representation of value.

6.5 bitcoin: an example of a blockchain using Proof of Work.

6.6 block: individual data unit of a blockchain, composed of a collection of transactions and a block header.

NOTE – A block may be immutable and considered as the digital entity described in clause 3.2.2 in [b-X.1255], however, it can be applied to other networks or other computational facilities.

6.7 block header [b-ISO/TC 307]: data structure that includes a cryptographic link to the previous block.

6.8 blockchain: a type of distributed ledger which is composed of digitally recorded data arranged

as a successively growing chain of blocks with each block cryptographically linked and hardened against tampering and revision.

6.9 blockchain as a service (BaaS): a cloud service category in which the capabilities provided to the cloud service customer are to deploy and manage a blockchain network enabling the ability of consensus, smart contract, transaction, crypto engine, block record storage, peer-to-peer connectivity and management using blockchain.

6.10 Byzantine fault tolerance: property that enables a system to continue operating properly even if some of its components fail or existence of intentional bad actors.

6.11 compliance: adherence to specified requirements.

6.12 consensus: agreement that a set of transactions is valid.

6.13 consensus mechanism: rules and procedures by which consensus is reached.

6.14 crash fault tolerance: property that enables a system to continue operating properly even if some of its components fail.

6.15 decentralized application: application that runs in a distributed and decentralized computing environment.

6.16 decentralized autonomous organization (DAO): a digital entity that manages assets and operates autonomously in a decentralized system, but also relies on individuals tasked to perform certain functions that the automaton itself cannot.

6.17 decentralized system [b-ISO/TC 307]: distributed system wherein control is distributed among the persons or organizations participating in the operation of system.

6.18 delegated proof of stake (DPoS): another approach to Proof of Stake where a set number of nodes are elected or selected to function as the block-producing full validating nodes for the network.

6.19 digital signature [b-X.800|ISO 7498-2]: data appended to, or a cryptographic transformation (see cryptography) of a data unit that allows a recipient of the data unit to prove the source and integrity of the data unit and protect against forgery, e.g., by the recipient.

NOTE – Consider the definition 'digital signature' as "Data appended to data units, or cryptographic changes made to data units, which allows the recipient of the data unit to confirm the origin and integrity of the data and protect the data from being forged."

6.20 distributed ledger: a type of ledger that is shared, replicated, and synchronized in a distributed and decentralized manner.

6.21 DLT oracle: service that supplies information to a distributed ledger using data from outside of a distributed ledger system.

6.22 fork: creation of two or more different versions of a distributed ledger.

NOTE – There are two types of forks. See clause 6.25 (hard fork) and clause 6.52 (soft fork).

6.23 genesis block: The first block in a blockchain that serves to initialize the blockchain.

6.24 governance [b-ISO/IEC 38500]: system of directing and controlling.

6.25 hard fork: change to the protocol or rules that result in a fork that is not backward compatible.

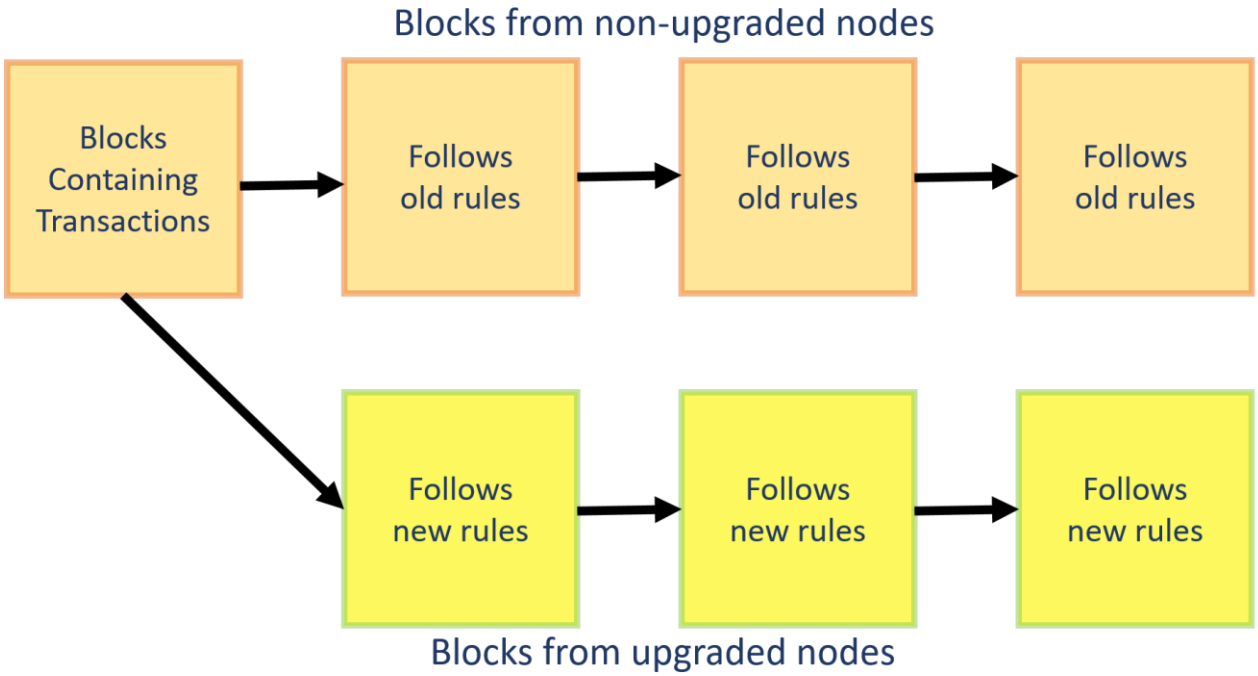

Figure 1 - Hard fork (redrawn from [b-BA])

6.26 hash function [b-NIST]: a function that maps a bit string of arbitrary length to a fixed-length bit string. Approved hash functions satisfy the following properties:

1. One-way: It is computationally infeasible to find any input that maps to any pre-specified output, and

2. Collision resistant: It is computationally infeasible to find any two distinct inputs that map to the same output.

6.27 hashing [b-NIST]: a method of calculating a relatively unique output (called a *hash digest*) for an input of nearly any size (a file, text, image, etc.). The smallest change of input, even a single bit, will result in a completely different output digest.

6.28 hybrid permission: a combination of permissionless and permissioned accessibility.

6.29 immutable [b-ISO/TC 307]: property of blockchain and distributed ledger systems that ledger records can only be added, but not removed or modified, and are designed not to allow changes to historical data over time.

6.30 incentive mechanism [b-ISO/TC 307]: method of offering reward for some activities concerned with the operation of a distributed ledger system.

NOTE – Incentives may be used to encourage the participation of players and/or rewarding for their contributions. Incentives may not be mandatory.

6.31 inter ledger interoperability: ability of two or more distributed ledger protocols to exchange information and to use information that has been exchanged with one another.

6.32 intra ledger interoperability: ability of two or more tokens within distributed ledger platform to operate with one another.

6.33 ledger: information store that keeps final and definitive (immutable) records of transactions.

6.34 Merkle tree [b-NIST]: a data structure where the data is hashed and combined until there is a singular root hash that represents the entire data structure.

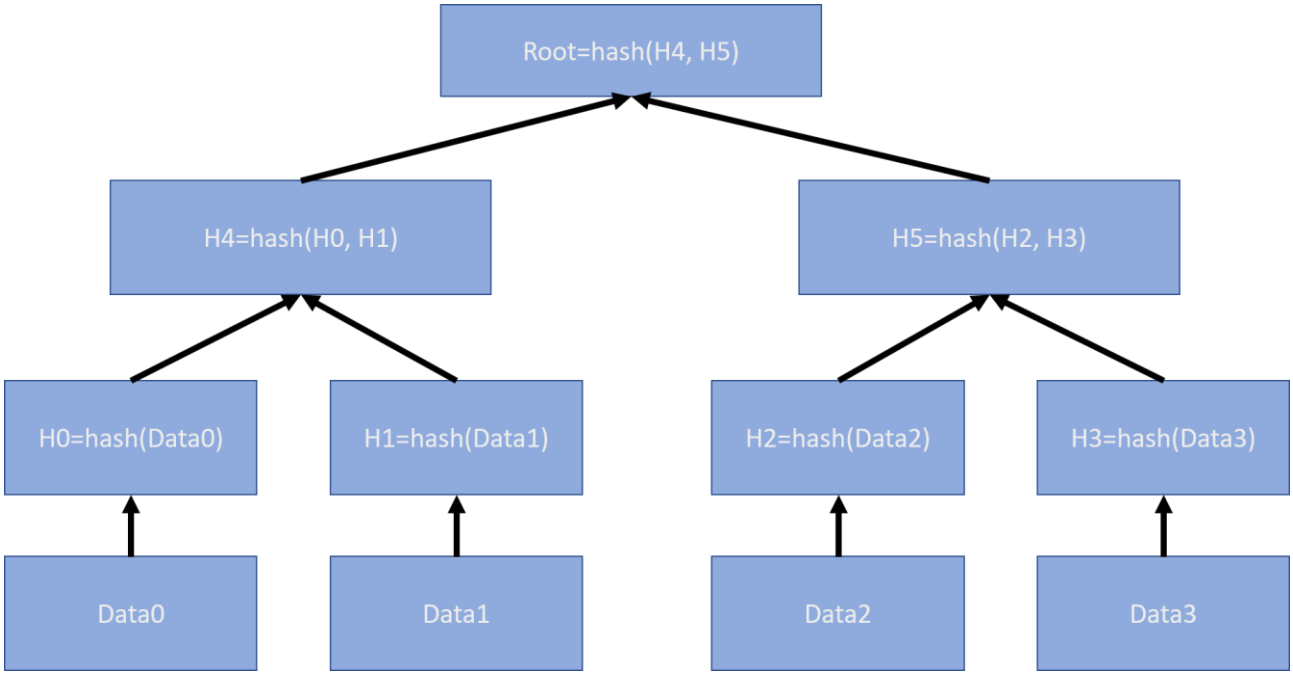

Figure 2 - Example of a Merkle tree (redrawn from [b-NIST])

6.35 node: device or process that participates in a distributed ledger network.

NOTE – Nodes can store a complete or partial replica of the distributed ledger.

6.36 nonfungible token (NFT): an entirely unique digital representation of asset.

6.37 offchain [b-ISO/TC 307]: related to a blockchain system, but located, performed or run outside that blockchain system.

6.38 onchain [b-ISO/TC 307]: located, performed or run inside a blockchain system.

6.39 participant: An actor who can access the ledger: read records or add records to.

6.40 peer-to-peer [b-ISO/TC 307]: relating to, using, or being a network of peers that directly share information and resources with each other without relying on a central entity.

NOTE – In the context of a distributed ledger system, peers are nodes.

6.41 permission [b-NIST]: intended allowable user actions (e.g., participate, read, write, execute).

6.42 permissioned [b-ISO/TC 307]: requiring authorization to perform a particular activity or activities.

6.43 permissionless [b-ISO/TC 307]: not requiring authorization to perform any particular activity.

6.44 permissioned distributed ledger system: distributed ledger system in which permissions are required to maintain and operate a node.

6.45 permissionless distributed ledger system: distributed ledger system where permissions are not required to maintain and operate a node.

NOTE – Examples of permissionless ledger are the Bitcoin and Ethereum blockchains, where any user can join the network and start mining.

6.46 proof of work: consensus process to solve a difficult (costly, time-consuming) problem that produces a result that is easy for others to correctly verify.

NOTE – Producing a proof of work can be a random process with low probability so that a lot of trial and error is required on average before a valid proof of work is generated. Bitcoin uses the Hash cash proof of work system.

6.47 proof of stake: consensus process, where an existing stake in the distributed ledger system (e.g., the amount of that currency that you hold) is used to reach consensus.

6.48 public key cryptography [b-ISO/IEC 2382]: cryptography in which a public key and a corresponding private key are used for encryption and decryption, where public key is disseminated, and private key is known only to the key owner.

NOTE – Users can digitally sign data with their private key, and the resulting signature can be verified by anyone using the corresponding public key.

6.49 public distributed ledger system [b-ISO/TC 307]: distributed ledger system which is accessible to the public for use.

6.50 private distributed ledger system [b-ISO/TC 307]: distributed ledger system which is accessible for use only to a limited group of DLT users.

6.51 smart contract: program written on the distributed ledger system which encodes the rules for specific types of distributed ledger system transactions in a way that can be validated, and triggered by specific conditions.

6.52 soft fork: change to the protocol or rules that result in a fork that is backward compatible.

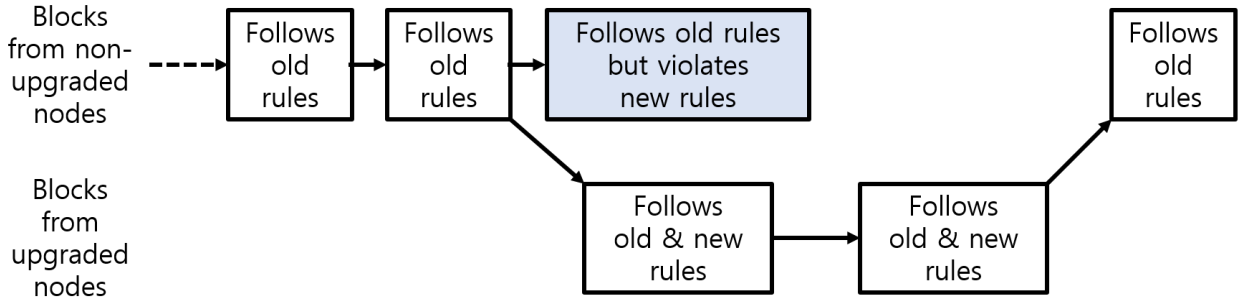

Figure 3 - Soft fork (redrawn from [b-BA])

6.53 subchain [b-ISO/TC 307]: logically separate chain that can form part of a blockchain system.

6.54 stateful contract: contract with specified states.

6.55 stateless contract: contract lacking specified states.

6.56 stateful execution of contract: execution of a program that occurs on all nodes that changes a set of bits representing value information stored on-chain within the contract itself. All nodes that

contain the contract must execute the program in order to change a set of bits representing value information.

6.57 stateless execution of contract: execution of a program that occurs on an individual node (or subset of nodes) that changes a set of bits representing value information stored on-chain but apart from the contract.

6.58 token: a digital representation of value on a shared distributed ledger that is owned and secured using cryptography to ensure its authenticity and prevent modification or tampering without the owner's consent.

6.59 token ecosystem: digital system or digital space where participants and users interact and coordinate with each other using tokens.

6.60 tokenomics (token economic): economics of a DLT based token.

6.61 transaction: whole of the exchange of information between nodes. A transaction is uniquely identified by a transaction identifier.

6.62 wallet: software and/or hardware used to generate, manage and store both private and public keys and addresses, which enable DLT users to transact. Some wallets may interact with smart contracts and allow single and/or multi-signature.

Annex A: Key points and rationale for DLT basic terminology

A.1 Defining distributed ledger technology

Distributed ledger technologies (DLTs), the most prominent implementation of which is Blockchain, enables large groups of nodes in the distributed ledger networks to reach agreement and record information without the need for a central authority.

A.2 How does DLT operate?

A distributed ledger is a type of ledger that is shared, replicated, and synchronized in a distributed manner. While there are currently several different types of distributed ledgers in existence, they share certain functional characteristics: a capability of ledger network's nodes to communicate directly with each other; a mechanism for nodes on the network to propose the addition of transactions to the block and for computer programs to manage processes; and a consensus mechanism by which the distributed ledger network can validate what is the agreed-upon newly added block.

Specific feature of Blockchain-based solutions distinguishing them from other DLT solutions is the storage of data in groups known as blocks, and that each validated block is cryptographically linked to the previous block, forming an ever-growing chain of data. Instead of being stored in a central location, the ledger is distributed across the nodes which keep their own copy of it. The nodes in the network strive to agree on the same chain of blocks as new valid blocks are being added.

A.3 DLT actors and components

The components involved in the DLT include user, DLT node, DLT service provider, and user groups. These components may belong to a single organization or separate organizations. Figure A.1 illustrates a typical example of components of the distributed ledger technology.

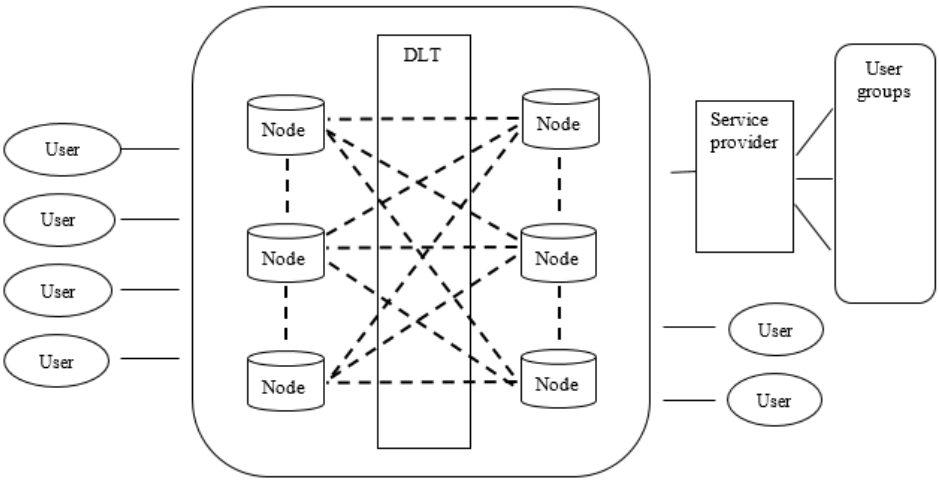

Figure A.1 - A typical example of DLT actors and components

A node is an individual system within the distributed ledger. Some of the nodes known as "full nodes" store the ledger data, pass along the data to other nodes, and ensure that newly added blocks are valid. A service provider is a component that offers a DLT based service to other parties by means of the service interfaces it provides. A user is a component that uses a service or consumes the output of the service provided by another component. A component may be a provider of some services and a consumer of others.

A user group (e.g., groups of people and organizations) is a set of DLT system users. A distributed ledger is information in digital form that has been validated by consensus, replicated, and stored in different nodes.

A.4 Types of DLT

Permissionless distributed ledger systems are decentralized ledger platforms open to anyone validating blocks, without needing permission from any authority. Permissioned distributed ledger systems are ones where users validating blocks shall be authorized.

A.5 Potential use cases for DLT

Distributed ledger technology can be used to decentralize and automate processes in a large number of sectors. The attributes of a distributed ledger technology allow for large numbers of entities or nodes, whether collaborators or competitors, to come to consensus on information and immutably store it.

The potential use cases for a distributed ledger technology are vast. People are looking at distributed ledger technology to disrupt most industries, from automotive, banking, education, energy and e-government to healthcare, insurance, law, music, art, real estate and travel. [b-DLT 2.1] contains an extensive study of DLT use cases.

A.6 Consensus mechanisms

Consensus mechanisms ensure convergence towards a single, immutable version of the ledger. They allow actors on the network to agree on the information recorded on the distributed ledgers, taking into consideration the fact that some actors can be untrustworthy or malicious. The most widespread consensus algorithms are proof-of-work, proof-of-stake and proof-of-authority.

In permissionless distributed ledger networks usually there are numerous validating nodes competing at the same time to validate the next block. They usually do this to obtain newly generated cryptocurrency and/or network transaction fees. They are generally comprised of mutually distrusting users that may only know each other by their public addresses.

A.7 Smart contracts

A smart contract is a computer program that is deployed using cryptographically signed transactions on the distributed ledger network (e.g., Ethereum's smart contracts, Hyperledger Fabric's chaincode). The smart contract is executed by nodes within the distributed ledger system. The results of the execution are validated by consensus and recorded on the distributed ledger.

Smart contract automation reduces costs, lowers risks of errors, mitigates risks of fraud and potentially streamlines many business processes.

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In developing this list of DLT terms and definitions, reference has been made to a large number of DLT publications, work and glossaries that already exist.

The list is far from exhaustive but includes:

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[b-DIN 16597] German National Standard DIN SPEC 16597:2018, *Terminology for blockchain.*

[b-DLT 2.1] Focus Group Technical Report ITU-T FG DLT D2.1:2019, *Distributed ledger technology use cases.*

[b-ISO/IEC 38500] ISO/IEC 38500:2015, *Information Technology -- Governance of IT for the Organization.*

[b-ISO/IEC 2382] ISO/IEC 2382:2015, *Information technology – Vocabulary.*

[b-ISO/TC307] ISO/CD 22739, *Blockchain and distributed ledger technologies – Terminology.*

[b-NIST] NISTIR 8202 (Draft):2018/01, *Blockchain Technology Overview.*

[b-X.800|ISO 7498-2] Recommendation ITU-T X.800|ISO 7498-2:1991, *Security architecture for Open Systems Interconnection for CCITT applications.*

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[b-X.das-mgt] Draft Recommendation ITU-T X.das-mgt, *Security framework for the data access and sharing management system based on the distributed ledger technology.*

[b-X.sa-dlt] Draft Recommendation ITU-T X.sa-dlt, *Security assurance for Distributed Ledger Technology.*

[b-X.sct-dlt] Draft Recommendation ITU-T X.sct-dlt, *Security capabilities of, and threats to Distributed Ledger Technology.*

[b-X.sradlt] Draft Recommendation ITU-T X.sradlt, *Security framework for distributed ledger technology.*

[b-X.srdrm-dlt] Draft Recommendation ITU-T X.srdrm-dlt, *Security requirements for digital rights management based on distributed ledger technology.*

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Technical Report FG DLT D1.2

Distributed ledger technology overview, concepts, ecosystem

Summary

This technical report is a deliverable of the ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT).

It provides an overview of distributed ledger technology (DLT), introduces key concepts and describes the DLT ecosystem.

Keywords

DLT; distributed ledger technology; ledger; blockchain; concepts; ecosystem

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Distributed ledger technology overview, concepts, ecosystem

1 Scope

This document provides an overview, concept and ecosystem for distributed ledger technology (DLT).

2 Definitions

This document uses the terms defined in [b-DLT 1.1].

3 Abbreviations and acronyms

This document uses the following abbreviations:

BFT Byzantine Fault Tolerant

DLT Distributed Ledger Technology

DPoS Delegated Proof of Stake

ID Identity

PoS Proof of Stake

PoW Proof of Work

4 Overview and concept of DLT

The overview and concept of DLT can be found in Annex A of [b-DLT 1.1]. Additionally, the following points require consideration.

4.1 Key characteristics

A distributed ledger is a ledger that is shared, replicated, and synchronized in a distributed manner.

The key characteristics of DLT systems are [b-NIST]:

- Append only – An append only ledger is used to provide full transactional history. Unlike traditional databases, transactions and values in a DLT are not overwritten.
- Immutable – Distributed ledgers are cryptographically secure and immutable, ensuring that the data contained within the ledger has not been tampered with, and that the data within the ledger is attestable.
- Shared – The ledger is shared amongst multiple nodes. Some nodes contain the full state of the ledger while other nodes do not necessarily contain the full state of the ledger. This provides transparency and optimal efficiency across the node participants in the DLT network.
- Distributed – The distributed nature of DLT allows for the scaling of nodes in a DLT network. By increasing the number of nodes, the ability for a bad actor to impact the consensus protocol used by the DLT is reduced thus, making it more resilient to attacks by bad actors.

4.2 Classification of DLT

There are three types of DLT systems: permissionless, permissioned and hybrid.

Permissionless distributed ledger systems are open to anyone validating blocks, without needing permission from any authority. Users are not required to obtain permissions to maintain and operate permissionless distributed ledger systems. Its systems are often implemented using open source software; freely available to anyone who wishes to download it.

Permissioned distributed ledger systems, on the other hand, require permissions. Users validating blocks must be authorized in permissioned distributed ledger systems. Since only authorized nodes are maintaining the distributed ledger, it is possible to restrict read access and to restrict who can issue transactions.

Hybrid distributed ledger systems combine the privacy benefits of a permissioned distributed ledger system with the security and transparency benefits of a permissionless distributed ledger system. This gives businesses significant flexibility to choose what data they want to make public and transparent and what data they want to keep private.

4.3 Consensus mechanisms

Consensus mechanisms are the rules and procedures by which nodes across a distributed ledger agree on validating transactions.

A key aspect of DLT technology is determining which user validates the next block. This is achieved by implementing one of many possible consensus mechanisms. For permissionless DLT networks, there are generally many nodes competing at the same time to validate the next block.

There are many types of consensus mechanisms, with the most common being: Proof of Work, Proof of Stake, and Byzantine fault tolerant-based [b-NIST].

In a proof of work (PoW) system, a node validates the next block by being the first to solve a computationally intensive puzzle. The solution to this puzzle is the "proof" that they have performed the work. The probability of validating a new block depends on the instantaneous computational power devoted to the task. As a reward for validating a block, the node (miner) will receive a certain amount of crypto assets or transaction fees.

Proof of stake (PoS) is a consensus process where an existing stake in a particular distributed ledger system (e.g., the amount of stored value held) is used to reach consensus instead of energy intensive computations. Proof of stake (PoS) is based on the idea that, since users must invest directly into a particular system to participate in consensus, they are more likely to want that system to succeed and less likely that they will want to subvert it. For example, stake is often an amount of crypto asset that the DLT network user has invested into the system. Nodes participating in the PoS consensus mechanism are rewarded by receiving the transaction fees included in each block they are the first to successfully validate. The Delegated Proof of Stake (DPoS) is another approach to PoS where a set number of nodes are elected or selected to function as the block-producing full validating nodes for the network.

In DLT systems, Byzantine faults may occur when some nodes in the network behave abnormally. The BFT-based consensus algorithm has been designed and implemented to solve this problem by ensuring that the distributed ledger system functions normally even with abnormal nodes involved in the network. In BFT-based consensus, all nodes in the network need to participate in the consensus process which involves performing multiple rounds of voting and communication to reach consensus on a block. It is therefore more compatible with small systems, which have a limited number of nodes. Additionally, since BFT requires that all participants agree on the list of participants in the network, the protocol is normally only used in permissioned distributed ledger systems.

5 Ecosystem of DLT

An ecosystem is a collection of stakeholders such as organizations and users in conjunction with other entities, performing separate roles.

There are four aspects of DLT ecosystems: the hardware aspect, business aspect, software development aspect and the protocol development aspect [b-GetSmarter].

5.1 Hardware aspect of the DLT ecosystem

The hardware aspect of DLT ecosystems is comprised of a large number of nodes where each node could either be a computer, server, or storage device. Three modalities of nodes can exist: block producing validating nodes, non-block producing full validating nodes, and partial/light nodes. A block producing full validating node participates in a consensus process and contains an entire replica of the distributed ledger, including every transaction that has been executed since its inception. A non-block producing full validating node does not participate in a consensus process and contains an entire replica of the distributed ledger, including every transaction that has been executed since its inception. A partial or light node contains only a partial transaction list but must be connected in some way to a full node to make sure that their data is accurate and useful.

In a permissionless DLT, anyone can create a node, but each node should be able to provide adequate processing power and storage capacity. The more nodes there are on the network, the more likely it is to be well distributed amongst varied stakeholders, thus resulting in a lower risk of fraud, error, or system failure.

The DLT network connects all the nodes to each other. For DLT systems, a stable, reliable, and sufficient supply of electricity is a mandatory requirement. The energy consumption of DLT networks using a PoW consensus mechanism, however, is generally high and may require consideration for energy sourcing. Many DLT users prefer a physical (hardware or paper) wallet to store their public and private keys and passwords, which then becomes part of the hardware ecosystem.

5.2 Business aspect of the DLT ecosystem

The business aspect of the DLT ecosystem consists of users, investors, block producers, corporations, and developers.

DLT users are entities that engage with a DLT by using a DLT application, product or service to accomplish a specific purpose such as an asset transfer.

Investors are the people or organizations that provide capital to create the DLT ecosystem. They are motivated by profit but are also values- and mission-based as many investors aim to help solve social and economic issues.

Block producers are full validating nodes that actively participate in a given DLT network's consensus mechanism. For DLT systems using PoW, miners are the block producers and they intend to profit from their efforts to validate DLT transactions. On the Bitcoin network, for instance, miners try to be the first to produce the solution to the highly-complex and computationally-intensive mathematical puzzles. Their reward is a certain number of bitcoins.

Corporations utilize DLT for business activities and will often push new technologies to a large group of customers or end-users. They basically create a space where end-users can transact more easily, interact with other stakeholders more efficiently, and spend time and money more wisely while the corporation itself benefits from increased data security and integrity on the backend. Corporations should, however, use DLT in compliance with applicable legislation and regulations.

Developers are the people who build the applications, products or services utilizing the DLT protocols and networks. They develop distributed applications and provide technical support.

5.3 Software aspect of the DLT ecosystem

DLT leverages various types of software applications. A "software ecosystem" is defined as a set of entities interacting with a shared market for software and services, together with relationships among them.

DLT applications can be written in a variety of languages including C++, Java, Go, Rust, Solidity, JavaScript, Python, and many others [b-Snowball]. Fundamentally, DLT should be language-neutral as long as each is fully compliant with the underlying requirements and software specifications.

However, each software language has its relative strengths and weaknesses, so careful consideration must be given in choosing the right language to meet the specific goals and needs of a given DLT.

These applications generally fall into three categories: financial, semi-financial, and non-financial applications. The first involves money being used and managed. The second category includes business processes which may involve money but focus on the completion of tasks or execution of contracts. The last category is very open-ended and may include anything from election voting, governance, data record storage, and ID authentication. There are literally tens of thousands of distributed applications that have been created to date, with many more being developed daily.

5.4 Protocol development aspect of the DLT ecosystem

The protocol aspect of DLT ecosystems consists of developers and academia.

Developers are involved with setting up DLT protocols that serve networks. The protocol layer is concerned mostly with how cryptographic keys interact with the network. There are two kinds of protocols: open-source and closed-source. Open-source development communities allow for anyone to download, audit and submit changes to the protocol. Accepting changes might be decided by a system of voting or through a responsible disclosure program. Closed-source DLT networks are employed by private entities and accessible only to operations of a specific class. The developer will encode the private information and alter the encoded value locally before sending it to an aggregator.

Researchers and academia aid in educating others on the implications of DLT systems and defining its limitations. With private companies and open source communities constantly releasing new DLT software, researchers and academics play an important role in providing formal peer reviews of the technical, environmental, economic, political, psychological, and sociological claims of the industry. These unbiased comparisons result in new knowledge that can then be used to inform all other stakeholders.

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International Telecommunication Union

ITU-T Technical Report

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

(1 AUG 2019)

ITU-T Focus Group on Application of
Distributed Ledger Technology
(FG DLT)

Technical Report FG DLT D1.3

Distributed ledger technology standardization landscape

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The procedures for establishment of focus groups are defined in Recommendation ITU-T A.7.

Deliverables of focus groups can take the form of technical reports, specifications, etc., and aim to provide material for consideration by the parent group in its standardization activities. Deliverables of focus groups are not ITU-T Recommendations.

The ITU Telecommunication Standardization Advisory Group established the ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT) in May 2017.

FG DLT concluded and adopted its Deliverables on 1 August 2019.

Type	**Number**	**Title**
Technical Specification	FG DLT D1.1	DLT terms and definitions
Technical Report	FG DLT D1.2	DLT overview, concepts, ecosystem
Technical Report	FG DLT D1.3	DLT standardization landscape
Technical Report	FG DLT D2.1	DLT use cases
Technical Specification	FG DLT D3.1	DLT reference architecture
Technical Specification	FG DLT D3.3	Assessment criteria for DLT platforms
Technical Report	FG DLT D4.1	DLT regulatory framework
Technical Report	FG DLT D5.1	Outlook on DLTs

The FG DLT Deliverables are available on the ITU webpage, at https://itu.int/en/ITU-T/focusgroups/dlt/.

For more information about FG DLT and its deliverables, please contact Martin Adolph (ITU) at tsbfgdlt@itu.int.

Technical Report FG DLT D1.3

Distributed ledger technology standardization landscape

Summary

This technical report is a deliverable of the ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT).

It describes the standardization landscape for distributed ledger technology (DLT), as of July 2019.

Keywords

DLT; distributed ledger technology; ledger; blockchain; standardization; standards; specifications

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Distributed ledger technology standardization landscape

1 Scope

This document describes the standardization landscape for distributed ledger technology (DLT), as of July 2019.

2 Abbreviations and acronyms

This document uses the following abbreviations:

API	Application Programming Interface
BIA COI	Blockchain for Industrial Applications Community of Interest
BiTA	Blockchain in Transport Alliance
DFC	Digital Fiat Currency
DFS	Digital Financial Services
DLT	Distributed Ledger Technology
DPM	Data Processing and Management
EIP	Ethereum Improvement Proposal
ERC	Ethereum Request for Comment
ETSI	European Telecommunications Standards Institute
FG	Focus Group
IEEE	Institute of Electrical and Electronic Engineers
ISG	Industry Specification Group
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
NFV	Network function virtualization
NGN	Next-generation network
NIST	National Institute on Science and Technology
PDL	Permissioned distributed ledger
Q	Question
SDGs	Sustainable Development Goals
SDN	Software-defined networking
SG	Study Group
UNECE	United Nations Economic Commission for Europe
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
W3C	World Wide Web Consortium

3 Standardization landscape

3.1 ITU-T

3.1.1 ITU-T Study Group 17: Security

SG17 established a new Question, Q14/17, security aspects of distributed ledger technologies, at its September 2017 meeting.

The Q14/17 terms of reference are available at https://itu.int/en/ITU-T/studygroups/2017-2020/17/Pages/q14.aspx.

Table 1 lists all DLT-related work items under development in SG17.

Table 1: DLT-related work items under development in Q14/17 and Q11/17

Recommendation	Title	Status
X.das-mgt	Security framework for data access and sharing management system based on distributed ledger technology	Under development
X.dlt-sec	Security considerations for using distributed ledger technology data in identity management	Under development
X.sa-dlt	Security assurance for distributed ledger technology	Under development
X.sct-dlt	Security threats of distributed ledger technology	Under development
X.sra-dlt	Security framework for distributed ledger technology	Under development
X.srip-dlt	Security requirements for intellectual property management based on distributed ledger technology	Under development
X.ss-dlt	Security services based on distributed ledger technology	Under development
X.stov	Security threats to online voting using distributed ledger technology	Under development
X.str-dlt	Security threats and requirements for digital payment services based on distributed ledger technology	Under development
X.tf-spd-dlt	Technical framework for secure software programme distribution mechanism based on distributed ledger technology	Under development
X.509 Amd.1	Proposed draft 1st amendment to Rec. ITU-T X.509 (2019) | ISO/IEC 9594-8:2017 Information technology - Open Systems Interconnection - The Directory: Public-key and attribute certificate frameworks Amd.1 Note – to address distributed PKI (blockchain based PKI).	Under development

The work items can be classified into three categories: (1) work for security for DLT, (2) work for security by DLT, and (3) security management, as shown in Figure 1.

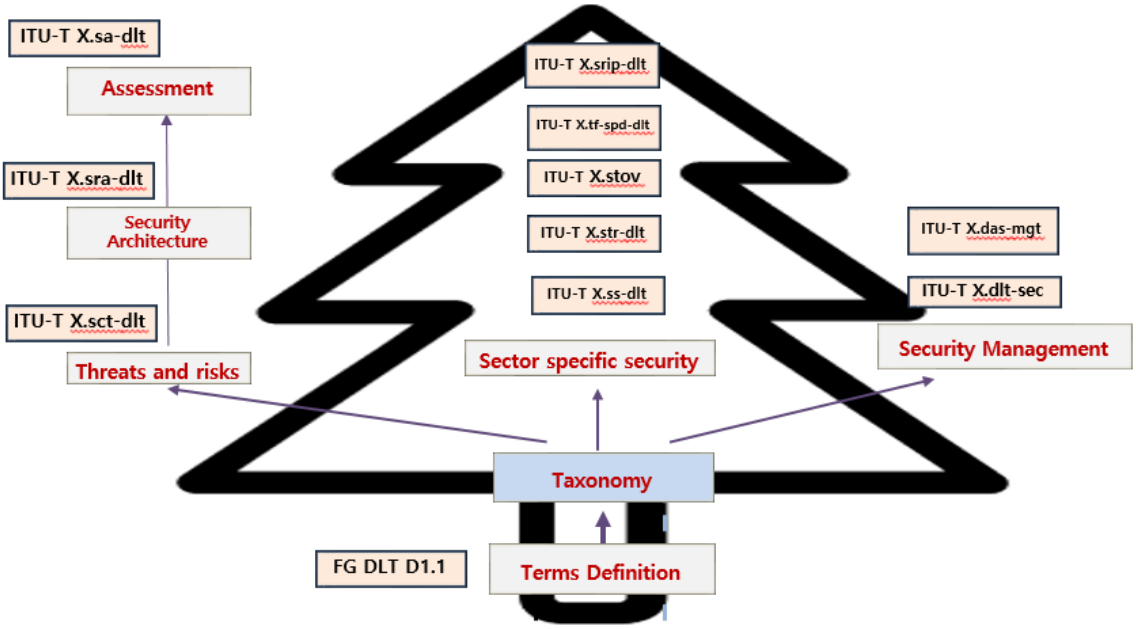

Figure 1: Categorization of work items in SG17

3.1.2 ITU-T Study Group 16: Multimedia coding, systems and applications

SG16 has established a new Question, Q22/16, Distributed ledger technologies and e-services.

The Q22/16 terms of reference are available at https://itu.int/en/ITU-T/studygroups/2017-2020/16/Pages/q22.aspx.

Table 2 lists all DLT-related work items under development in SG16 (this also includes work items in Q24/16).

Table 2: DLT-related work items under development in SG16

Question	Recommendation	Title	Status
Q22/16	F.DLS	Requirements for distributed ledger systems	Under development
Q22/16	F.DLT-AC	Assessment criteria for distributed ledger technologies	Under development
Q22/16	H.DLT	Reference framework for distributed ledger technology	Under development
Q22/16	H.DLT-DE	Digital evidence services based on distributed ledger technology	Under development
Q24/16	F.DLT.HC.req	Requirements of distributed ledger technologies (DLT) for human-care services	Under development
Q24/16	F.DLT.SM.PHR	Service models of distributed ledger technologies (DLT) for personal health records (PHRs)	Under development
Q24/16	F.HFS-BC	Requirements and framework for blockchain-based human factor service models	Under development

3.1.3 ITU-T Study Group 13: Future networks, with focus on IMT-2020, cloud computing and trusted network infrastructures

SG13 has DLT-related work items in Q2/13, Next-generation network (NGN) evolution with innovative technologies including software-defined networking (SDN) and network function virtualization (NFV), and in Q17/13, Requirements, ecosystem, and general capabilities for cloud computing and big data.

Table 3 lists all DLT-related work items under development in SG13.

Table 3: DLT-related work items under development in SG13

Question	Recommendation	Title	Status
Q2/13	Y.NGNe-BC-reqts	Scenarios and Capability Requirements of Blockchain in Next Generation Network Evolution	Under development
Q17/13	Y.BaaS-reqts	Cloud computing - functional requirements for blockchain as a service	Under development

3.1.4 ITU-T Study Group 20: Internet of things (IoT) and smart cities and communities (SC&C)

SG20 has DLT-related work items in Q3/17 (Architectures, management, protocols and Quality of Service), Q4/17 (e/Smart services, applications and supporting platforms), and Q7/20 (Evaluation and assessment of Smart Sustainable Cities and Communities).

Table 4 lists all DLT-related work items under development in SG20.

Table 4: DLT-related work items under development in SG20

Question	Recommendation	Title	Status
Q3/20	Y.dec-IoT-arch	Decentralized IoT communication architecture based on information centric networking and blockchain	Under development
Q3/20	Y.IoT-rf-dlt	OID-based Resolution framework for transaction of distributed ledger assigned to IoT resources	Under development
Q4/20	Y.BC-SON	Framework of blockchain-based self-organization networking in IoT based environments	Under development
Q4/20	Y.IoT-BoT-fw	Framework of blockchain of things as decentralized service platform	Under development
Q7/20	Y.SSC-BKDMS-arc	Reference architecture of blockchain-based unified KPI data management for smart sustainable cities	Under development

3.1.5 ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT)

The Focus Group on Application of Distributed Ledger Technology (FG DLT) was set up in May 2017 to identify and analyze DLT-based applications and services, draw up best practices and guidance for their implementation and propose a way forward for DLT-related standardization work in ITU-T Study Groups.

The terms of references are available at https://itu.int/en/ITU-T/focusgroups/dlt/.

FG DLT concluded and adopted its Deliverables on 1 August 2019 (see Table 5).

Table 5: Deliverables under FG DLT

Title	Status
Distributed ledger technology terms and definitions	Completed
Distributed ledger technology overview, concepts, ecosystem	Completed
Distributed ledger technology standardization landscape	Completed
Distributed ledger technology use cases	Completed
Distributed ledger technology reference architecture	Completed
Assessment criteria for distributed ledger technology platforms	Completed
Distributed ledger technology regulatory framework	Completed
Outlook on distributed ledger technologies	Completed

3.1.6 ITU-T Focus Group on Digital Currency including Digital Fiat Currency (FG DFC)

The Focus Group on Digital Currency including Digital Fiat Currency (FG DFC) was set up in May 2017 to analyze the impact of the introduction of DFC over mobile money and outline potential use cases and areas of standardization for DFC. The group held its final meeting in June 2019 and submitted its deliverables to TSAG for further consideration (see Table 6).

Table 6: DLT-related work items under FG DFC

Title	Status
Digital currency implementation checklist for central banks report	Completed
Regulatory challenges and risks for central bank digital currency	Completed
Reference documentation: Governance aspects of digital fiat currency	Completed
Taxonomy and definition of terms for digital fiat currency	Completed
Reference architecture and use cases	Completed
Protection assurance for digital currencies	Completed
Protection assurance use case for a payment transaction	Completed

3.1.7 ITU-T Focus Group on Data Processing and Management to support IoT and Smart Cities & Communities (FG-DPM)

SG20 established a Focus Group on Data Processing and Management in March 2017 to develop a standardization roadmap for data management.

Table 7 gives an overview of DLT-related work items that have been developed by the focus group.

Table 7: DLT-related work items under FG-DPM

Title	Status
Technical Report D3.5: Overview of blockchain for supporting IoT and SC&C in DPM aspects	Completed
Technical Specification D3.6: Blockchain-based data exchange and sharing technology	Completed
Technical Specification D3.7: Blockchain-based data management for supporting IoT and SC&C	Completed

3.1.8 ITU-T Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE)

A new Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies was established by ITU-T Study Group 5 (Environment, climate change and circular economy) in May 2019. The goal of this Focus Group is to identify the standardization needs to develop a sustainable approach to AI and other emerging technologies, including DLT. The work of this group will address the environmental efficiency, as well as water and energy consumption of emerging technologies, and provide guidance to stakeholders on how to operate these technologies in a more environmentally efficient manner.

3.1.9 ITU-T Focus Group on Digital Financial Services (FG DFS)

The Focus Group on Digital Financial Services (DFS) operated between June 2014 and 2016 to analyze projects that support financial inclusion and develop a strategy for standardization of DFS. Table 8 gives an overview of DLT-related work items that have been developed by the focus group.

Table 8: DLT-related work items under FG-DFS

Title	Status
Distributed ledger technologies and financial inclusion	Completed
Competition aspects of digital financial services	Completed

3.2 ISO

3.2.1 ISO Technical Committee 307: Blockchain and distributed ledger technologies

ISO/TC 307, Blockchain and distributed ledger technologies, was established in September 2016.

As of July 2019, TC 307 is comprised of six working groups and one study group as shown in Table 9.

Table 9: ISO/TC 307 structure

Group	Title
WG1	Foundations
WG2	Security, privacy and identity
WG3	Smart contracts and their applications
JWG4	Joint ISO/TC 307 - ISO/IEC JTC 1/SC 27 WG: Blockchain and distributed ledger technologies and IT Security techniques
WG5	Governance
WG6	Use cases
SG7	Interoperability of blockchain and distributed ledger technology systems

The work items under development in each Working Group of TC 307 are listed in Table 10.

Table 10: Projects under development in ISO/TC 307 (as of June 29, 2019)

Group	Projects	Status
WG1	ISO 22739 Blockchain and distributed ledger technologies -- Terminology	DIS ballot before November 2019
	ISO 23257 Blockchain and distributed ledger technologies -- Reference architecture	2nd CD ballot before November 2019

Group	Projects	Status
	ISO TS 23258 Blockchain and distributed ledger technologies -- Taxonomy and Ontology	WD
	Study on “Data flow and data taxonomy for blockchain and distributed ledger technologies	Under study
WG2	ISO TR 23567 Sec management of digital asset custodians	DTR ballot
	Study on “Security evaluation of consensus models“	Under study
WG2 & WG3	Study on “Security issues of Smart Contracts”	Under study
WG3	ISO TS 23259 Blockchain and distributed ledger technologies -- Legally binding smart contracts	WD
	ISO TR 23455 Blockchain and distributed ledger technologies -- Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems	Publication
	Study report on Supply chains and Trade facilitation	Under study
JWG 4 Joint WG with ISO/IEC JTC1 SC27	ISO TR 23244 Blockchain and distributed ledger technologies -- Privacy and personally identifiable information protection considerations	WD
	ISO TR 23245 Blockchain and distributed ledger technologies -- Security risks, threats and vulnerabilities	CD
	ISO TR 23246 Blockchain and distributed ledger technologies -- Overview of identity management using blockchain and distributed ledger technologies	WD
JWG	ISO TR 24332 Information and documentation – Application of blockchain technology to records management – Issues and considerations	PWI
WG5	ISO TS 23635 Blockchain and distributed ledger technologies -- Guidelines for governance	WD
WG6	ISO TR Blockchain and Distributed Ledger Technologies - Use cases	New TR
	Study on Non-Functional Requirements	Study period
SG7	ISO/NP TR 23578 Blockchain and distributed ledger technologies -- Discovery issues related to interoperability	
	ISO NP TS Interoperability Framework	For NWIP ballot

3.3 IEEE Standards Association

Table 11 gives an overview of DLT-related work items under development in various IEEE working groups.

Table 11: DLT-related work items under development in IEEE

WG	Work item	Title	Status
CEWG - Cryptocurrency Exchange Working Group	P2140.1	Standard for General Requirements for Cryptocurrency Exchanges	Under development
	P2140.2	Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges	Under development

WG	Work item	Title	Status
	P2140.3	Standard for User Identification and Anti-Money Laundering on Cryptocurrency Exchanges	Under development
	P2140.4	Standard for Distributed/Decentralized Exchange Framework using DLT (Distributed Ledger Technology)	Under development
	P2140.5	Standard for Custodian Framework of Cryptocurrency	Under development
BACWG - Blockchain Against Corruption Working Group	P2141.1	Standard for the Use of Blockchain in Anti-Corruption Applications for Centralized Organizations	Under development
EIBCTWG - E-Invoice Business Using Blockchain Technology Working Group	P2142.1	Recommended Practice for E-Invoice Business Using Blockchain Technology	Under development
CPWG - Cryptocurrency Payment Working Group	P2143.1	Standard for General Process of Cryptocurrency Payment	Under development
	P2143.2	Standard for Cryptocurrency Payment Performance Metrics	Under development
	P2143.3	Standard for Risk Control Requirements for Cryptocurrency Payment	Under development
TIDMWG - Trusted IoT Data Management Working Group	P2144.1	Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management	Under development
	P2144.2	Standard for Functional Requirements in Blockchain-based Internet of Things (IoT) Data Management	Under development
	P2144.3	Standard for Assessment of Blockchain-based Internet of Things (IoT) Data Management	Under development
Blockchain working group (BOG/CAG/blockchain_wg)	P2418.1	Framework of Blockchain Use in Internet of Things	Under development
Data Format for Blockchain Systems (C/SAB/DBC)	P2418.2	Standard Data Format for Blockchain Systems	Under development
Distributed Ledger Technology in Agriculture (C/SAB/DTLA)	P2418.3	Standard for the Framework of Distributed Ledger Technology (DLT) Use in Agriculture	Under development
DLT in Connected and Autonomous Vehicles (VT/ITS/DLTCAV)	P2418.4	Standard for the Framework of Distributed Ledger Technology (DLT) Use in Connected and Autonomous Vehicles (CAVs)	Under development
Blockchain working group (BOG/CAG/blockchain_wg)	P2418.5	Standard for Blockchain in Energy	Under development
BDLTH WG - Blockchain and Distributed Ledger Technology(DLT) in Health	P2418.6	Standard for the Framework of Distributed Ledger Technology (DLT) Use in Healthcare and the Life and Social Sciences	Under development

WG	Work item	Title	Status
BSCF_WG - Blockchain in Supply Chain Finance_Working Group	P2418.7	Standard for the Use of Blockchain in Supply Chain Finance	Under development
BGAWG - Blockchain for Government Affairs Working Group	P2418.8	Standard for Blockchain Applications in Governments	Under development
CBSTWG - Cryptocurrency Based Security Tokens Working Group	P2418.9	Standard for Cryptocurrency Based Security Tokens	Under development
DAWG - Digital Asset Working Group	P2418.10	Standard for Blockchain-based Digital Asset Management	Under development

3.4 W3C

W3C working groups and community groups have published three draft documents as in Table 12.

Table 12: DLT-related drafts published by W3C

Group	Title	Status
Verifiable Claims Working Group	Verifiable Credentials Data Model 1.0: Expressing verifiable information on the Web	Candidate Recommendation
Blockchain Community Group	The Web Ledger Protocol 1.0: A format and protocol for decentralized ledgers on the Web	Draft Specification
Credentials Community Group	Decentralized Identifiers (DIDs) v0.13: Data Model and Syntaxes	Draft Specification

3.5 UN/CEFACT

The United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) under the UN Economic Commission for Europe (UNECE) has embarked on the development of regulatory/policy frameworks and international standards of emerging technologies including blockchain technology.

Their work has involved the exploration of relevant use cases of blockchain towards the attainment of the SDGs. UN/CEFACT has published two white papers on blockchain technology, with one focusing on an introduction to blockchain technology for trade policy makers, and the other focusing on a gap analysis of technical aspects of blockchain and its relation to UN/CEFACT deliverables.

A separate information paper on how blockchain technology can be used to facilitate trade-related business processes was published in its initial version. The final three sections covering use cases and challenges specific to finance, healthcare and government services require additional external input; the entire document will be re-edited and re-published – planned for the end of 2019.

3.6 ETSI

ETSI established an Industry Specification Group (ISG) on Permissioned Distributed Ledger (PDL) in 2018. The ISG PDL work items are listed in Table 13.

Table 13: Work items under development in ETSI ISG PDL

Work Item	Title	Status
DGR/PDL-001_Landscape	PDL Landscape of Standards and Technologies	Under development - Technical Body Approval
DGR/PDL-002_CDPR	PDL Applicability and compliance to data processing requirements for connected machines	Under development - Early Draft
DGR/PDL-003_App_scenarios	PDL Application Scenarios	Under development - Early Draft

3.7 CEN/CENELEC

In 2017, CEN and CENELEC established a joint Focus Group on Blockchain and Distributed Ledger Technologies, FG-BDLT, to identify gaps in blockchain and DLT standardization for Europe and map them to ISO/TC 307's ongoing work items.

FG-BDLT published a white paper in 2018 with recommendations for blockchain and DLT standardization in Europe. The group is expected to release a newer version of the white paper in 2019, to reflect emerging issues within Europe concerning Blockchain and DLT standardization.

3.8 NIST

The National Institute on Science and Technology (NIST) under the US Department of Commerce set up the Blockchain for Industrial Applications Community of Interest (BIA COI) in 2017.

The goal of this group is to provide guidelines that will improve the synergy between all the stakeholders in the blockchain ecosystem and reduce the complexity, cost, and delay of adoption of blockchain technologies.

BIA COI published NIST.IR.8202 in October, 2018 to provide a high-level technical overview of blockchain technology and to discuss its application to cryptocurrency in depth.

3.9 DIN

The German Institute for Standardization, DIN, is currently contributing to DLT-related standardization as a participating member of ISO/TC 307.

They are, however, engaged in their own DLT-related standardization work, separate from ISO, as listed in Table 14.

Table 14: DLT-related work items under DIN

Work Item	Title	Status
DIN SPEC 4997	Privacy by Blockchain Design: A standardised model for processing personal data using blockchain technology	Under Review
DIN SPEC 3103	Blockchain and distributed ledger technologies in application scenarios for Industrie 4.0	Completed

3.10 UNE

The Spanish Association for Standardization, UNE, within their CTN71/SC307/GT1 committee, established a work item titled "Modelo Descentralizado de Identidad", a DLT-based model for decentralized identities (DIDs) used by a variety of pilots within the European Self Sovereign Identity Framework (ESSIF). This "de-facto" standard is also implemented on Alastria.

Table 15: DLT-related work items under UNE

Work Item	Title	Status
CTN 71/SC 307/GT1	Decentralized Model of Identity	Under Review

3.11 Community standards

DLT standards development has been most actively done by industry and community organizations. Their work is different from that of formal standards developing organizations as the specifications developed are usually published with an accompanying repository of open-source implementation code.

The Linux Foundation is an example of a community-driven organization that provides support for a range of cross-industry blockchain applications. Hyperledger, hosted by the Linux Foundation, presently has a community of over 200 companies that are focused on the development and implementation of enterprise blockchain. Notably, their work has led one of their frameworks, Hyperledger Fabric, to be considered a de facto standard for enterprise blockchain platforms.

The Ethereum platform is also governed by a series of standards that have been developed and are continually maintained by the Ethereum community through a process known as the Ethereum Improvement Proposals (EIPs). They define standards for the Ethereum platform, which include core protocol specifications, interface/client APIs specifications and application-level standards, typically known as the Ethereum Request for Comment (ERC) standards.

Perhaps the most known standard in use is ERC-20, which is used for smart contracts on the Ethereum blockchain for implementing fungible tokens.

The cross-industry applicability of DLT has also created a need for industry-specific standards development. Organizations such as the Blockchain in Transport Alliance (BiTA), which was established in August, 2017, are working towards serving this need. BiTA have focused their standardization efforts on the transportation industry and have published two standards as listed in Table 16.

Table 16: DLT-related standards published by BiTA

Title	Status
BiTAS Std 120-2019: Location Component Specification	Completed
BiTAS Tracking Data Framework Profile	Completed

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