# OECD Blockchain Primer

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This Primer provides an introduction to blockchain technology, outlines some of the potential benefits it can bring, and considers the risks and challenges it poses. While not comprehensive, it is an overview of the key concepts and terms intended to help people better understand this emerging technology and its growing impact.

# A technology? A currency? The new internet?

**Blockchain has the potential to transform the functioning of a wide range of industries.** Its features can increase the transparency and traceability of goods, data and financial assets, facilitate market access and improve the efficiency of transactions. Fulfilling blockchain's potential, however, depends on a policy environment that allows innovation and experimentation, while balancing the risks of misuse. Governments will play a significant role in shaping policy and regulatory frameworks that help address challenges presented by the technology, and foster transparent, fair and stable markets as blockchain develops.

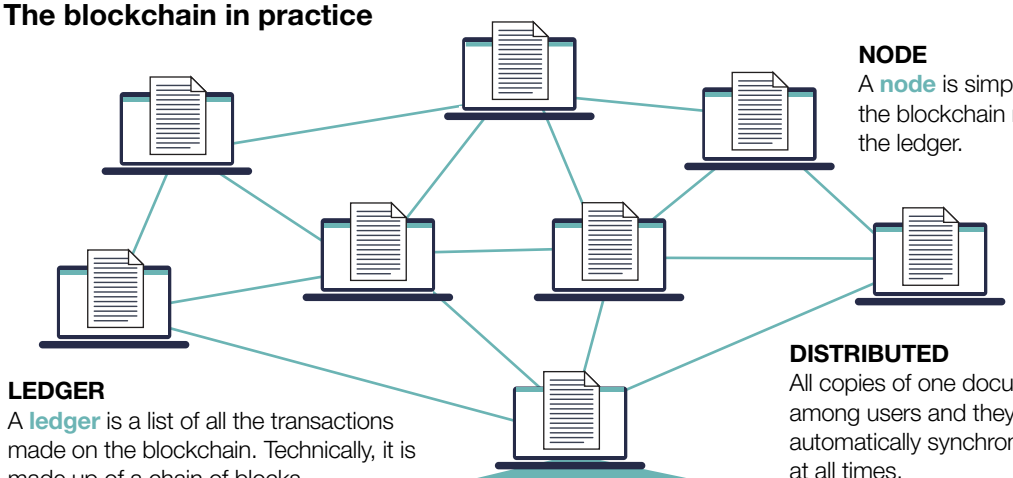
Fundamentally, blockchain is a combination of already existing technologies that together can create networks that secure trust between people or parties who otherwise have no reason to trust one another. Specifically, it utilises distributed ledger technology (DLT) to store information verified by cryptography among a group of users, which is agreed through a pre-defined network protocol, often without the control of a central authority. The marriage of these technologies gives blockchain networks key characteristics that can remove the need for trust, and therefore enable a **secure transfer of value and data directly between parties**.

Due to this unique ability, blockchain technology can diminish the role of intermediaries, who can command market power, collect significant fees, slow economic activity, and are not necessarily trustworthy or altruistic keepers of personal information. Although mostly known for its digital financial asset applications (like Bitcoin), blockchain technology is poised to have an impact on a wide range of sectors. The OECD is exploring the policy implications in a variety of areas including health, transportation, agriculture, environment, and supply chain management.

# What is blockchain?

**A blockchain is a shared ledger of transactions between parties in a network, not controlled by a single central authority.** You can think of a ledger like a record book: it records and stores all transactions between users in chronological order. Instead of one authority controlling this ledger (like a bank), an identical copy of the ledger is held by all users on the network, called nodes.

## The blockchain in practice



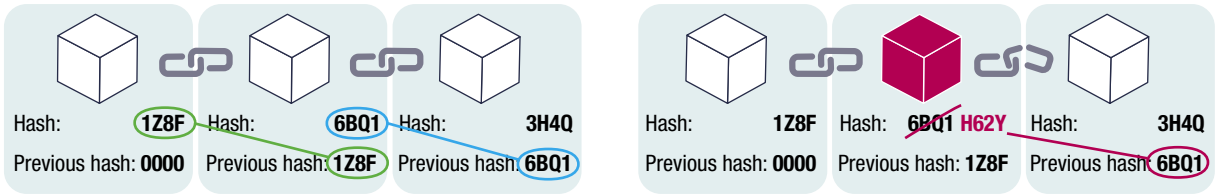
**NODE**
A node is simply a computer on the blockchain network that stores the ledger.

**LEDGER**
A ledger is a list of all the transactions made on the blockchain. Technically, it is made up of a chain of blocks.

**DISTRIBUTED**
All copies of one document are spread among users and they are constantly and automatically synchronised, hence identical at all times.

**BLOCKCHAIN UNDER THE HOOD**

A block is comprised of a group of transactions from the same time period, like a page from a record book.




*Source:* Savjee, (2017)

**Inside each block:**
Hash
Previous block's hash
Transaction data
Timestamp

**Along with its own hash, each block stores the hash of the block before it.**
A hash is a unique string of letters and numbers created from text using a mathematical formula. Blocks are therefore "chained" together making the ledger (almost) immutable or unable to be changed. To add a block, it may first need to be mined and then approved by a number of notes through a consensus mechanism.

# Different types of blockchain

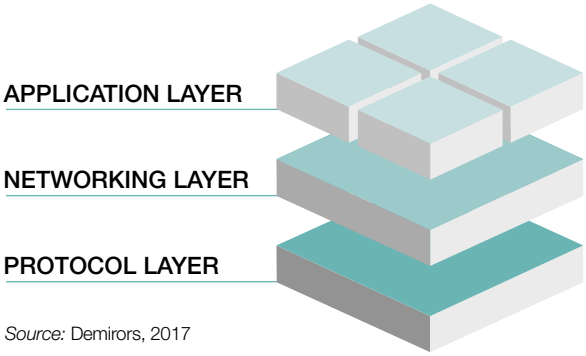
**Before going further, it is important to note that not every blockchain is made the same.** While there are a number of variable features, two of the most important are the **"openness" of the platform** (public or private) and the **level of permissions required to add information** to the blockchain (permissioned or permissionless). **Public** blockchains (like Bitcoin) are open for anyone to read and view, while **private** blockchains can only be viewed by a chosen group of people. Similarly, **permissioned** blockchains permit just a select group of users to write (i.e. generate transactions for the ledger to record) and commit (i.e. verify new blocks for addition to the chain). In contrast, **permissionless** blockchains allow anyone to contribute and add data to the ledger.

**Table 1. The main types of blockchain segmented by permission model**

| | | | READ | WRITE | COMMIT | EXAMPLE |
|---|---|---|---|---|---|---|
| BLOCKCHAIN TYPES | OPEN | Public permissionless | Open to anyone | Anyone | Anyone | Bitcoin, Ethereum |
| | | Public permissioned | Open to anyone | Authorised participants | All or subset of authorised participants | Supply chain ledger for retail brand viewable by public |
| | CLOSED | Consortium | Restricted to an authorised set of participants | Authorised participants | All or subset of authorised participants | Multiple banks operating a shared ledger |
| | | Private permissioned "enterprise" | Fully private or restricted to a limited set of authorised nodes | Network operator only | Network operator only | External bank ledger shared between parent company and subsidiaries |

*Source:* Hileman & Rauchs, 2017

## The layers of blockchain




*Source:* Demirors, 2017

Blockchain is comprised of three layers that each add different components to its development. It is not necessary to get involved in the most technical layers in order to develop an application or use a blockchain application.

The **protocol layer** lays the foundational structure of the blockchain. It determines the computing language the blockchain will be coded in and any computational rules that will be used on the blockchain.

The **networking layer** is where the rules set up on the protocol layer are actually implemented.

The **application layer** is where networks and protocol are used to build applications that users interact with.

# Blockchain's key characteristics

### Distributed

One of the core aspects of a blockchain is that it is a distributed ledger, meaning that the database is maintained and held by all nodes in the network. No central authority holds or updates the ledger, rather each node independently constructs its own record by processing every block (group of transactions), deciding if it is valid, then voting via the **consensus mechanism** on their conclusions. Once a change in the record is agreed, each node updates its own ledger.
In contrast, traditional databases are stored and maintained centrally, which can make them high-value targets for hackers and criminals.

### Immutable

In general, once a transaction is added to a blockchain ledger, it cannot be undone.
This immutability is one of the principal aspects that contribute to the trustworthiness of blockchain transactions. A blockchain's immutability is secured through its use of cryptography (see below for an explanation of **hashing**). In a traditional, centralised database, an authorised user can connect to the server to add or modify the data without the approval or detection of other users. Because all the data is held in one place, if the security of the server or the authority that runs the server is compromised, data can be modified or permanently deleted. This may sometimes be irreversible and occur without anyone else realising it.

### Agreed by consensus

No block can be added to the ledger without approval from specified **nodes** in the network. Rules regarding how this consent is collected are called **consensus mechanisms**. Consensus protocols are crucial in ensuring that every block is valid and that all participants agree and maintain the same version of the ledger. They heavily affect the incentives for nodes to act honestly and are therefore the most important variables when designing a blockchain.

## Misconceptions about blockchain

### Pseudonymous

Contrary to popular belief, in general, blockchain technology does not allow its users to be totally anonymous. Rather, public blockchain platforms tend to be **pseudonymous**: user identities can be anonymous but their accounts are not, as all of their transactions are visible to all other users. On these platforms, user accounts can be created without any identification or authorisation process. This allows users to use a pseudonym. **Permissioned** blockchains can require a user's identity to be verified before they are able to access or use the blockchain.

### …Well "almost" immutable…

While rare, it is possible for the blockchain to be compromised if nodes pool their resources and collude to approve incorrect ledger entries. However, the larger the network, the more difficult it becomes to carry out this attack. In most systems, it would cost the attacker many more resources to carry out the attack than they would gain from the attack itself. Additionally, some private blockchains allow for central authority nodes to change information on the ledger. Advances in quantum computing (supercomputing) threaten some current cryptographic security measures, but there is equally the likelihood that blockchain's security will evolve with quantum computing capabilities.

# Blockchain under the hood: How does blockchain actually work?

## Hashing: a cryptographic fingerprint

**A hash is like a digital fingerprint; it is unique to each piece of data on the blockchain.** Users put information regarding their transaction (name of receiver and sender along with the amount transferred) into a cryptographic hashing algorithm – a complex mathematical formula – and receive a set of letters and numbers that is distinct to that transaction. The specific input, if unchanged, will always produce the same exact hash. If, however, any part of the data input is changed (for example a malicious actor changes the amount transferred), the hash would change to an entirely different set of characters and make it incompatible with the rest of the chain. Therefore, even without seeing the details of the transaction, nodes can quickly tell that the data within the block has been tampered with and reject that version of the ledger. It is this cryptographic security that makes blockchain ledgers more trustworthy and "almost" immutable.

### Examples of hashes

| Input | Hash output (using SHA 256 algorithm) |
|---|---|
| **OECD** | 879D5ACDCDA51A6F1B00EBFE77513D9B19F574499C867997EE1FB6B1FA6DDBB0 |
| **OeCD** | 19C91C8433AC66422E8B13A468B3E96D5D7924BEB1164F8412484900C7C1EDC6 |

*Note:* Even subtle changes like upper or lower case significantly alter the hash.

## Mining

For some blockchains, in order to add blocks to the ledger, transfers must go through a mining process. Mining is a way of adding transaction records, via blocks, onto a public ledger. Miners are nodes in the network that ensure the transactions in the block are valid. Specifically, they ensure that senders have not already used the funds they want to send to receivers. Once miners finish the verification, they have to ask the network for **consent** to add the new block to the ledger. In order to do so, they have to follow the **consensus mechanisms** chosen for the platform.

## Consensus

One of blockchain's key characteristics is the consensus mechanisms it uses to gather consent. Agreement among nodes regarding the "state" of the ledger is essential for the function of the blockchain ledger. The bitcoin blockchain utilises a consensus model called Proof of Work, which requires the miner to compete against other miners to create and broadcast blocks for approval. If successful, they are rewarded in Bitcoin. There are other consensus mechanisms like Proof of Stake, Proof of Authority, Proof of Elapsed Time, and Proof of Burn – all of these are variations on the means for the network to agree on changes to the ledger.

# What are digital financial assets?

## A digital asset that works as a medium of exchange

The term **tokenisation** describes the process of transferring rights to a real world asset into a digital representation – or token – on the blockchain. Being in possession of that digital token then gives you the right to that asset and the ability to trade and track it digitally.

There are three main types:

**Payment tokens** Commonly known as a cryptocurrency, a payment token can be a store of value and a unit of measurement, e.g. Bitcoin.

**Utility tokens** A token that represents a right to a good or service, similar to a gift card, e.g. StorjCoin.

**Security tokens** A token that provides equity or equity like investment in a company. The holder of the token has rights to the company's future profits, e.g. tZERO.

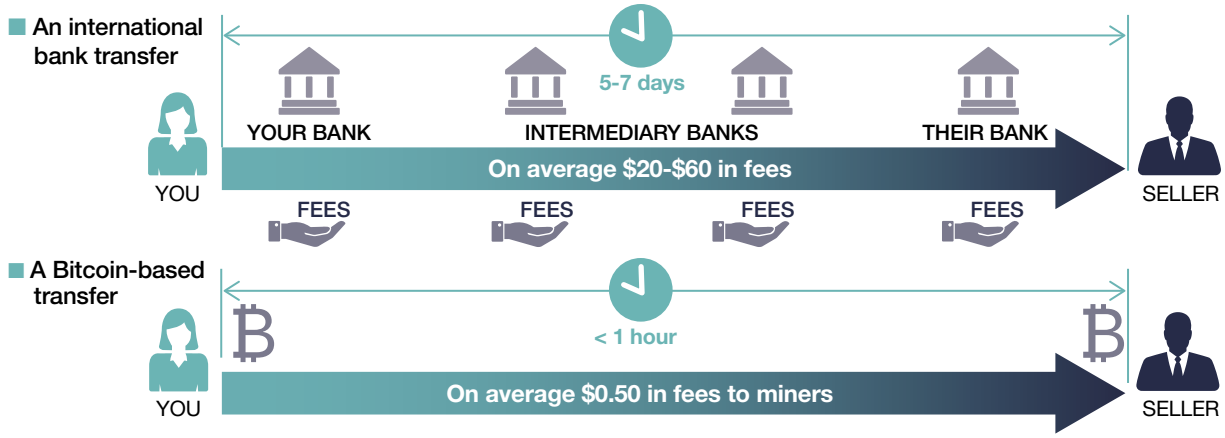
## Why is this important? What can it be used for? One example: Bitcoin

In today's financial system, banks are an essential intermediary for financial transactions and transfers. They verify the identity of the sender, the ability of the sender to make a transfer (i.e. a sufficient account balance) and accuracy of the recipient's address. In this context, the bank acts as the only trusted third party.

However given the bank stores all data on a single centralised ledger, it therefore creates a **single point of failure**, whereby hackers or malicious actors can direct all their efforts for cyberattacks or manipulation to this specific entity. These financial intermediaries also charge **fees** to process transactions. In the case of international remittances, these fees are significant compared to the overall value of the transaction.

It was in this environment that the first blockchain application, a digital currency (cryptocurrency) called **Bitcoin**, was born. It created a peer-to-peer currency that enables users to transfer value to one another without having to go through a bank. Due to Bitcoin's use of cryptographic hashing, mining, and consensus mechanisms, users are able to verify transactions without needing a central authority controlling a single ledger.

**Comparing bank transfers and Bitcoin**



# Blockchain beyond finance

**Blockchain technology goes far beyond cryptocurrencies and tokens**, and its usefulness as a wider economic and administrative tool is well worth exploring. The table below describes just a small sample of blockchain's potential to transform supply chains, healthcare and the energy sector.

**Table 2. Examples of blockchain's potential in supply chains, healthcare and the energy sector**

| Policy area | Description | Potential benefits | Potential risks/Obstacles |
|---|---|---|---|
| **Due diligence in supply chains** | Blockchains allow multiple parties to access the same database to track and record and audit products as they move along the supply chain | **Enhanced transparency**<br>A more transparent supply chain will help companies and consumers identify risks of adverse impacts (i.e. human rights abuse and financial crime), and on that basis, prioritise further efforts to prevent or mitigate such risks.<br>**Sharing value of due diligence**<br>Using blockchain technology to tokenise due diligence data (attaching a monetary value to access to the data), could potentially help fund due diligence efforts.<br>**Financial inclusion**<br>Blockchain technology can lead to greater integration of informal actors and SMEs in the formal supply chain by helping overcome cash flow barriers through self-executing smart contracts. | **Difficulty controlling data quality**<br>Widely known as the "garbage in garbage out" issue where the information entered on the blockchain is only as good as its source.<br>**Upfront costs and lack of access**<br>In order to link the physical world to the digital, supply chain stakeholders have to invest in technology as well as facilitate access to and encourage uptake of the technology.<br>**Fragmentation**<br>Despite being created for very similar purposes, multiple blockchain initiatives have developed, operating on different platforms, identifying and collecting information differently, and with different governance structures. |
| **Healthcare** | Blockchain could be used to provide more robust patient healthcare information data management systems. Instead of information siloed in different data systems, patients and healthcare providers could choose what they share and with whom. | **Continuity of care**<br>Information can be shared between different healthcare stakeholders and end users could find it easier to share information to new providers.<br>**Cost effectiveness**<br>Providing better data sharing between stakeholders can increase the ability of healthcare organisations to provide cost effective care and reduce clerical errors that are at best inefficient and at worst life threatening. | **Privacy rules**<br>While some healthcare blockchain solutions will make only high level demographic information publicly viewable, it is conceivable that the combination of demographic data and geographic location could reveal sensitive information.<br>**Data security**<br>Given the information stored (or linked onto the blockchain) is highly sensitive, data security is a potential risk. |
| **Energy** | Blockchain can enable decentralised peer-to-peer electricity markets, allowing individuals and entities to balance supply and demand and trade electricity without going through a central entity. | **Lower transaction costs**<br>Without intermediaries, costs can be significantly reduced along the electricity value chain. This could potentially lead to more competition and a broader range of options for consumers.<br>**Facilitating distributed and low carbon electricity**<br>Blockchain could reduce the complexity of managing systems with large numbers of small-scale renewable and distributed energy resources, accelerating their deployment. | **Scalability and technical performance**<br>As is, several types of blockchain have difficulties scaling (for example, due to data volumes and transaction speeds).<br>**Energy consumption**<br>To reach scale in energy applications, blockchain technologies will have to develop less energy-intensive frameworks for processing transactions. |

# Blockchain beyond borders

**The areas where major blockchain progress is taking place are as diverse as the applications they are creating.** The global nature of blockchain's development can help distribute opportunities for wealth creation and economic development more widely than before. It is important for governments to develop the right policies to harness the potential benefits of this technology while mitigating its risks and potential for misuse. To do so, it is essential for countries to cooperate in order to share best practices and ensure interoperability. Regulatory fragmentation will hinder the progress towards useful applications of blockchain technology.

## The global development of blockchain

● Economies engaged in different stages of using blockchain

*Note: The economies engaged in different stages of using blockchain include: Argentina, Australia, Austria, Barbados, Belgium, Bermuda, Brazil, Cambodia, Canada, Chile, China, Denmark, Estonia, Finland, France, Georgia, Germany, Ghana, Hong Kong (China), India, Israel, Japan, Kazakhstan, Kenya, Luxembourg, Malta, Mauritius, Mexico, Netherlands, Norway, Palestinian Authority, Papua New Guinea, Russia, Senegal, Singapore, South Africa, South Korea, Sweden, Switzerland, Thailand, Tunisia, Ukraine, United Arab Emirates, United Kingdom, United States, Venezuela.*

*Source:* OECD calculations based on data collected by the Illinois Blockchain Initiative.
https://illinoisblockchain.tech and https://bit.ly/blockchain-govt-tracker

## The role of the OECD

The OECD provides a forum for discussion, sets international standards, and helps build capacity in governments – and is bringing these core competencies to the opportunities and challenges presented by blockchain. It is already helping governments find the right experts and practitioners to engage with, consider the need for cooperation in the international policy environment, and identify and share best practice for governments managing and using blockchain.

An integrated and holistic approach is key to maximising the benefits of this technology, both between sectors and between markets. The OECD's multidisciplinary expertise and deep links with industry, academia, governments and other international organisations mean it is able to join the dots for domestic priorities and global actions. If blockchain is going to be one of the transformative technologies of our time, the OECD is here to make sure governments are ready.

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