6.1 Introduction to Blockchain

The blockchain is based on cryptography and Decentralized Systems. The following subtopics will help to provide the required fundamentals and background to understand the blockchain explained in further sections.
Read more about Blockchain by visiting the following links:

Readings:

1. 101 Blockchains. (n.d.). Learn blockchain basics concepts. https://101blockchains.com/flash-cards/blockchain-basics/
2. Anusha. (2022). A beginners guide to understand the blockchain ecosystem. Analytics Vidhya. https://www.analyticsvidhya.com/blog/2022/08/a-beginners-guide-to-understand-the-blockchain-ecosystem/

Then, watch this 25-minute 16-second video to learn how blockchain works.

But how does bitcoin actually work?

https://youtu.be/bBC-nXj3Ng4

Source: (3Blue1Brown, 2017)

Cryptography

Blockchain fundamentally works on cryptography methods. Algorithms for hashing, key exchange, public-private key etc. will be beneficial to understand the working of Blockchain.

Readings

1. Sundaramoorthy, T. (2017). Hashing and public key cryptography for beginners. Medium. https://medium.com/@thyagsundaramoorthy/hashing-and-public-key-cryptography-for-beginners-292aaf14efae
2. 101 Blockchains. (2022). Cryptographic Hashing: A beginner's guide. https://101blockchains.com/cryptographic-hashing/
3. Jackson, A. (2021). Beginner's guide to Hash functions in Cryptography. Venafi. https://www.venafi.com/blog/beginners-guide-hash-functions-cryptography

Peer-to-Peer Networking

Readings

1. Jenkov, J. (2024). Peer-to-Peer (P2P) networks. https://jenkov.com/tutorials/p2p/index.html
2. ComputerNetworkingNotes. (2022). Peer to peer networks explained. https://www.computernetworkingnotes.com/networking-tutorials/peer-to-peer-networks-explained.html

Decentralised Systems

Reading

1. Jenkov, J. (2022). Decentralized systems introduction. https://jenkov.com/tutorials/decentralized-systems/index.html

6.1.1 The Blockchain Ecosystem

The blockchain ecosystem is a combination of four key components. All together makes any application of blockchain functional. For example, in a cryptocurrency network.

1. Developers

Developers are the creators of any new blockchain network. These build and update the blockchain network.

2. Nodes

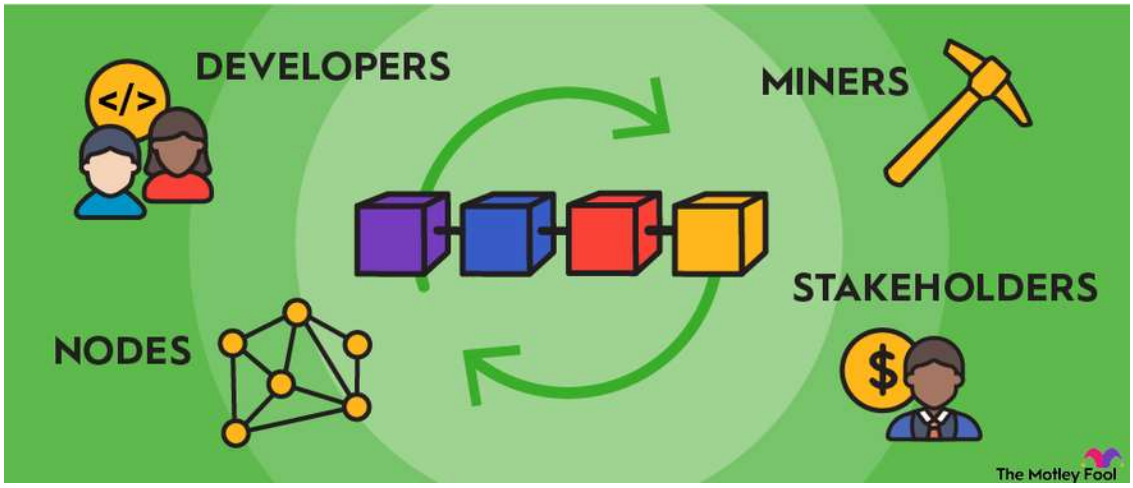
Nodes are hardware parts of a blockchain network. These are devices on which the code written by developers for a blockchain network runs. Nodes also keep an up-to-date history of blockchain transactions.

3. Miners/validators

Miners or validators are all those selected participants participating in the blockchain's transaction validation process. A blockchain can have either miners or validators, depending on its validation system (You will learn about this under proof-of-work vs proof-of-Stake in a further section.).

4. Stakeholders

Stakeholders are also the end-users of blockchain networks. In a cryptocurrency network, stakeholders hold native cryptocurrency.



Source: Components of blockchain ecosystem (Lyle Daly, 2024)

Reading

Daly, L. (2024). What is a blockchain ecosystem? The Motley Fool. https://www.fool.com/investing/stock-market/market-sectors/financials/blockchain-stocks/blockchain-ecosystem/

6.1.2 Fundamental of Blockchain

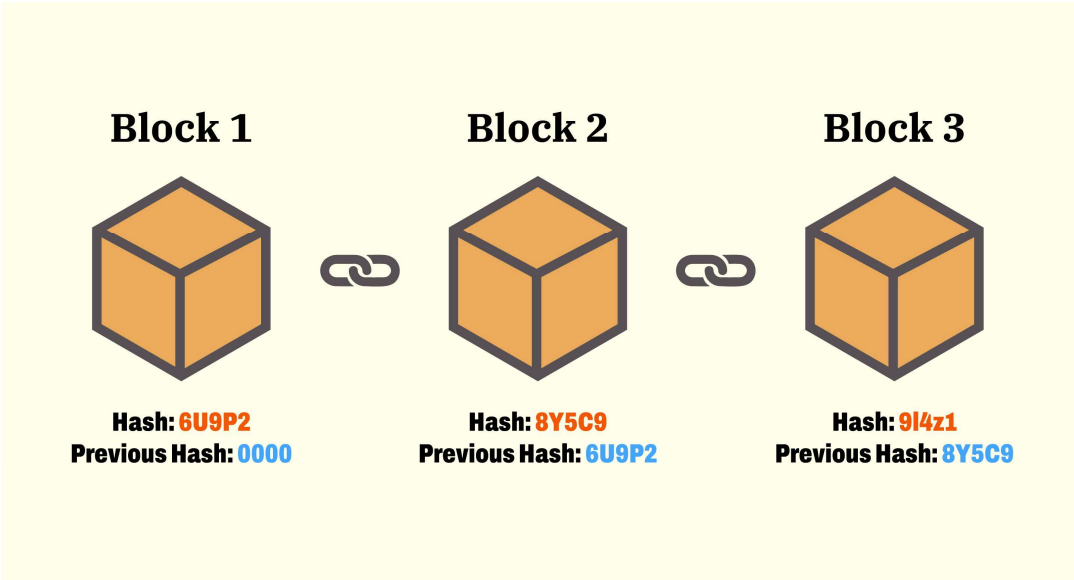
What is Blockchain

A blockchain is a distributed ledger technology (DLT) that consists of a growing list of records, called blocks, that are securely linked together using cryptography.

Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree, where leaves represent data nodes).

The timestamp proves that the transaction data existed when the block was created. Since each block contains information about the block previous to it, they effectively form a chain (compare linked list data structure), with each additional block linking to the ones before it.

An example of Blockchain



Source: Steps for adding a new block to a blockchain network (Cruz, 2022)

Consequently, blockchain transactions are irreversible because, once they are recorded, the data in any given block cannot be altered retroactively without altering all subsequent blocks.

Blockchains are typically managed by a peer-to-peer (P2P) computer network for use as a public distributed ledger, where nodes collectively adhere to a consensus algorithm protocol to add and validate new transaction blocks (Wikipedia, n.d.).

Watch the 6-minute video to learn how a blockchain work.

How does a blockchain work - Simply Explained

https://youtu.be/SSo_EIwHSd4

Source: (Simply Explained, 2017)

How does blockchain work?

Blocks in a blockchain contain more than transaction data, they also have cryptographic hash functions or hashes.

Hashes are the outcome of the mathematical algorithms used in cyberspace to verify data integrity. However, many other applications and uses of hashes depend upon the implementation. So, hashes fulfil a crucial role within blockchain systems and are the reason blockchain works in the first place.

Hashes appear as a variable series of numbers and letters on a block, such as 4760RFLG07LDD492K8381O82P78C29QWMN02C1051B6624E99. This number-letter combination is generated from the data within a block and functions as its digital signature.

Each block includes the hash of the previous block in its chain. This is how blocks are linked together and how blockchain networks maintain their integrity. Modifying any content within a block would change the hash, which is a red flag for others in the network.

Put it all together, you get a self-regulated network without intermediaries, where third parties cannot monitor or interfere with transactions (Cruz, 2022).

The features of Blockchain

1. Transparency
2. Traceability
3. Security
4. Decentralisation

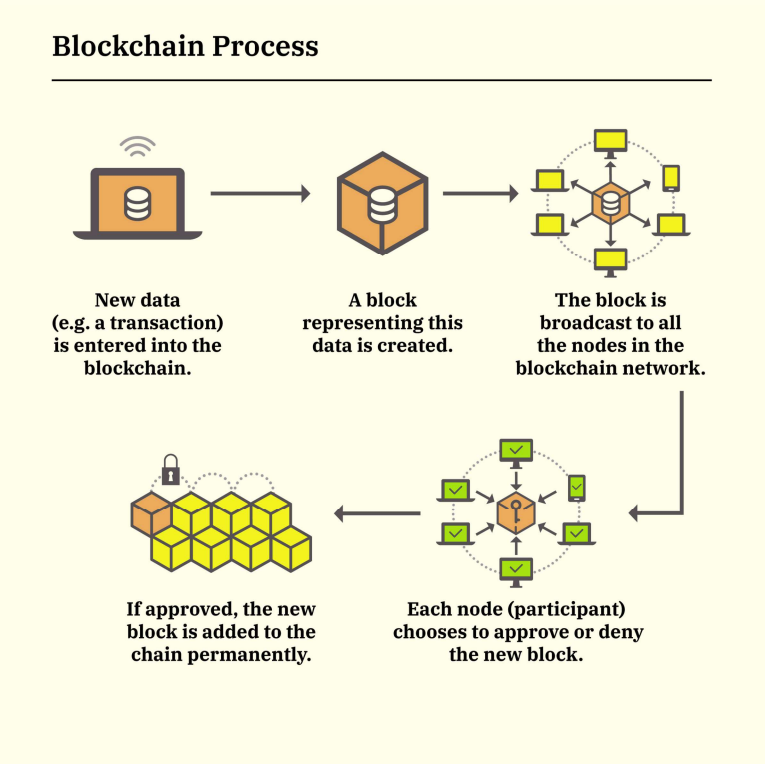
Readings

1. Hayes, A. (2024). Blockchain facts: What is it, how it works, and how it can be used? Learn what these digital public ledgers are capable of. Investopedia. https://www.investopedia.com/terms/b/blockchain.asp
2. Cruz, G.O.R. (2022). What is blockchain? Money. https://money.com/what-is-blockchain/

6.1.3 Blockchain Process

To add a new block to the existing blockchain network, there are mainly five main steps that is required.

1. New Data (Example: a transaction) is entered into the blockchain.
2. A block representing this data is created.
3. The block is broadcast to all the nodes in the blockchain network.
4. Each node (participant) chooses to approve or deny the new block.
5. If approved, the new block is added to the chain permanently.



Source: Steps for adding a new block to a blockchain network (Cruz, 2022)

Mining: Proof of work and Proof of Stake

The process in which computers compete to create new blocks is called “mining.”

1. Proof of Work

In this approach, nodes directly compete "to solve a complex mathematical equation". The node that solves the equation first gets the "proof" of their "work" and is rewarded in terms of the "right to mine" the next block of a transaction. Finally, the node with mining rights (miner) gets rewarded for processing the block.

2. Proof of Stake

In this approach, the node is selected by using a computer algorithm. This approach brings randomness to node selection. Under this, the nodes with more of the networks' currency are more likely to get selected by providing their "stake" in the network over raw computing power. The selected node for processing the block are known as validators.

References

Cruz, G.O.R. (2022). What is blockchain? Money. https://money.com/what-is-blockchain/

6.1.4 Type of Blockchain Networks

Blockchain networks can be grouped into four main classes based on the type of node participation. The fundamental workings of these networks are the same, and only applications vary.

1. Public Blockchain

The public blockchain is permissionless, so anyone can join the network by following the blockchain process. Such networks are good for trust, security and transparency. However, scalability and high energy consumption are major concerns of these

networks. These networks primarily work in peer-to-peer mode and remove the need for authorization to join, read, or write anonymously.
Examples: Bitcoin, Ethereum, Litecoin, NEO

2. Private Blockchain

As the name suggests, the private blockchain works based on permission and any participants have to obtain permission to join the network or participate in the networking process, i.e. mining or validating. By limiting the number of participants, private blockchains achieve good speed and solve the scalability issue. However, such a network has less trust as it is controlled in a centralized manner.
Examples: MultiChain and Hyperledger projects, Corda

3. Hybrid or Semi-private

The hybrid blockchain network combines public and private approaches and tries to solve the bottlenecks of both these approaches. So, it provides good flexibility and high performance, but it also has limited transparency due to having some part as the private network.
Examples: Dragonchain, XinFin, Ripple

4. Consortium

The consortium blockchain is mainly like private networks. However, it also has some features of public blockchains. So, unlike one centralized management in the private network, the consortium network is controlled by many central authorities collaborating on a decentralized network.
Examples: Marco Polo, Quorum, Energy Web Foundation, IBM Food Trust

6.1.5 Cryptocurrency, Smart Contract and NFT

Cryptocurrency

Blockchain technology has many applications, with cryptocurrency being the most popular.

Bitcoin and other types of cryptocurrency

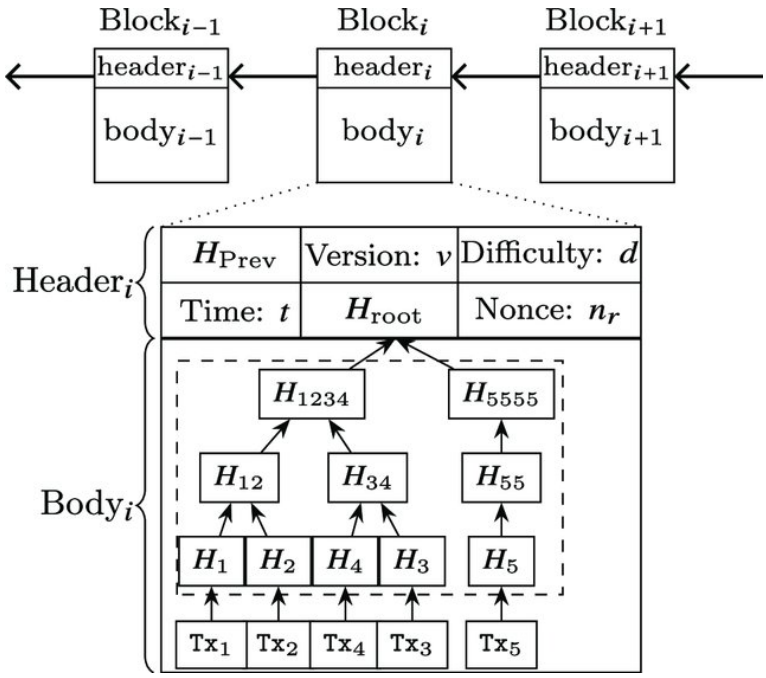
Bitcoin, the first cryptocurrency, remains the most well-known blockchain application. It gave rise to many other cryptocurrencies. Some of the popular cryptocurrencies are shown below.

Source: Types of cryptocurrency (Simplilearn, 2018)

Check out this Blockchain Projects and Resources webpage to learn info more about cryptocurrencies.

The virtual currencies are designed to act as money and a form of payment outside the control of any one person, group or entity, thus removing the need for third-party involvement in financial transactions. It is rewarded to blockchain miners for the work done to verify transactions and can be purchased on several exchanges (The Investopedia team, 2024).

Refer to the diagram below for the structure of the Bitcoin blockchain.



Source: Data structure of the Bitcoin blockchain (Hu et al., 2021, p.4)

Watch the following 12-minute 48-second video, focusing on how Bitcoin transactions work (3:05).

What is Blockchain? | Introduction to Blockchain Technology | Blockchain Tutorial | Simplilearn

https://youtu.be/WeuJqKEfSxM

Source: (Simplilearn, 2018)

Smart contracts

A smart contract is a computer code that can be built into the blockchain to facilitate, verify, or negotiate a contract agreement. Smart contracts operate under a set of conditions to which users agree. When those conditions are met, the terms of the agreement are automatically carried out.

Watch the following 4-minute 16-second video to learn about Smart Contracts.

Smart contracts - Simply Explained

https://youtu.be/ZE2HxTmxfrI

Source: (Simply Explained, 2017)

Non-fungible token (NFT)

NFT stands for non-fungible token. NFT is also a digital token like cryptocurrency; both are known as digital assets.

However, unlike cryptocurrencies, which are fungible, or interchangeable, NFTs are singular and unique.

Watch the following 3-minute 33-second video to learn what is an NFT.

NFT's Explained in 4 minutes!

https://youtu.be/FkUn86bH34M

Source: (Simply Explained, 2021)

Read the following article to find out more about Blockchain technology.

Reading

Levy, A. (2022). 15 applications for blockchain technology. The Motley Fool. https://www.fool.com/investing/stock-market/market-sectors/financials/blockchain-stocks/blockchain-applications/

6.1.6 Self-check quiz 1

1. Blockchain is used for _____.

    ANS: Securing and storing data

3. Blockchain and Cryptocurrency are the same.

    ANS: False

4. Bitcoin is one type of cryptocurrency.

    ANS: True

5. _____ and _____ are two popular applications of Blockchain.

    ANS: Cryptocurrency, Smart Contract

6.2 Applications using Blockchain and Big Data

In the previous section, you learned about the fundamentals of blockchain and various basic constructs of how blockchain works. Now, you will explore some key applications of blockchain and will learn how blockchain with big data works together to achieve the goals.

Watch the following 7-minute video to learn more about how Blockchains can be used.

Blockchains: how can they be used? (Use cases for Blockchains)

https://youtu.be/aQWfINQuP_o

Source: (Simply Explained, 2015)

Blockchain and Big Data

Next, let's learn how Blockchain is related to Big Data in this 3-minute 41-second video.

Data Driven #5: Blockchain and Big Data

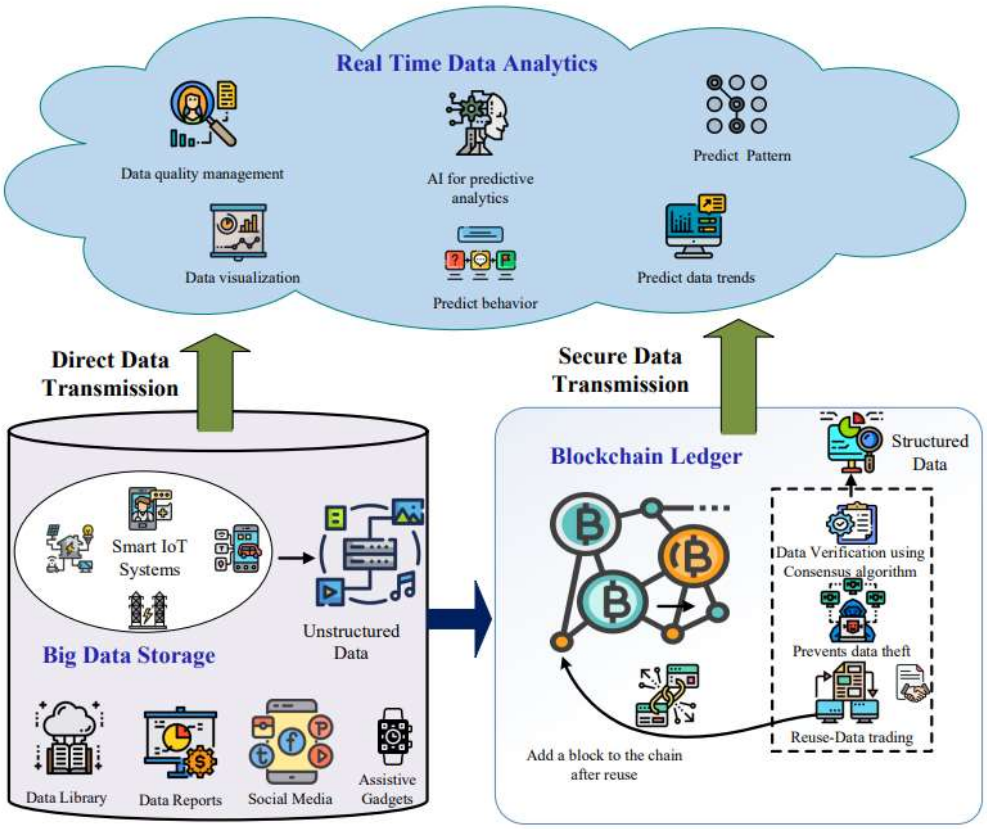
https://youtu.be/Wz_PT3W29Lo

Source: (Syncfusion, Inc, 2016)

The following are the two main benefits of bringing Blockchain to Big Data according to Fedak (2018):

- Blockchain-generated Big Data is secure, as it cannot be forged due to the network architecture.
- Blockchain-based Big Data is valuable, meaning it is structured, abundant and complete, making it a perfect source for further analysis.

Refer to the diagram below for an example of Big Data transition model that is secured with blockchain:



Source: Secured blockchain services for big data processing (Deepa et al., 2022, p.6)

Readings

- Anand, A. (2022). 8 benefits of blockchain in big data transformation. Analytics Steps. https://www.analyticssteps.com/blogs/8-benefits-blockchain-big-data-transformation
- Deepa, N., Pham, Q.-V., Nguyen, D.C., Bhattacharya, S., Prabadevi, B., Gadekallu, T.R., Maddikunta, P.K.R., Fang, F., & Pathirana, P. N. (2021). A survey on blockchain for big data: Approaches, opportunities, and future directions. Future Generation Computer Systems, Vol 131, 209-226. https://doi.org/10.48550/arXiv.2009.00858
- Oodles, E. S. (2021) Benefits of using big data in supply chain management. ERP Solutions oodles. Medium. https://erpsolutionsoodles.medium.com/benefits-of-using-big-data-in-supply-chain-management-1bcc1f6c915f

6.2.1 Application of Blockchain and BigData -1 : Supply Chain

Supply chain management is one of the most used applications of Big data. The supply chain has many activities that range from improving delivery times to identifying ways to reduce the communication gap between manufacturers and suppliers.

Analytics reports enable decision-makers to achieve operational efficiency and monitor performance to improve productivity. Blockchain is being introduced to big data pipelines for supply chains to improve the security and privacy of data and transactions.

Watch the following 4-minute 34-second video for an explanation of blockchain for the supply chain.

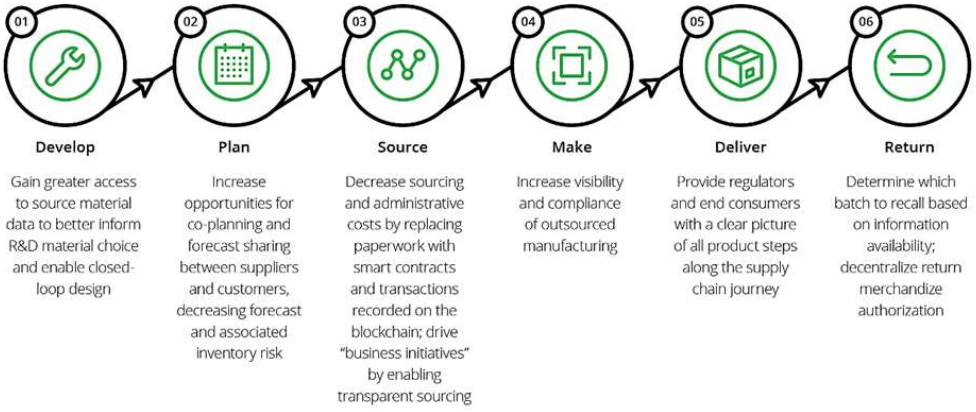
What is Blockchain in Supply Chain? Applications, Advantages, Examples and Trends - AIMS Education

https://youtu.be/jMihd-gqb6I

Source: (AIMS Education, UK, 2020)

Many big companies are already working with blockchain for their supply chain management. A few examples as listed in an article by McKinsey & Company (2017) are as follows:

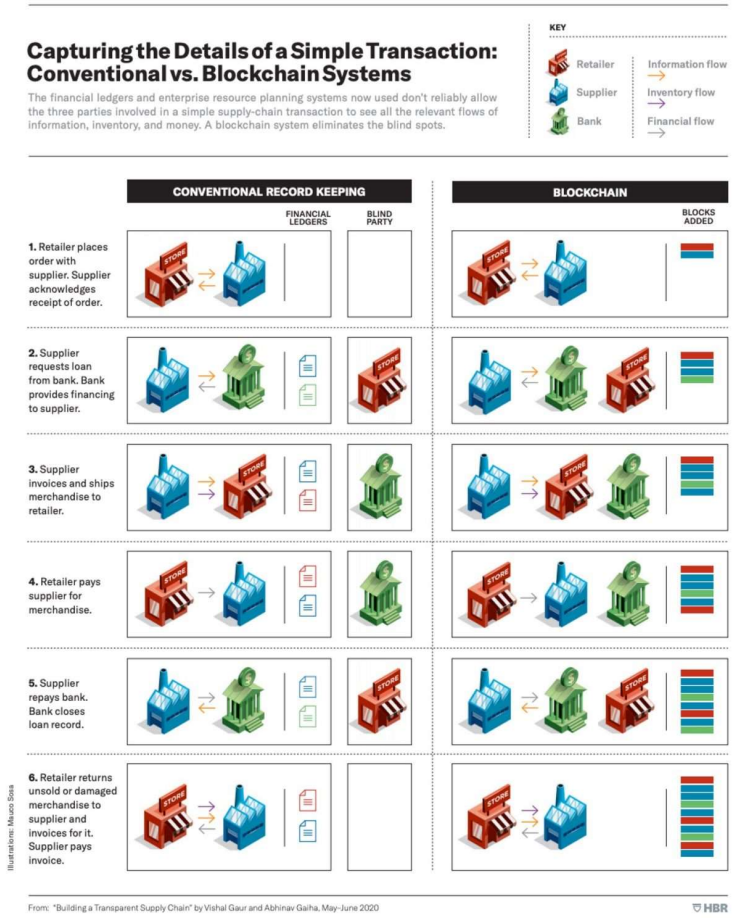
- Walmart tested an application that traced pork in China and produced in the US to authenticate transactions and the accuracy and efficiency of record keeping.
- Maersk and IBM are working on cross-border, cross-party transactions that use blockchain technology to help improve process efficiency.
- BHP is introducing a blockchain solution that replaces spreadsheets for tracking internal and external samples from various providers.
- Provenance, a UK start-up, just raised $800,000 to adopt blockchain technology to trace food. It previously piloted tracing tuna in the Southeast Asian supply chain.



Source: Driving value in the supply chain (Deloitte, 2022)

Conventional vs Blockchain Systems

Refer to the diagram below for a comparison between the conventional and blockchain systems.



Source: Conventional vs Blockchain Systems (Gaur & Gaiha, 2020)

Primary and Secondary benefits of Blockchain in Supply Chain [Source]

According to Deloitte (2023)'s article 'Using blockchain to drive supply chain transparency', supply chains can leverage Blockchain technology in the following ways:

Primary potential benefits

- Increase traceability of material supply chain to ensure corporate standards are met
- Lower losses from counterfeit/gray market trading
- Improve visibility and compliance over outsourced contract manufacturing
- Reduce paperwork and administrative costs

Secondary potential benefits

- Strengthen corporate reputation through providing transparency of materials used in products
- Improve creditability and public trust of data shared
- Reduce potential public relations risk from supply chain malpractice
- Engage stakeholders

Readings

- Alicke, K., Davies, A., Leopoldseder, M. & Niemeyer, A. (2017). Blockchain technology for supply chains--A must or a maybe? McKinsey & Company. https://www.mckinsey.com/capabilities/operations/our-insights/blockchain-technology-for-supply-chainsa-must-or-a-maybe
- Gaur, V., & Gaiha, A. (2020). Building a transparent supply chain. Harvard Business Review. https://hbr.org/2020/05/building-a-transparent-supply-chain
- Henry W., Kathawate R., Chen, E. & Coulter, J. (2023). Using blockchain to drive supply chain transparency and innovation. Deloitte. https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html

- IBM. (n.d.). Blockchain for supply chain solutions. https://www.ibm.com/blockchain-supply-chain

6.2.2 Application of Blockchain and BigData - 2: Healthcare System

In the previous section, you learn about blockchain and big data applications for supply-chain management. In that security and privacy of data are primarily for financial and business gain. Recently, the digital healthcare system has been growing rapidly, and lots of data is being generated and shared among all involved parties. However, the privacy and security of healthcare data are more critical and involve human lives.

Source: Capacities of blockchain technology for the healthcare domain (Haleem et al., 2021).

According to Haleem et al. (2021), 'a Blockchain network is used in the healthcare system to **preserve and exchange patient data through hospitals, diagnostic laboratories, pharmacy firms, and physicians**. Blockchain applications can accurately identify severe mistakes and even dangerous ones in the medical field.'

Watch the 3-minute 32-minute video below to learn how Blockchain can impact the healthcare industry.

3 Ways How Blockchain Will Change Healthcare - The Medical Futurist

https://youtu.be/Oga9J0NFwAA

Source: (The Medical Futurist, 2018)

Blockchain in Healthcare: Use case

Next, learn a use case of blockchain in healthcare by watching this 8-minute 31-second video.

Blockchain in Healthcare | Use Case

https://youtu.be/dvFOMm6mBao

Source: (Telusko, 2019)

The STL Partners (2022) article lists five additional use cases of blockchain in healthcare as follows:

- Supply chain transparency
- Patient-centric electronic health records
- Smart contracts for insurance and supply chain settlements
- Medical staff credential verification
- IoT security for remote monitoring

Read the articles below to learn about Blockchain in healthcare in greater detail.

Readings

1. Daley, S. (2022). Blockchain in healthcare: 18 examples to know. Built In. https://builtin.com/blockchain/blockchain-healthcare-applications-companies
2. Deloitte. (2018). Blockchain: Opportunities for health care. https://www2.deloitte.com/us/en/pages/public-sector/articles/blockchain-opportunities-for-health-care.html
3. Haleem, A., Javaid, M., Singh, R. P., Suman, R., & Rab, S. (2021). Blockchain technology applications in healthcare: An overview. International Journal of Intelligent Networks, 2, (Pp 130–139). https://doi.org/10.1016/j.ijin.2021.09.005
4. STL Partners. (2022). 5 blockchain healthcare use cases. https://stlpartners.com/articles/digital-health/5-blockchain-healthcare-use-cases/

6.2.3 Application of Blockchain and Big Data - 3 : Finance

The popularity and acceptance of blockchain started with Bitcoin, and much earlier applications and use of blockchain were motivated for financial gain or application of finance management.

- 91% of banks had invested in blockchain solutions by 2018.
- 66% of institutions expect to be in production and running at scale with blockchain.

- (IBM, n.d.) -

Watch the following 4-minute 40-second video to learn about Blockchain in the finance industry.

Blockchain: The future of finance? | FinNext

https://youtu.be/Ys6JV3-uiqw

Source: (Mint, 2022)

As stated the ConsenSys (2022) article, digital financial instruments offer the following business benefits:

- **Authenticity and scarcity**: Digitisation ensures data integrity, and enables asset provenance and full transaction history in a single shared source of truth
- **Programmable capabilities**: Code that addresses governance, compliance, data privacy, identity (KYC/AML attributes), system incentives and features that manage stakeholder participation (for voting and other rights)— can be built into the assets themselves
- **Streamlined processes**: Heightened automation increases overall operational efficiency. It enables real-time settlement, audit and reporting; and it reduces processing times, the potential for error and delay, and the number of steps and intermediaries required to achieve the same levels of confidence in traditional processes
- **Economic benefits**: Automated, more efficient processes trigger reduced infrastructure costs, operation costs, and transaction costs
- **Market reactivity**: Digital securities allow greater customization than standardized securities, and can be issued within shorter timeframes. Issuers

can create bespoke digital financial instruments directly matched to investor demand.

- **New products and markets**: Secure, scalable and rapid asset transfers, fractionalized ownership of real-world assets, tokenized micro-economies, and more

The article also listed the use cases of Blockchain in financial services as follows:

- Capital markets
- Asset management
- Payment and remittances
- Banking and Lending
- Trade finance
- Insurance

Read the following articles to learn more about Blockchain in finance:

Readings

1. ConsenSys. (2022). Blockchain in financial service. https://consensys.net/blockchain-use-cases/finance/
2. Daley, S. (2022). Blockchain in finance: What it is and how it's used. Built In. https://builtin.com/blockchain/blockchain-banking-finance-fintech
3. IBM. (n.d.). Blockchain for financial services. https://www.ibm.com/blockchain/industries/financial-services

6.2.4 Application of Blockchain and BigData -4 : E-Governance

In the last decade, most governments have moved many governance operations online under the term e-governance. Such large-scale migration resulted in many privacy and security issues, and in recent years, many governments have implemented many security solutions to protect e-governance infrastructure, data and transactions. With the same goal, now government organisations are adopting blockchain solutions for various services and programs.

KSI Blockchain

KSI is a blockchain technology designed in Estonia and used globally to ensure networks, systems and data are free of compromise, all while retaining 100% data privacy. The KSI Blockchain is deployed in Estonian government networks (e-Estonia, n.d.). Watch the 2-minute 56-second video below to learn the details.

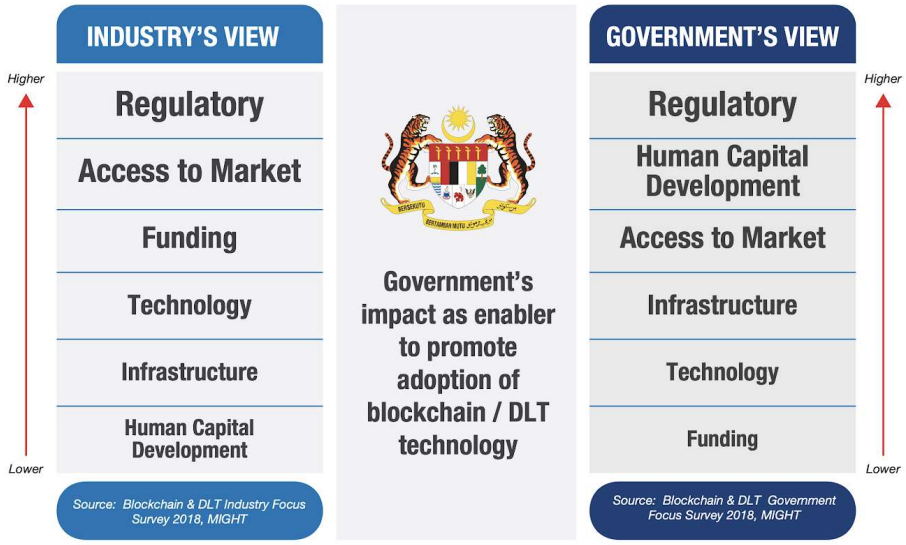
Cybersecurity Ecosystem in Estonia - Technology

https://youtu.be/xvknTeiSLv8

Source: (e-estonia, 2021)

Blockchain in government: Malaysian perspectives and applications

The Malaysian government is also exploring and adopting Blockchain solution as laid out in 'Blockchain and distributed ledger technology (DLT) initiatives in Malaysia 2019'.

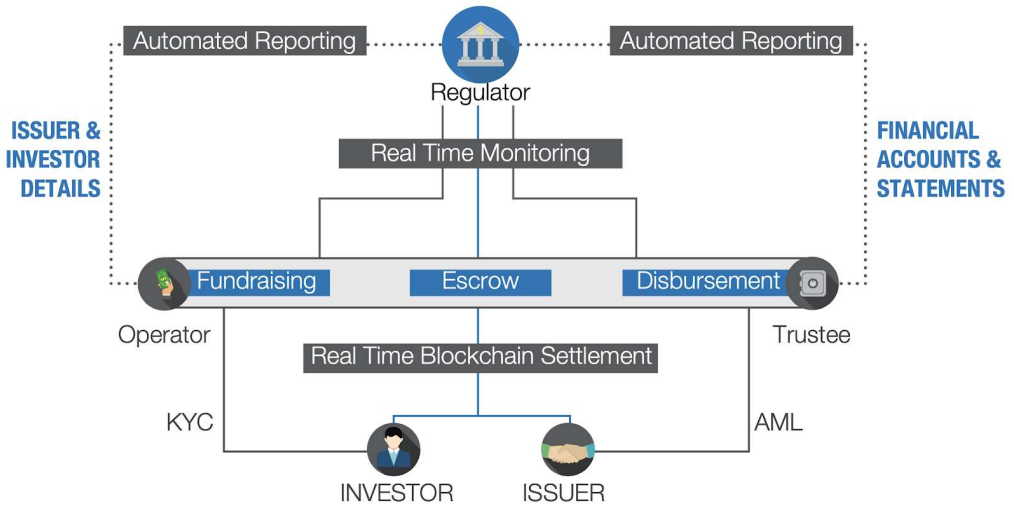


Source: Malaysian Industry-Government Group for High Technology (MIGHT) (Remitano, 2020)

Government Use-case: Project Castor: Securities Commission Malaysia

Securities Commission Malaysia launched Project Castor in 2018 to test and research the feasibility of using blockchain technology for the underlying market infrastructure for unlisted and over-the-counter (OTC) markets. The commission has

since launched many notable initiatives supporting the local blockchain and crypto industry.



Source: Project Castor, MIGHT (Remitano, 2020)

There are many other in-use applications of blockchain in the government section. You can find a few popular global use cases as explained in IBM's webpage 'Blockchain for government'.

According to Nagware (2022), a blockchain-based government has the following advantages:

- Secure storage of government, citizen, and business data
- Reduction of labor-intensive processes
- Reduction of excessive costs associated with managing accountability
- Reduced potential for corruption and abuse
- Increased trust in government and online civil systems

Visit the following links for further reading on Blockchain for governance.

Readings

1. Bolshev, V. (2021). Blockchain and e-governance in smart cities. Scholarly Community Encyclopedia. https://encyclopedia.pub/entry/15784
2. Nagware, K. (2022). Blockchain in e-governance. Linkedin. https://www.linkedin.com/pulse/blockchain-e-governance-kamlesh-nagware/?trk=pulse-article

3. Remitano. (2020). Malaysia's first 'blockchain village' + 10 other government initiatives. https://remitano.com/forum/au/post/1659-malaysias-first-blockchain-village-plus-10-other-government-initiatives

6.2.5 Self-check quiz 2

1. Choose possible application of blockchain.

   ANS: Digital Health Care, Financial services, E-commerce

2. Private companies and organizations can only use blockchain; governments do not accept blockchain-based applications.

   ANS: False

3. Crytocurrencies are global currency and accepted by all governments and banks.

   ANS: False