1. Digital Distributed Ledgers

This section provides a comprehensive introduction to digital distributed ledgers and smart contracts.

Distributed ledgers have the potential to transform the way people and organizations handle identity, transaction, and debt information. I have heard the terms "distributed ledger" and "mutual distributed ledger" and "shared ledger" and "digital ledger" and "global digital distributed ledger" used interchangeably. I will use the term digital distributed ledger.

The purpose of this module is to give you a good, solid working knowledge of digital distributed ledgers.

1.1. Description of a digital distributed ledger

A digital distributed ledger[1] is an indestructible and un-editable decentralized computer record, or ledger. A digital distributed ledger provides a full and complete history of transactions in that ledger. Ledgers can be as public and open or private and limited as the use case demands. Ledgers can be permissioned or permission-less in determining who can add new transactions. Different approaches can be used to determine how new transactions are authorized (proof-of-stake, proof-of-work, consensus, identity mechanisms) before they can add new information to the ledger. Ledgers can be interlinked with one or more other ledgers.

1.2. Characteristics of a digital distributed ledger

The following is a summary of the characteristics of a digital distributed ledger:

- No hackers can corrupt information because there is no centralized version; there are many versions and they all must agree
- Immutable (unchangeable, secure, set in stone)
- No centralized administrator/authority owns the system
- Entries into ledger are "notarized" (similar to idea of notary public)
- Public or private; permissioned or permission-less
- Machine readable
- Stand alone or interlinked with other ledgers

1.3. Cryptocurrency

Cryptocurrency and blockchain is explained well and thoroughly in the article *The Crypto Story*[2].

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[1] Wikipedia, *Distributed Ledger*, https://en.wikipedia.org/wiki/Distributed_ledger

[2] Bloomberg, Matt Levine, *The Crypto Story*, https://www.bloomberg.com/features/2022-the-crypto-story/
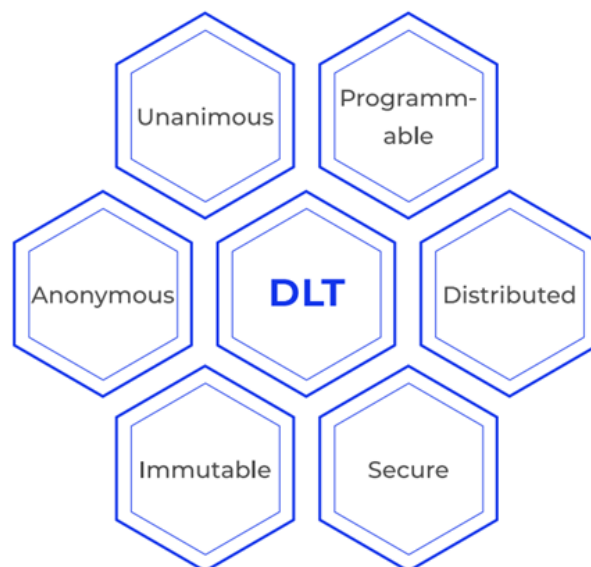
1.4. Blockchain

The key innovation that enables computerized digital distributed ledgers is the blockchain technology[3]. Blockchain technology is used to maintain what amounts to a continuously growing list of translational data records hardened against tampering and revision, even by operators, using advanced cryptography (basically, cryptographic mathematics). Blockchain is a consensus algorithm. But blockchain is only one approach to implementing a digital distributed ledger[4].

As Gabriel Tumlos of KPMG put it in his paper *Blockchains, Distributed Ledgers in Finance and Accounting*, "Blockchains introduced a trust-minimizing transactional platform that all but eliminates the need for a vulnerable third party and allows accounting systems to take their logical next step."

Rejolut provides a very good summary of blockchain use cases in the document *Top Blockchain Use Cases for Enterprises*[5].

Per Rajolut,

> A blockchain is a publicly accessible, decentralized, and distributed database that is managed by various users across multiple nodes connected via a peer-to-peer (P2P) network. Blockchain is a distributed ledger technology (DLT) that allows users to digitally verify issued transactions without the need for a trusted third-party (TTP) authority. Blockchain typically provides a secure and autonomous consentaneous technique to growing the DLT over time while maintaining the data unchangeable and irrefutable. The following are the primary properties of Blockchain-DLT:

MIT provides an excellent explanation as to exactly how blockchain works[6].

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[3] Marco Iansiti and Karim R. Lakhani, Harvard Business Review, *The Truth about Blockchain*, https://hbr.org/2017/01/the-truth-about-blockchain

[4] UK Government Chief Scientific Adviser, *Distributed Ledger Technology: beyond block chain*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf

[5] Rejolut, Top Blockchain Use Cases for Enterprises, https://rejolut.com/wp-content/uploads/2022/11/Blockchain-Use-Cases.pdf

1.5. Hashgraph

An alternative consensus algorithm to blockchain for implementing digital distributed ledgers is hashgraph. This article, *Blockchain Just Became Obsolete: the Future is Hashgraph*[7], helps you understand the difference between blockchain and hashgraph. In particular, this 10 minute video[8] referenced in the article is very helpful.

1.6. Semantic blockchain

Another alternative to creating digital distributed ledgers is semantic web technologies to represent a blockchain[9].

1.7. Web Ledger

The W3C seems to be getting behind Web Ledger[10].

1.8. Neurochain

NeuroChain[11] is described in a white paper as, "NeuroChain is an evolution of the Blockchain that integrates machine learning and AI to drastically improve the performance and capabilities of distributed systems. It's a distributed ecosystem specifically designed to carry collective AI applications."

1.9. Triple entry accounting system

The idea of triple entry accounting was first introduced by Yuji Ijiri in 1989 in his book *Momentum Accounting & Triple-Entry Bookkeeping*[12]. In 2005, cryptographer Ian Grigg provided a more well-known example of a triple-entry accounting system, in a paper, *Triple Entry Accounting*[13]. Some are saying that triple-entry accounting is the most important invention of the last 500 years[14].

With triple entry accounting, both parties to a transaction would complete a transaction and simultaneously record information about that transaction in a shared ledger. Once that happens, it's necessary to ensure that that information about that transaction can't be changed. Ejectively, triple entry accounting connects different sets of books which makes it very hard for errors or fraud to go undetected[15].

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[6] MIT, How Blockchain Works, http://blockchain.mit.edu/how-blockchain-works/

[7] Justin Danneman, *Blockchain Just Became Obsolete: the Future is Hashgraph*, https://squawker.org/technology/blockchain-just-became-obsolete-the-future-is-hashgraph/

[8] YouTube, *Hashgraph Introduction*, https://youtu.be/ZrFrXFdRW4k

[9] Ben Gartner, *Semantic Blockchain*, https://www.slideshare.net/bengardner135/semantic-blockchain

[10] W3C, *Web Ledger*, https://w3c.github.io/web-ledger/

[11] Neurochain Whitepaper, https://www.neurochaintech.io/pdf/NeuroChain-Business-White-Paper-March-19-2018-V1342833.pdf

[12] Yuji Ijiri, *Momentum Accounting & Triple-Entry Bookkeeping*, American Accounting Association, https://www.goodreads.com/book/show/15067963-momentum-accounting-triple-entry-bookkeeping

[13] Ian Grigg, *Triple Entry Accounting*, http://iang.org/papers/triple_entry.html

[14] Daniel Jeffries, *Why Everyone Missed the Most Important Invention in the Last 500 Years*, https://hackernoon.com/why-everyone-missed-the-most-important-invention-in-the-last-500-years-c90b0151c169

[15] YouTube, *Triple Entry Accounting (Video)*, https://www.youtube.com/watch?v=wWXy7wUDEoQ

1.10. Contrasting single-, double-, and triple-entry accounting

The following helps you understand triple-entry accounting by contrasting it to single-entry and double-entry accounting:

- A **single-entry** is not much more than a glorified list.

- **Double-entry** is in essence posting a transaction to two different single-entry ledgers with different parties responsible for each ledger. When you use a double-entry ledger what the transaction represents has to be explained by reasoning, the two transactions logically go together. Removing or changing part of the transaction will make the transaction illogical. Double-entry allows for the detection of errors and the differentiation of an unintentional error from fraud.

- **Triple-entry** further builds on double-entry in that triple-entry links a transaction in two double-entry ledgers and the link is publicly available for all to see the transaction. You are still able to explain the reasoning behind the entry but additionally the transaction is visible for all to see which makes it very tough to lie since others are watching. It would be illogical for the transaction to not be reflected the same in both ledgers. Triple-entry accounting synchronizes the accounting records of both sides of a transaction making errors and fraud even harder to exist within an accounting system.

1.11. Smart contracts

A smart contract[16] is a computer program that is stored in a digital ledger[17]. A smart contract is digital. A smart contract is a program whose execution is autonomous and transparent; its execution cannot be reverted and it is not possible to modify the history of the program. One smart contract can interact with other smart contracts.

Smart contracts can be functional programs, declarative programs, logic programs, or other types of programs.

Another term for smart contracts is logical contracts[18].

A smart contract is defined as a contract that enforces itself. Where a regular contract is a piece of paper or PDF that contains text; a smart contract is a computer program that can be run on computer hardware which automatically executes those conditions.

A logical contract is a smart contract that has two pieces. First, you have declarative rules and facts. Second, you have a general piece of software than understands the declarative rules and facts.

A vending machine is an example of a smart contract. The vending machine is a contract. Bearers of coins can put the coins into the vending machine in exchange for the vending machine to give you what you have selected from the machine.

[16] Philippe, Camacho, *Introduction to Smart Contracts*, https://www.slideshare.net/philippecamacho/smart-contracts

[17] Youtube, *Smart contracts - Simply Explained*, https://www.youtube.com/watch?v=ZE2HxTmxfrI

[18] Logical Contracts, http://logicalcontracts.com/

Smart contracts and logical contracts are the application of the vending machine idea to lots of different things.

1.12. Real-time audit or continuous audit

A triple entry accounting system opens the possibility of the real-time audit[19] or the continuous audit. In their paper *Imagineering Audit 4.0*[20], Jun Dai and Miklos Vasarhelyi of Rutgers University provide a comprehensive description of how a real-time audit works including the diagram below:

Audit 4.0 of Inter-Business Parties
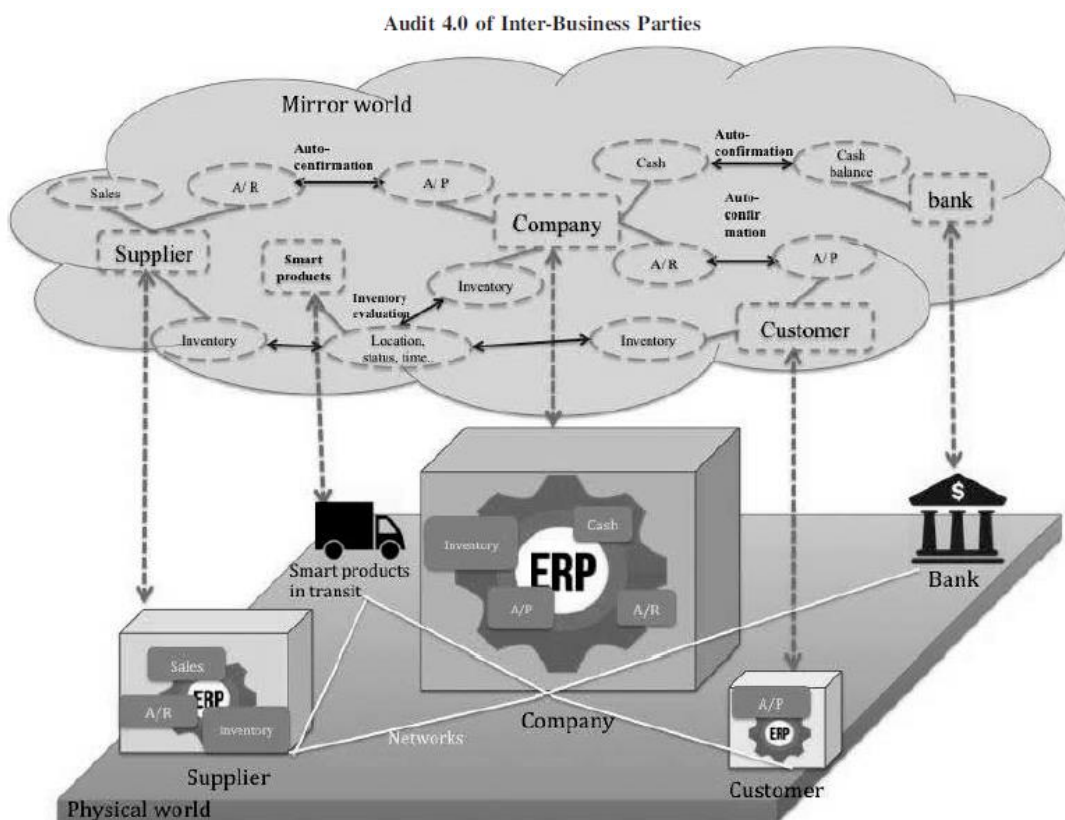
1.13. Use cases for digital distributed ledgers

What can digital distributed ledgers be used for[21]? This video mentions the following use cases:

- Regulatory records
- Delivery records
- Chain of custody

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[19] Francois Badenhorst, AccountingWeb, *Rise of the Real Time Audit*,
https://www.accountingweb.co.uk/practice/general-practice/rise-of-the-real-time-audit

[20] Jun Dai and Miklos Vasarhelyi, JOURNAL OF EMERGING TECHNOLOGIES IN ACCOUNTING, *Imagineering Audit 4.0*, http://aaajournals.org/doi/abs/10.2308/jeta-10494?code=aaan-site

[21] YouTube, *InterChainZ: Sharing Ledgers for Sharing Economies*,
https://www.youtube.com/watch?v=Hwhigpr4720

- Property titles
- Know your customer
- Digital rights management
- Loyalty management
- Motor insurance
- Proof of authenticity
- Account portability
- Anti-money laundering
- Peer-to-peer lending
- Personal insurance
- Corporate credit
- Trading records

There are likely many other uses for a digital distributed ledger.

1.14. Financial report as a transaction

Don't limit yourself by thinking that a "transaction" is an accounting transaction such as an invoice. While transactions can be recorded, so can events, circumstances, and other phenomenon that affect, say, a business during a period. That sounds a lot like the sort of information from a financial report. A report is a transaction. The "payload" of the transaction is the information in the report itself. XBRL-based digital general purpose financial reports, say to a regulator like the Securities and Exchange Commission, are really transactions that hold complex information structures about the financial condition and financial position of an economic entity.

What XBRL brings to the table is an ability to agree on and document the relations between the reported facts in the complex transactions we refer to as financial reports. But XBRL can also be used to make sure that smaller transactions that go into these ledgers adhere to agreed upon business rules. This keeps information within those digital distributed ledgers correct.

If digital distributed ledgers are used to their full potential, it could enable a fundamental shift in the way economic entities transact business with one another. How will this impact the role of accountants and auditors? Time will tell.

1.15. Impact of distributed ledgers on accounting

Hitendra Patil summarized 22 ways distributed ledger technology and blockchain will change the accounting profession[22]. While I do not agree with everything on the list, the list is worth considering:

1. Eventually, accounting firms will go away, just like bookstores.
2. An accountant will NOT become extinct. She will be just doing something (absolutely, totally) different (and surely more **valuable** work).

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[22] Hitendra Patil, CPA Trendlines, *22 Ways Blockchain Will Change the Accounting Profession Forever*, http://cpatrendlines.com/2017/07/03/22-ways-blockchain-will-impact-accounting-profession/

3. Auditors, rather the current way audit processes work, will go away too.

4. This is because "audit" will be easy and highly cost-effective with access to a public shared ledger.

5. A client will NOT provide information, data and documents to the accountant – ever.

6. Gone forever will be the days when a client sent a shoebox full of receipts to the accountant.

7. Client's accounts books, and the blockchains – the shared ledgers – will get created constantly and automatically, as and when transactions are taking place. Sometimes even before they happen!

8. Just like the doctors and nurses who monitor the patients' health, accountants will monitor financial health of clients, but online, in real time and almost always remotely.

9. Clients will NOT need to file tax returns. This is because the government will have the information already and the government will refund the extra taxes deducted from financial transactions. People won't be able to avoid or evade or pay fewer taxes than they owe – ever. So, people will NOT ask accountants to prepare tax returns. Instead, they will seek advice to "prepare for" optimized tax deductions.

10. Clients will NOT run out of cash to run their businesses – at least not fast. This is because banks will release cash automatically into their checking accounts when needed, as financing on their "preauthorized linked assets" will be created automatically, online, in real time.

11. Accountant will tell clients the precise time when they will lose those assets if the bank keeps putting cash into their checking account.

12. Clients can see the future of their business. Every day. Every minute. At the speed their business operates, their accountant will show them the balance sheet of future months and years.

13. If a client's business has started to go downhill, his accountant will tell him precisely how many days or months he has before he will lose everything.

14. If a client's business is on an upswing, she will know precisely when will it reach stagnation stage based on performance of her industry peers and as the impact of new technologies and regulations kicks in. In other words, her accountant will tell her how much time she has to create a new product or service to keep the upswing intact.

15. Clients will make and receive fewer payments. This is not because their business is slow but because vendors and customers will settle monetary transactions on net basis, not on gross basis – because everyone's accounts books will be networked.

16. Clients' books will tell them, automatically, who are their "currently good" customers who are likely to be bad ones in the near future, even when revenue from them is growing, as their books will be synced with their customers' books.

17. Client's books will also tell them, automatically, who are their "currently bad" customers who are likely to be good ones in the near future, even when

revenue from them is actually reducing, as their books will be synced with their customers' books.

18. Clients' books will tell them automatically which of their customers and vendors are likely to go out of business and by when, because their books will be networked. And of course, they too will know, online, in real time, if their accountant's business is doing well or bad.

19. Hold on! Clients' accounting is NOT going to be emotionless robotics. Just the data and information handling will be robotic. Clients will still have their accountants as their even more trusted advisor, in the flesh.

20. Clients WON'T have to make appointments with their accountants anymore. Clients can ask an accountant or a financial advisor – online or by phone, in real time – by picking the one they want from several out there. Clients won't even have to send any accounting data to them. Clients will just share it with accountants while the online session lasts.

21. Today's accountants will be tomorrow's business strategists and growth directors for their clients.

22. And yes, there will be NO fees to be paid for "accounting." Clients will pay their accountant only for use of her knowledge, experience and wisdom to help them navigate their business and financial situations.

While it is hard to say exactly which of these predictions will become reality and when; the list provides a clear understanding of the trajectory accounting, reporting, and auditing will take.

1.16. Implementing distributed ledgers

Key to implementing a distributed ledger appropriately is security[23]. But the security issues will be addressed. The following is a summary of additional resources that are helpful in understanding and implementing distributed ledgers:

- How does the blockchain work?

- Demystifying Blockchain and Distributed Ledger Technology – Hype or Hero?

- Mutual distributed ledgers

- Unblock the shared economy - Growing trust in mutual distributed ledgers – such as the Blockchain technology underlying Bitcoin – will change financial services for the better: Three page concise overview of what mutual distributed ledgers do.

- The Digital ledger landscape: This is a 70 slide presentation that provides a lot of details about distributed ledgers.

- InterChainZ: Sharing Ledgers for Sharing Economies: This is a 5 minute video that explains distributed ledgers.

- Crash Course on Mutual Distributed Ledgers (BlockChains):

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[23] European Union Agency for Network and Information Security, *Distributed Ledger Technology & Cybersecurity - Improving information security in the financial sector*, https://www.enisa.europa.eu/publications/blockchain-security

- [Rubix, and initiative by Deloitte](#): Part of Rubix appears to be "[blockchain as a service](#)".

- [How to Implement Block Chain and Distributed Insfrastructure in Financial Services](#): Blockchain's and distributed ledger technology's potential to make ledgers more transparent, trustworthy and efficient leads to suggestions that it can possibly revolutionize financial services. But applying the blockchain within each firm's context is complicated, and it is as yet unclear what business needs, if any, the blockchain will truly resolve. Ernst & Young explains the blockchain's potential to change financial services, explores possible applications and describes the issues worth considering when applying the technology.

- [Distributed Ledger Technologies](#)

- EY, [Blockchain reaction: Tech Plans for Critical Mass](#)

- Deloitte, [Blockchain technology. A game changer in accounting?](#)

- [A brief history of blockchain](#)

- [Hyperledger](#), an enterprise blockchain

- [Multichain](#), Open source private blockchain

- [How bitcoin will disrupt accounting and auditing](#)

- [The Truth about Blockchain](#), Harvard Business Review

- Journal of Accountancy, [Why CPAs need to get a grip on blockchain](#)

- CPA Trendlines, [22 ways Blockchain will Change the Accounting Profession Forever](#)

1.17. Blockchain versus Database

101 Blockchains provides this excellent comparison of a blockchain and a database which helps you understand the differences between and the pros and cons of each[24]:

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[24] 101 Blockchains, *Blockchain Vs Database: Understanding The Difference*, https://101blockchains.com/blockchain-vs-database-the-difference/
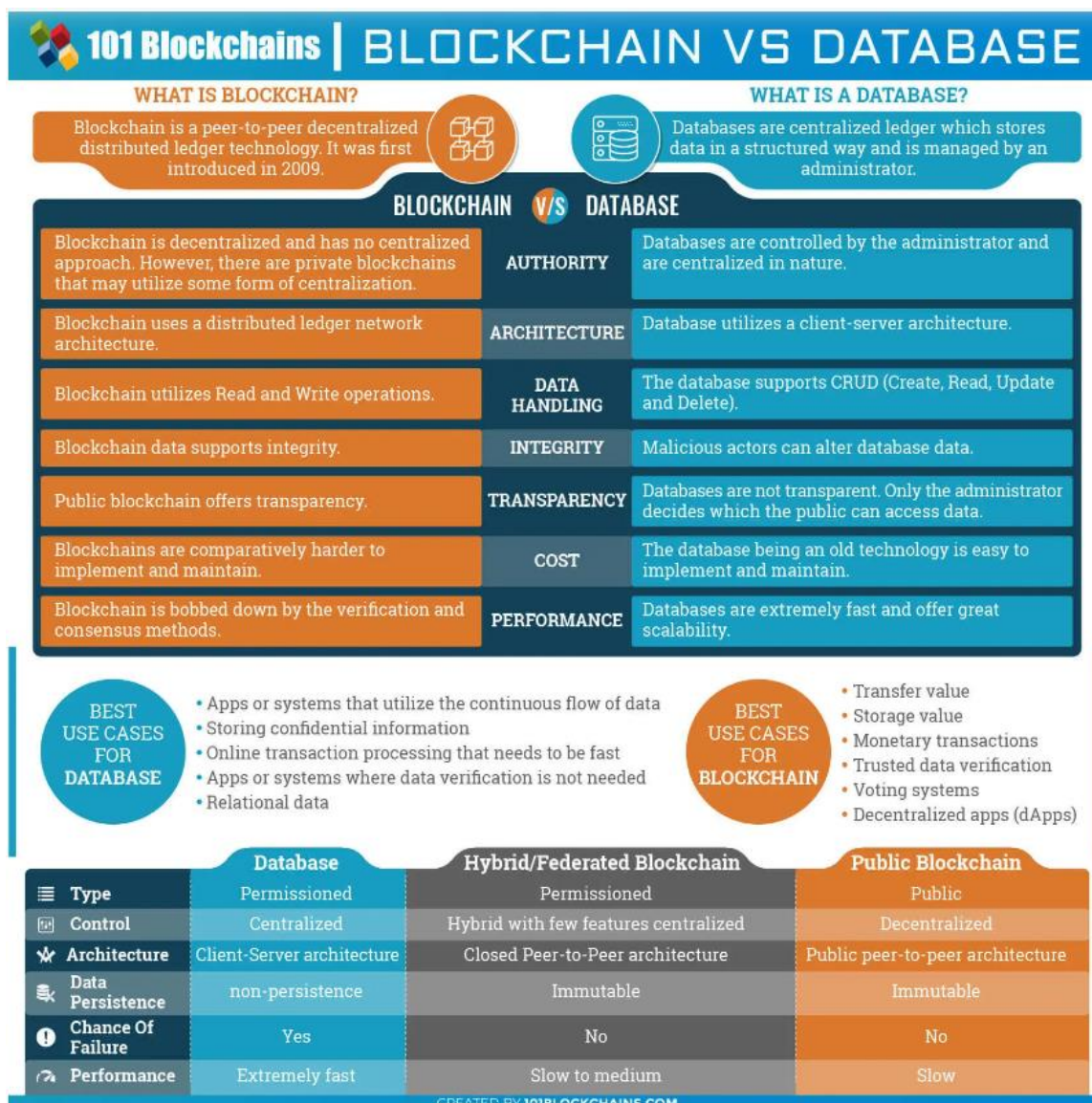
Basically, blockchains and databases are both tools. You want to use the right tool for the job.

1.18. Block chain is foundational, not disruptive

A Harvard Business Review article, *The Truth About Blockchain*, explains how this technology will be adopted[25]. The article states,

> True blockchain-led transformation of business and government, we believe, is still many years away. That's because blockchain is not a "disruptive" technology, which can attack a traditional business model with a lower-cost solution and overtake incumbent firms quickly. Blockchain is a foundational technology: It has the potential to create new foundations for our economic

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[25] Marco Iansiti and Karim R. Lakhani, Harvard Business Review, *The Truth About Blockchain*, https://hbr.org/2017/01/the-truth-about-blockchain

and social systems. But while the impact will be enormous, it will take decades for blockchain to seep into our economic and social infrastructure. The process of adoption will be gradual and steady, not sudden, as waves of technological and institutional change gain momentum. That insight and its strategic implications are what we'll explore in this article.

The HBR article goes on to explain how foundational technologies take hold. The article states that the adoption of foundational technologies typically happens in four phases. Each phase is defined by the novelty of the applications and the complexity of the coordination efforts needed to make them workable.

Applications low in novelty and complexity gain acceptance first. Applications high in novelty and complexity take decades to evolve but can transform the economy. TCP/IP technology, introduced on ARPAnet in 1972, has already reached the transformation phase, but blockchain applications are in their early days.

Blockchain could remake accounting[26]. The change might take time, but it will be a steady process.

1.19. Distributed Ledgers + Smart Contracts + XBRL

XBRL can serve as a payload for an entry into a distributed ledger[27]. Because XBRL is a database (XBRL instance), a declarative approach to representing logic (XBRL taxonomy schema, linkbases, and XBRL formula), and a run-time (XBRL processor, XBRL Formula processor); XBRL offers an entire global standard ecosystem for working within the blockchain.

1.20. Non-fungible Tokens (NFTs)

NFTs (non-fungible tokens[28]) are all the rage these days; but understanding exactly what an NFT is can be challenging. This article, *7 Things You Should Know about NFTs*[29], is a good place to start learning about NFTs. Another moving piece of the NFT puzzle is staking[30]. I am still trying to get my head around staking.

Understanding NFTs is easier when you understand the characteristics of an NFT. This article, What Are NTFs and How Do They Work[31] points out these characteristics:

- **Non-interoperable**: NFTs are unique and unlike fungible tokens which are all the same basically and any one is just as good as any other; NFTs are not interchangeable.

- **Indivisible**: NFTs cannot be divided into smaller denominations.

- **Indestructible**: NFTs are stored on the blockchain and can never be destroyed.

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[26] Tom Hood, YouTube.com, *Blockchain Might Remake Accounting - Tom Hood Discusses Big Data and Blockchain Technology*, https://www.youtube.com/watch?v=mdbO7ZSc4B4

[27] Digital Distributed Ledgers + Smart Contracts + XBRL,
http://xbrlsite.azurewebsites.net/2018/Library/DistributedLedgersSmartContractsXBRL.pdf

[28] YouTube, NFTs, https://youtu.be/X_AugmQpwho

[29] *7 Things You Should Know about NFTs*, https://academy.binance.com/en/articles/7-things-you-should-know-about-nfts

[30] *Staking Cryptocurrencies*, http://xbrl.squarespace.com/journal/2021/5/9/staking-cryptocurrencies.html

[31] *What Are NTFs and How Do They Work*, https://www.coindesk.com/what-are-nfts

- **Verifiable**: Because NFTs exist on a blockchain they can be traced back to the original creator.

This video, *Could Enjin SUPERCHARGE Gaming NFTs?!*[32] (at minute 6:50) points out three aspects of determining value of an asset:

- **Rarity**: How scarce is it?

- **Provenance**: Where did it come from?

- **Quality/Utility**: How good is the asset or how good does the asset serve your specific needs?

Machine-readable metadata can be turned into an NFT. What is an example of machine-readable metadata? All the rules that I have created for US GAAP and IFRS can be turned into NFTs. Why? Because the rules are useful in verifying an XBRL-based financial report has been correctly created.

The document *Top 30 NFT Uses Cases for Enterprises*[33], published by Rejolut has excellent information about NFTs.

1.21. Prototype Blockchain

I created a prototype blockchain that helps you understand how blockchains work[34]. It is not a real blockchain but it can help understand how a blockchain can be used to create an immutable digital ledger.

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[32] *Could Enjin SUPERCHARGE Gaming NFTs?!,* https://youtu.be/4ozLTBG83eE?t=410

[33] Rejolut, Top 30 Use Cases for Enterprises, https://rejolut.com/wp-content/uploads/2022/10/Top-30-NFT-Use-Cases-For-Enterprises-compressed_1.pdf

[34] Blockchain prototype, http://xbrlsite-app.azurewebsites.net/io/blocks/0x139be5ba59184c2a9871feb0fc28f112b946de44e9914b1198bfd942553ed92e.html

1.22. Auditchain

Auditchain[35] is a decentralized continuous audit and reporting protocol ecosystem that is built using blockchain technology. To understand more about Auditchain, read the white paper they provide.

Auditchain has an interesting graphic that puts NFTs at the center of modern accounting:

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[35] Auditchain, https://auditchain.com/

The following is a prototype interface that Auditchain provides for verifying a report and the assurance level provided for the verified report: