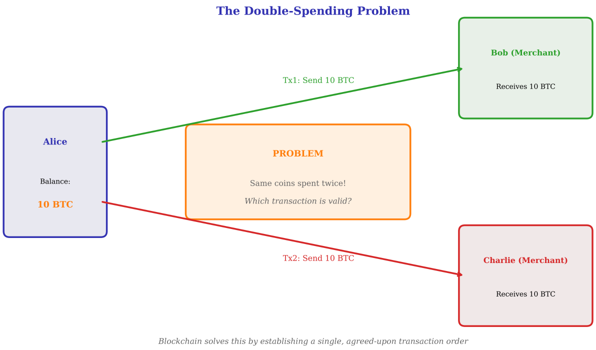
Lesson 13: What is Blockchain?

Module 2: Blockchain and Cryptocurrencies

Digital Finance

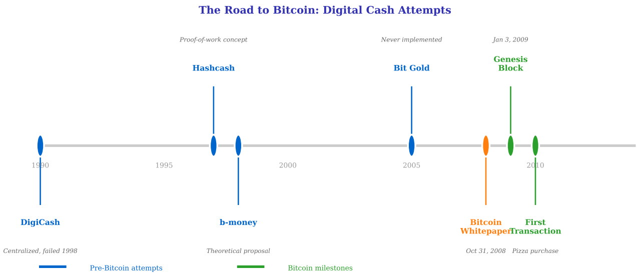
December 13, 2025

The Trust Problem in Digital Transactions



Digital transactions require trust mechanisms—blockchain removes the need for intermediaries.

The Evolution of Digital Cash



Understanding history helps predict future developments in the technology.

Satoshi Nakamoto's Breakthrough (October 2008)

Bitcoin Whitepaper:

- "Bitcoin: A Peer-to-Peer Electronic Cash System"
- 9 pages, published on cryptography mailing list
- Combined existing cryptographic primitives in novel way
- Genesis block mined January 3, 2009

Core Innovations:

- Proof-of-Work consensus
- Decentralized timestamp server
- Longest chain rule
- Economic incentives (mining rewards)

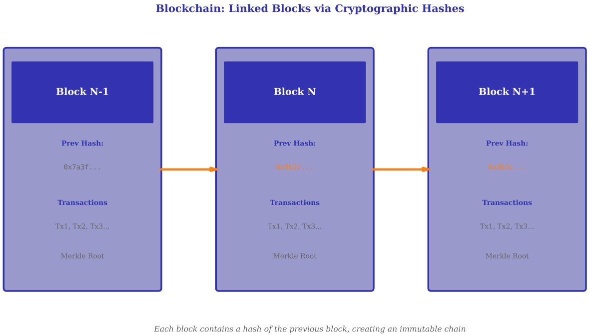
Mystery Identity:

- Unknown person/group
- Disappeared April 2011
- Owns 1M BTC (never moved)
- Multiple theories, no proof

Genesis block message:
"The Times 03/Jan/2009
Chancellor on brink of
second bailout for banks"

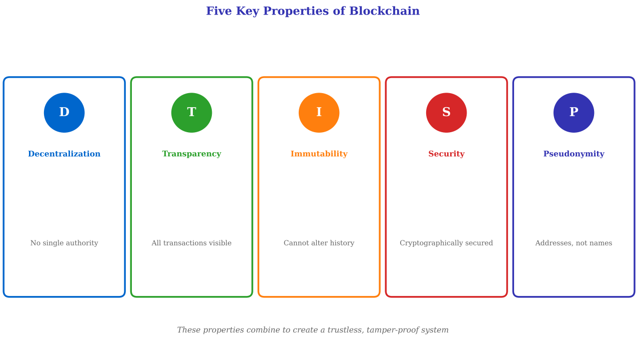
Bitcoin combined existing cryptographic primitives in a novel way to solve double-spending.

What is a Blockchain? Core Definition



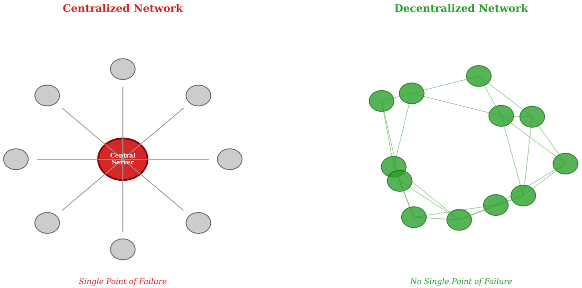
Blockchain: a chain of cryptographically linked blocks forming an immutable ledger.

Blockchain Properties



These five properties distinguish blockchain from traditional databases.

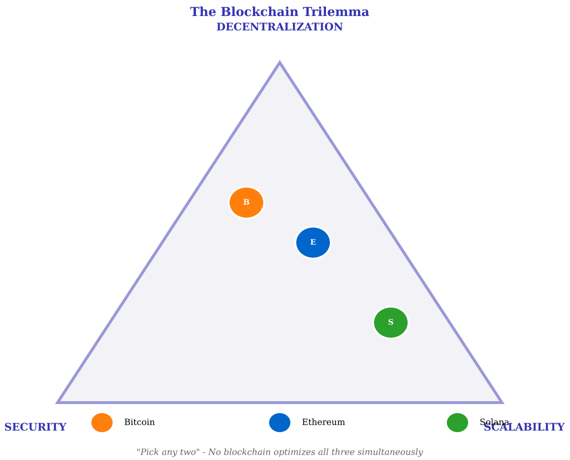
Centralized vs Decentralized Systems



Blockchain uses decentralized architecture for resilience and censorship resistance

Centralized systems trade trust for efficiency; decentralized systems trade efficiency for trustlessness.

The Blockchain Trilemma



The blockchain trilemma forces trade-offs between decentralization, security, and scalability.

How Blockchain Works: Simplified Flow

Transaction Lifecycle (6 Steps):

1. **Initiation:** User broadcasts transaction to network
2. **Validation:** Nodes verify signature and sufficient balance
3. **Mempool:** Valid transactions wait in memory pool
4. **Block Creation:** Miner/validator selects transactions for new block
5. **Consensus:** Network agrees on new block (PoW/PoS)
6. **Finalization:** Block added to chain, transaction confirmed

Typical Confirmation Times:

- Bitcoin: 10 minutes per block (6 blocks for finality = 1 hour)
- Ethereum: 12 seconds per block (32 blocks for finality = 6-7 minutes)
- Solana: 400ms per block (instant practical finality)

Understanding the process flow is key to identifying optimization opportunities.

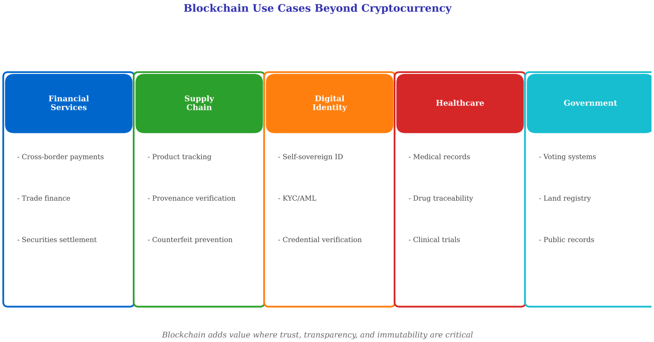
Public vs Private Blockchains

Feature	Public (Permissionless)	Private (Permissioned)
Access	Anyone can join	Invited participants only
Validators	Anyone can become validator	Pre-approved validators
Transparency	Fully transparent	Controlled visibility
Speed	Slower (global consensus)	Faster (known validators)
Energy	High (PoW) or Medium (PoS)	Low (simple consensus)
Use Cases	Cryptocurrencies, DeFi	Enterprise, supply chain
Examples	Bitcoin, Ethereum	Hyperledger, R3 Corda
Trust Model	Trustless	Trust in consortium

Hybrid Models: Some networks (e.g., VeChain) combine public chain with private enterprise features

Public and private blockchains serve different use cases with different trust models.

Blockchain Use Cases Beyond Cryptocurrency



Real-world applications demonstrate the practical value of blockchain technology.

Real-World Example: Walmart Food Traceability

Problem: 2018 E. coli outbreak in romaine lettuce took weeks to trace source

Solution: Walmart + IBM Food Trust (Hyperledger Fabric)

Before Blockchain:

- Manual record keeping
- 7 days to trace mango origin
- Paper-based documentation
- Information silos
- Difficult recalls

After Blockchain:

- Digital immutable records
- 2.2 seconds to trace origin
- Real-time visibility
- Shared data access
- Precise, fast recalls

Impact: Reduced food waste, improved consumer safety, lower liability costs

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Case studies provide concrete evidence of technology impact and adoption patterns.

Limitations and Challenges

Technical Limitations:

- Scalability: Low TPS vs Visa (24,000 TPS)
- Energy: Bitcoin uses 150 TWh/year
- Storage: Bitcoin blockchain ¿ 500 GB
- Finality: Long confirmation times
- Irreversibility: No undo for mistakes

Adoption Barriers:

- Regulatory uncertainty
- User experience complexity
- Integration with legacy systems
- Lack of interoperability
- Environmental concerns (PoW)
- Volatility (for crypto)

Key Insight: Blockchain is not a universal solution - use only when decentralization and immutability are critical requirements

Understanding limitations helps identify appropriate use cases and avoid over-engineering.

Blockchain vs Traditional Database

When to Use Blockchain vs Traditional Database

Aspect	Traditional DB	Blockchain
Control	Centralized	Distributed
Trust	Trust the admin	Trustless
Performance	1000s TPS	10-1000 TPS
Data modification	CRUD operations	Append-only
Transparency	Private by default	Public by default
Cost	Lower	Higher

Use Traditional Database when:

Single org, high performance, privacy needed

Use Blockchain when:

Multiple parties, trust issues, auditability

Use blockchain ONLY if multiple parties need shared write access without mutual trust.

The Hype Cycle: Where Are We?

Gartner Hype Cycle for Blockchain (2015-2024):

- **2015-2017:** Peak of Inflated Expectations - "Blockchain will change everything"
- **2018-2020:** Trough of Disillusionment - ICO crash, failed enterprise pilots
- **2021-2022:** Slope of Enlightenment - Real use cases emerge (DeFi, NFTs, CBDCs)
- **2023-2024:** Plateau of Productivity - Mature applications in specific domains

Current Reality (2024):

- Cryptocurrencies: Established asset class (total market cap $2T)
- DeFi: $50B+ total value locked, real financial infrastructure
- Enterprise: Selective adoption where justified (supply chain, trade finance)
- CBDCs: 130+ countries exploring, 11 launched (e.g., Nigeria eNaira, Bahamas Sand Dollar)

Technology adoption follows predictable patterns—timing matters for investment decisions.

Bitcoin Network Statistics (2024)

Network Metrics:

- **Hash Rate:** 600 EH/s
- **Active Addresses:** 1M/day
- **Transactions:** 400k/day
- **Block Size:** 1-2 MB average
- **Nodes:** 17,000 reachable
- **Mining Difficulty:** Adjusts every 2016 blocks

Next halving: April 2024 (reward drops to 3.125 BTC)

Economic Metrics:

- **Market Cap:** $850B
- **Circulating Supply:** 19.5M BTC
- **Max Supply:** 21M (hard cap)
- **Block Reward:** 6.25 BTC (halves every 4 years)
- **Fees:** $2-50 per transaction
- **Energy:** 150 TWh/year (0.5% global)

Network metrics provide objective measures of adoption and ecosystem health.

Ethereum Network Statistics (2024)

Post-Merge Metrics:

- **Consensus:** Proof-of-Stake (Sept 2022)
- **Validators:** 950,000
- **Staked ETH:** 32M (27% of supply)
- **Transactions:** 1.2M/day
- **Smart Contracts:** 50M deployed
- **Energy:** 99.95% reduction vs PoW

DeFi Ecosystem:

- **TVL:** $25B
- **DEX Volume:** $50B/month
- **NFT Sales:** $500M/month
- **Gas Fees:** $1-20 (varies)
- **ERC-20 Tokens:** 500k
- **Layer 2 Adoption:** Growing (Arbitrum, Optimism)

EIP-4844 (Proto-Danksharding) expected 2024 - major scalability upgrade

Network metrics provide objective measures of adoption and ecosystem health.

Key Terminology Summary

Block: Batch of transactions
Blockchain: Chain of cryptographically linked blocks
Node: Computer maintaining blockchain copy
Miner: Node creating new blocks (PoW)
Validator: Node validating blocks (PoS)
Consensus: Agreement mechanism
Hash: Cryptographic fingerprint
Nonce: Number used once (PoW)
Difficulty: Mining puzzle hardness

Mempool: Pending transactions pool
UTXO: Unspent transaction output
Gas: Transaction fee unit (Ethereum)
Smart Contract: Self-executing code
DeFi: Decentralized finance
Layer 1: Base blockchain
Layer 2: Scaling solution on top
Fork: Protocol rule change
51% Attack: Majority control threat

Lesson 14: Blocks and Cryptographic Hashing

What We'll Cover:

- Block structure and anatomy
- SHA-256 hash function in depth
- Avalanche effect demonstration
- Hash pointers and Merkle trees
- Why blockchain is immutable
- Practical examples and calculations

Prepare:

- Review basic binary and hexadecimal notation
- Understand exponential growth (important for hash space)
- Install Bitcoin Core or blockchain explorer for hands-on exploration

Summary: Key Takeaways

1. **Trust Problem:** Blockchain solves double-spending without intermediaries
2. **Satoshi's Innovation:** Combined existing cryptography with economic incentives
3. **Core Properties:** Decentralization, transparency, immutability, security
4. **Trilemma:** Cannot maximize decentralization, security, and scalability simultaneously
5. **Not a Panacea:** Use only when multiple parties need shared, tamper-proof records
6. **Real Adoption:** Cryptocurrencies, DeFi, supply chain, identity - but still early stage
7. **Public vs Private:** Different trust models and use cases
8. **Evolution:** From hype (2017) to practical applications (2024)

"Blockchain is a solution looking for the right problems - choose wisely."