

Competing Chains: What Happens When the Blockchain Forks

A Visual Guide to Fork Resolution in Distributed Networks

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BSc Blockchain, Crypto Economy & NFTs

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By the end of this lecture, you will be able to:

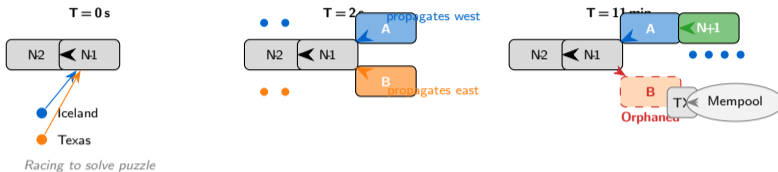
1. Trace a fork's lifecycle from creation through resolution using visual diagrams
2. Explain how individual nodes perform a chain reorganization (reorg)
3. Describe what happens to a user's transaction when the block containing it is orphaned

No prerequisites beyond basic blockchain structure (blocks, hashes, mining).

This lecture focuses on natural (accidental) forks — not hard forks or protocol upgrades

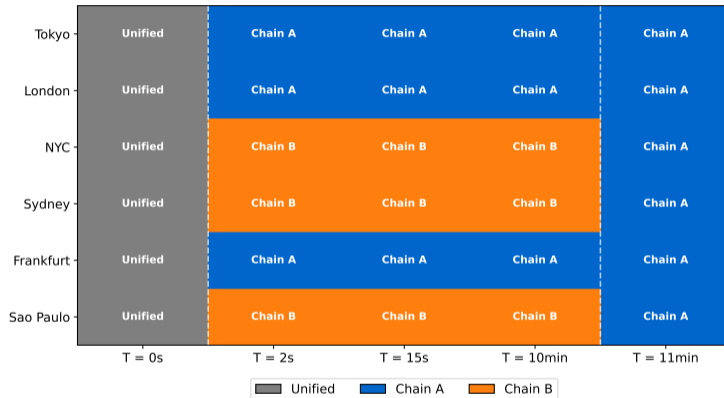
A Fork Is Born: Three Snapshots in Time

Two miners find valid blocks within seconds of each other. Here is what happens next, in three panels.



The entire process takes ~10–20 minutes. No votes, no leaders — just one rule applied independently.

What Each Node Sees During a Fork



- **What you see:** 6 nodes in different cities, each independently choosing which chain to follow based on which block arrived first
- **Key pattern:** The network is temporarily partitioned — both sides believe they have the correct chain
- **Takeaway:** No node is wrong. Every node follows the same rule. Convergence happens when new information (Block N+1) arrives

Each node acts independently — consensus emerges from identical rules, not communication

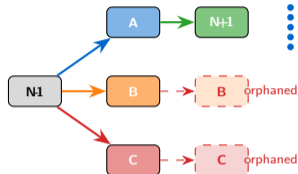
Reorganization: How a Node Switches Chains

When a node discovers a chain with more cumulative work, it performs a **reorganization** (reorg) — an automatic chain switch. The winning branch becomes the **canonical chain** (the single agreed-upon history).



A reorg is automatic and instant. The node does not ask permission — it follows the rule.

Three Competing Chains? Same Rule, Same Outcome

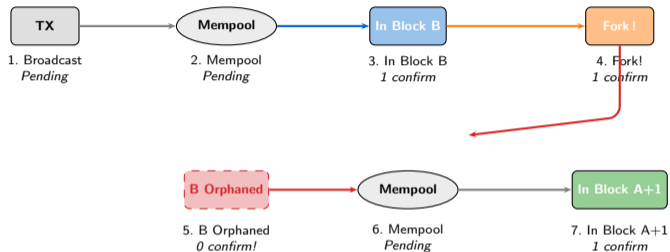


- Three-way forks are theoretically possible but extremely rare in practice
- The rule does not change: **most cumulative work wins**
- Even with 10 competing chains, resolution takes at most 2–3 extra blocks (~20–30 minutes)
- **Example:** If 3 miners find blocks within 2 seconds, the network splits 3 ways temporarily. The first branch to get Block N+1 wins.

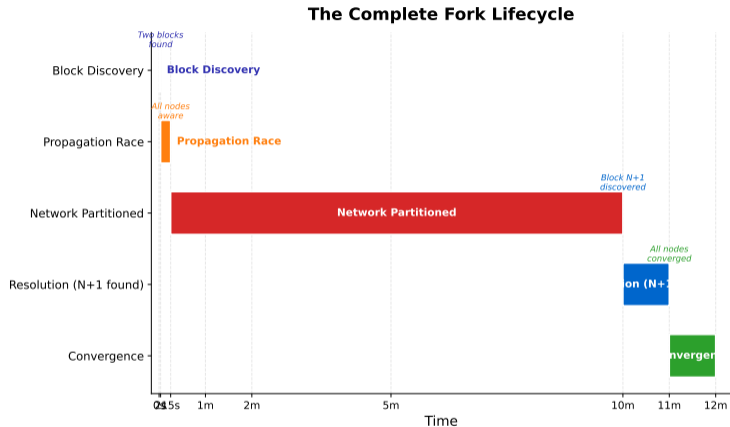
The chain selection rule works for any number of competing chains — it always converges

Your Transaction's Journey Through a Fork

Follow Alice's 1 BTC payment to Bob through a fork event.



Alice's transaction is never lost — it returns to the mempool and is re-confirmed within 1–2 blocks

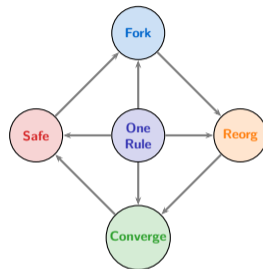


- **What you see:** The complete lifecycle of a natural fork from block discovery to network convergence
- **Key pattern:** The partition phase (~10 minutes) dominates — most time is spent waiting for the next block
- **Takeaway:** Total fork duration is ~10–20 minutes. The network has no downtime — both chains process transactions

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Core Ideas

1. **Forks are a feature, not a bug** — temporary disagreement is the expected cost of decentralization
2. **Every node follows one rule** — build on the chain with the most cumulative work to establish a single canonical chain. No voting, no leader.
3. **Reorgs are automatic** — nodes switch chains instantly when they discover more work elsewhere
4. **Your transactions are safe** — orphaned block transactions return to the mempool and are re-included within 1–2 blocks



Fork resolution is emergent — individual rules produce collective agreement

Reorg Mechanics

- Bitcoin Core implements reorgs in `validation.cpp`
- `ConnectBlock()`: validates and applies a new block to the chain tip
- `DisconnectBlock()`: reverses a block's effects (rolls back UTXO set changes)
- During a reorg, the node calls `DisconnectBlock()` for each block on the losing branch, then `ConnectBlock()` for each block on the winning branch

Key Numbers

Metric	Value
Natural fork frequency	~1–2 per week
Avg. resolution time	~10–20 min
Orphan rate	~0.1–0.5% of blocks
Largest accidental fork	24 blocks (Mar 2013)
Cost per orphaned block	~\$320K (3.125 BTC)



Reference: Bitcoin Core source, `validation.cpp` — `ConnectBlock()` and `DisconnectBlock()`

Quiz — Part 1 (Q1–Q5)

Q1. *[Understand]* What happens when two miners find valid blocks at the same height?

- A) The newer block is rejected B) Both blocks are valid; the network temporarily forks C) Nodes vote on which block to keep D) The block with more transactions wins

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Answer: B – Both blocks satisfy the difficulty target; the network must resolve the fork via the chain selection rule.

Q2. *[Understand]* During a fork, what determines which chain nodes follow?

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Answer: C – Nodes follow the heaviest chain (most cumulative proof-of-work), not the longest or earliest.

Q3. *[Apply]* A node currently follows Chain B. It receives Chain A, which has more cumulative work. What does the node do?

- A) Ignore Chain A and continue on Chain B B) Wait for other nodes to switch first C) Ask a central server which chain is correct D) Automatically switch to Chain A and return Chain B's transactions to the mempool

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Answer: D – The node performs an automatic reorganization: disconnect B, connect A, recycle B's transactions.

Q4. [Understand] What is a blockchain reorganization (reorg)?

- A) A planned upgrade to the blockchain software B) A node switching from a lighter chain to a heavier chain after discovering more cumulative work C) Miners voting to change the block reward D) Reorganizing transactions within a single block

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Answer: B – A reorg is the automatic process of abandoning a lighter branch in favour of a heavier one.

Q5. [Apply] Alice sends 1 BTC to Bob. The transaction is included in Block B, which is later orphaned. What happens to Alice's transaction?

- A) The 1 BTC is permanently lost B) Alice must resend the transaction manually C) The transaction returns to the mempool and is typically re-included in the next block D) Bob receives the BTC despite the orphan

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Answer: C – Transactions from orphaned blocks are recycled into the mempool and re-mined.

Quiz — Part 2 (Q6–Q10)

Q6. *[Analyze]* Three miners find valid blocks A, B, and C within 2 seconds. How does the network resolve this three-way fork?

- A) The oldest block wins automatically
- B) Nodes vote among the three candidates
- C) The first branch to get extended with a new block wins; the other two are orphaned
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Q7. *[Understand]* Why do forks occur more frequently when block intervals are shorter?

A) Shorter intervals use weaker cryptography B) Shorter intervals mean blocks are smaller and propagate faster C) Block propagation time becomes a larger fraction of the interval, increasing the chance of simultaneous discovery D) Miners collude more often with faster blocks

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Q8. *[Analyze]* A merchant accepts a payment with 1 confirmation. During a fork, that confirmation is lost. How many confirmations does the merchant now have?

A) Still 1 — confirmations cannot be lost B) 0 — the transaction dropped back to unconfirmed status C) –1 — the transaction is penalized D) The transaction is permanently cancelled

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Answer: B – A reorg can remove confirmations. The transaction returns to unconfirmed (0 confirmations).

Q9. [Apply] Node X is in Tokyo and Node Y is in New York. Miner A in Iceland and Miner B in Brazil find blocks simultaneously. Which node likely sees which block first?

- A) Both nodes see both blocks at the same time
- B) Node X likely sees Miner A's block first (closer); Node Y likely sees Miner B's block first (closer)
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Answer: B – Network latency and geographic proximity determine which block each node receives first.

Q10. *[Evaluate]* Bitcoin has a 10-minute block interval and $\sim 0.3\%$ fork rate. A hypothetical blockchain with 1-second blocks would have what fork rate?

- A) Also $\sim 0.3\%$ — fork rate is independent of block time B) Much higher — propagation delay becomes a huge fraction of the block interval C) Lower — faster blocks mean faster resolution D) Exactly 3% — fork rate scales linearly with block interval

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