



# Build a Decentralized Network

FinTech

Lesson 18.3



# Class Objectives

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



Describe the components of a blockchain system and how they combine to form a network.



Articulate the role that the proof of work consensus mechanism plays in keeping the blockchain network synchronized.



Explain how a difficulty factor influences the proof of work algorithm challenge.



Integrate a proof of work consensus mechanism into the PyChain blockchain.



Explain why the validation process is important to the integrity of a blockchain.

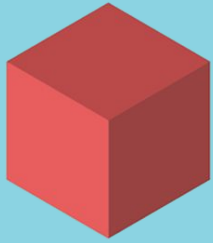


Validate an entire blockchain by comparing the hash values between blocks.

# Decentralized Systems

# Decentralized Systems

In the first two lessons, Python was used to build a basic blockchain that can securely store financial or other data records.



**First Block  
Distributed Ledger**

	A	B	C	D
1	XC14ADF	T45W46	A563537	D546563

**Second Block  
Distributed Ledger**

	A	B	C	D
1	XC14ADF	T45W46	A563537	D546563
2	N579689	J788567	Q4W4W6	6785795

**Third Block  
Distributed Ledger**

	A	B	C	D
1	XC14ADF	T45W46	A563537	D546563
2	N579689	J788567	Q4W4W6	6785795
3	SFG5354	7578576	GHD784	L787656

**Fourth Block  
Distributed Ledger**

	A	B	C	D
1	XC14ADF	T45W46	A563537	D546563
2	N579689	J788567	Q4W4W6	6785795
3	SFG5354	7578576	GHD784	L787656
4	SHG8757	GHDG746	5664QR6	ADFAFDA

# Decentralized Systems

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Considerations when opening the blockchain:

01

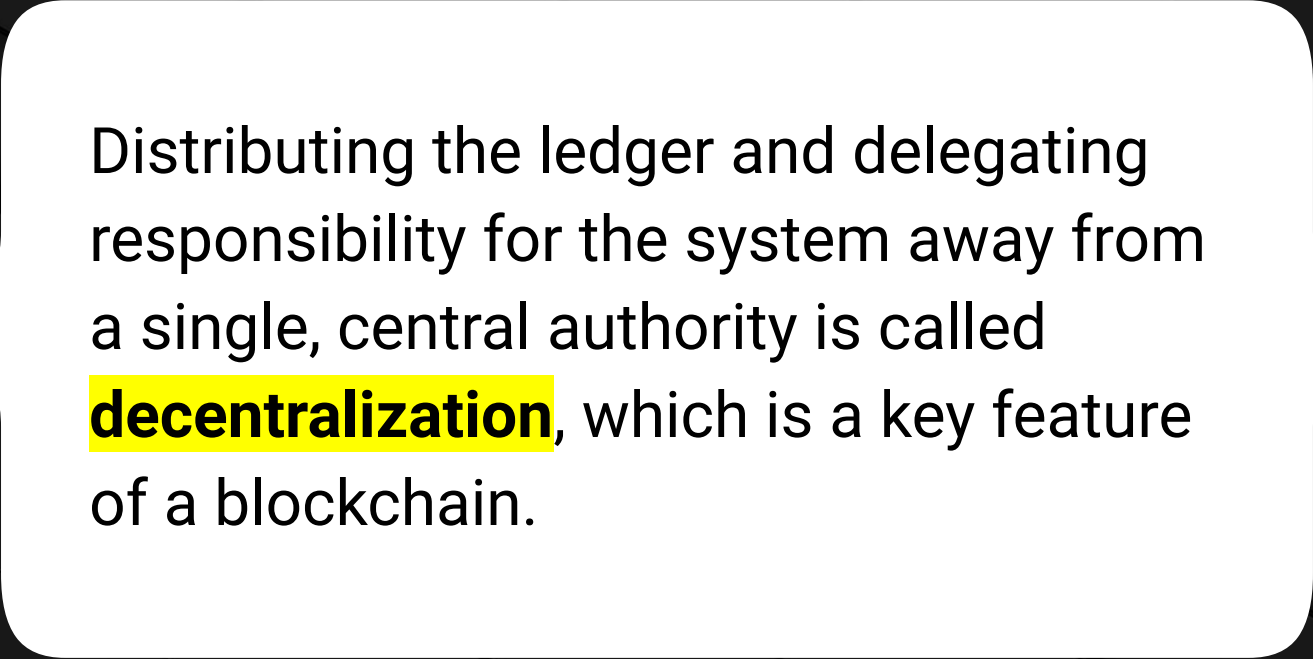
How should the system be shared?

02

Who should become the central authority over the system and its processes?

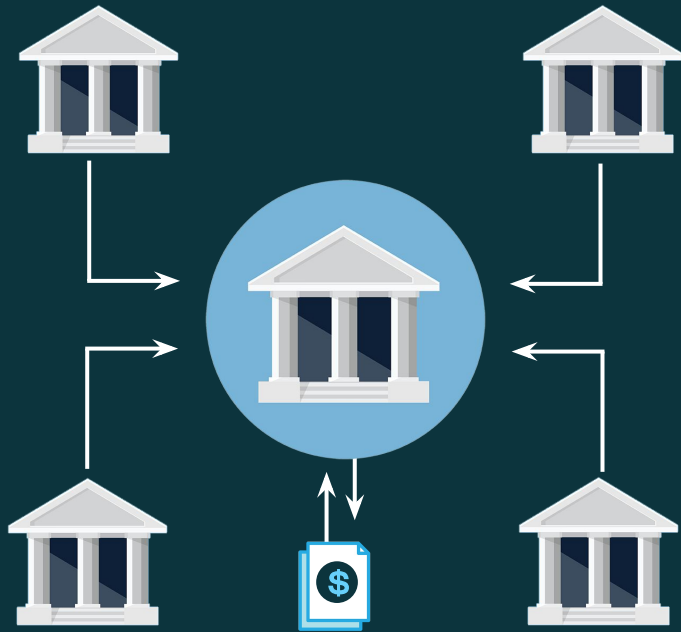
03

Should a central authority monitor the system in order to ensure the legitimacy of all the transactions? Or, should responsibilities for the ledger be distributed among all of its participants?

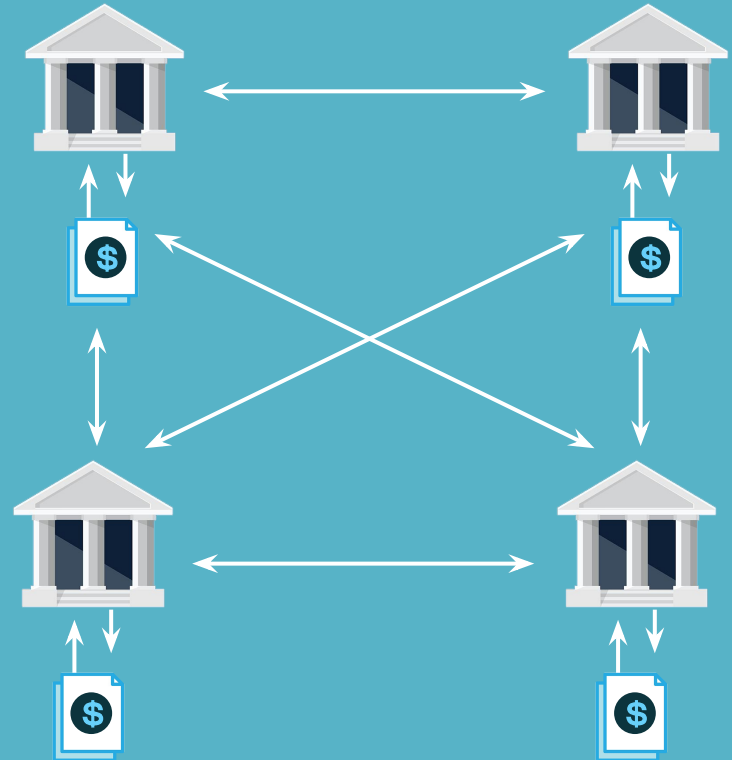


Distributing the ledger and delegating responsibility for the system away from a single, central authority is called **decentralization**, which is a key feature of a blockchain.

In a **centralized** system, a central authority monitors and audits transactions in order to protect the system from fraud and other problems.

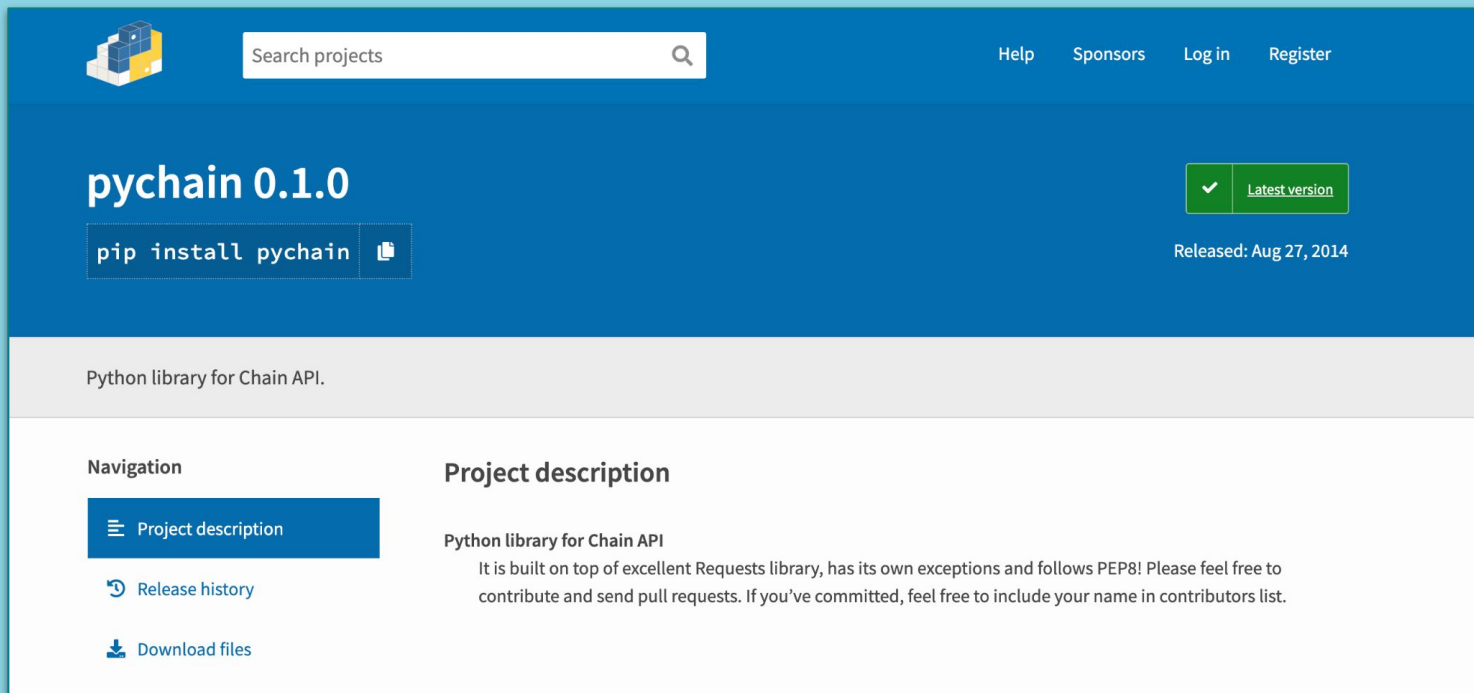


In a **decentralized** blockchain system, no single entity bears the responsibility of monitoring the system. Instead, rules that govern and protect the system are built into the blockchain functionality.



# Decentralized Systems

We'll enhance our PyChain by adding an algorithm that allows decentralized participants to agree on recorded transactions across the entire system.



The screenshot shows the PyChain project page on the Python Package Index (PyPI). The header is blue with the PyChain logo (a stack of blocks) on the left, a search bar in the center, and links for Help, Sponsors, Log in, and Register on the right. The main content area has a blue background. On the left, the text 'pychain 0.1.0' is displayed in large white font. Below it is a button with the text 'pip install pychain' and a document icon. On the right, there is a green checkmark icon and a button labeled 'Latest version'. Below these, it says 'Released: Aug 27, 2014'. A light gray banner below the main header contains the text 'Python library for Chain API.' The bottom section is white and divided into two columns. The left column is titled 'Navigation' and contains three links: 'Project description' (highlighted with a blue background), 'Release history', and 'Download files'. The right column is titled 'Project description' and contains the text 'Python library for Chain API' followed by a paragraph: 'It is built on top of excellent Requests library, has its own exceptions and follows PEP8! Please feel free to contribute and send pull requests. If you've committed, feel free to include your name in contributors list.'

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**pychain 0.1.0**

✓ Latest version

Released: Aug 27, 2014

`pip install pychain`

Python library for Chain API.

**Navigation**

- Project description
- Release history
- Download files

**Project description**

Python library for Chain API

It is built on top of excellent Requests library, has its own exceptions and follows PEP8! Please feel free to contribute and send pull requests. If you've committed, feel free to include your name in contributors list.



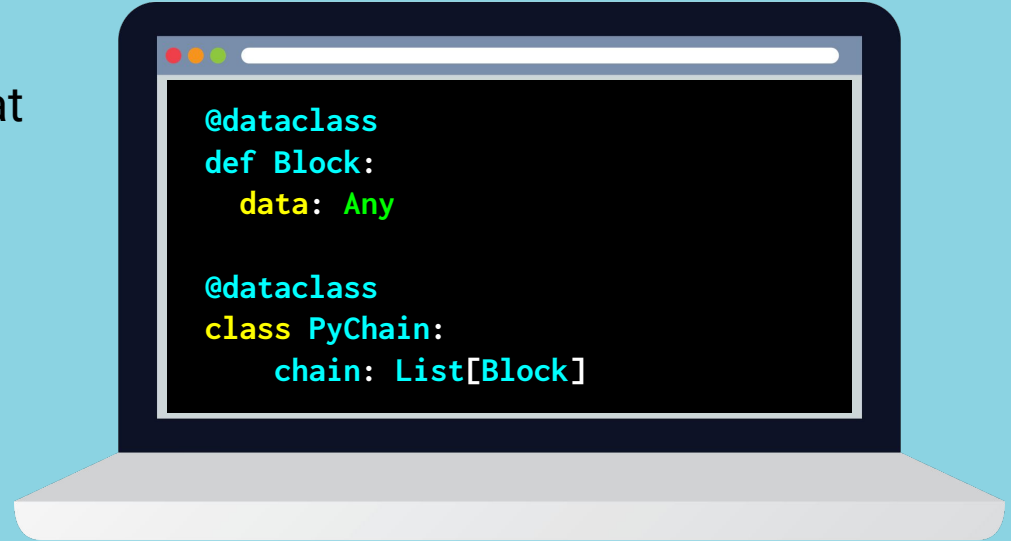
# Components of a Blockchain System

# Blockchain Nodes

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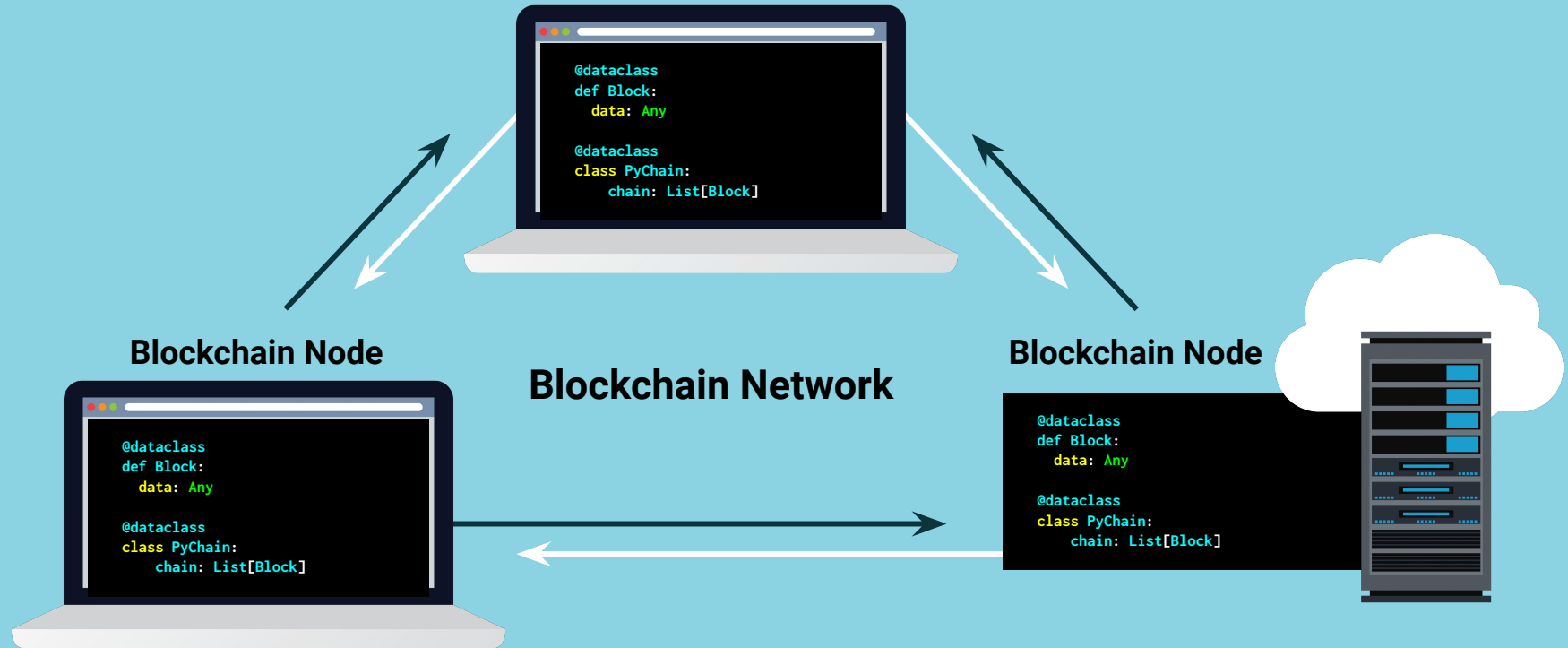
Software, like a Python program, can be used to digitally record data and store it in chained blocks.

In blockchain systems, a device that runs this software—that is, the device that a participant uses to access and add data to the blockchain—is called a node.



# Blockchain Nodes

Each node is likely a laptop or desktop computer, but it can also be a server in the cloud.



# Blockchain Nodes

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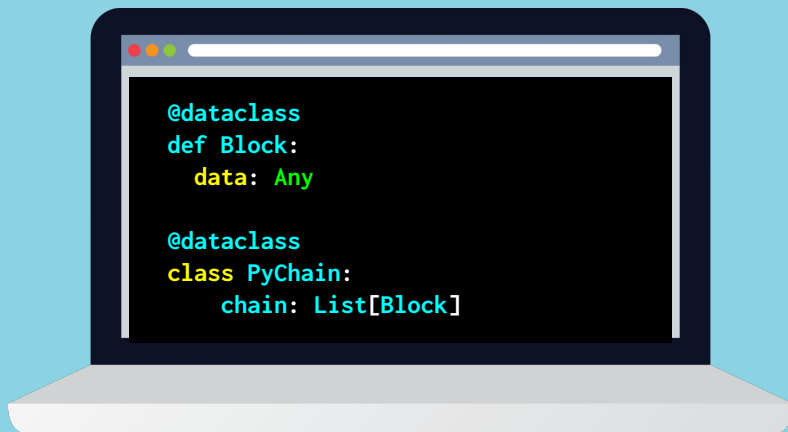
Each blockchain node has two primary responsibilities:

01

Storing a complete copy of the blockchain.

02

Running the software that establishes the communication and operation of the system.



# Single-Node System

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In a single-node system, the blockchain software is designed to allow users to store and access records through the command line or web application.

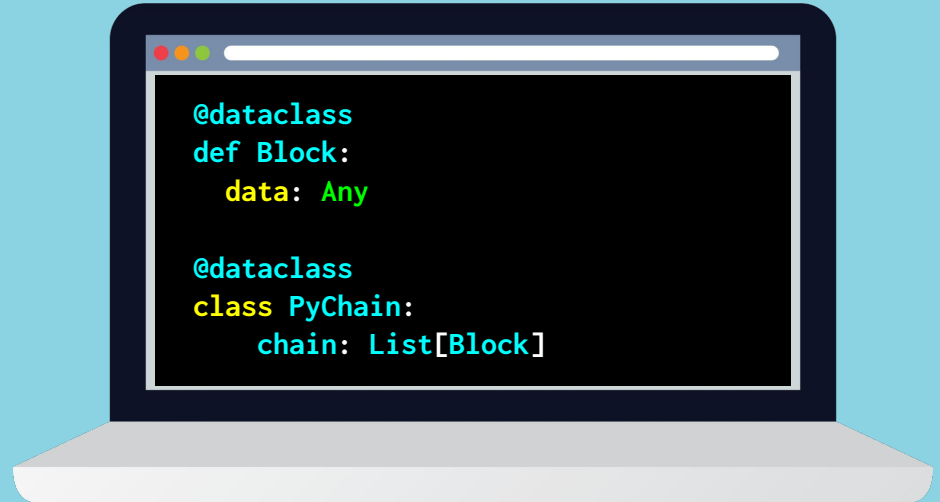
Examples:

01

A Python program

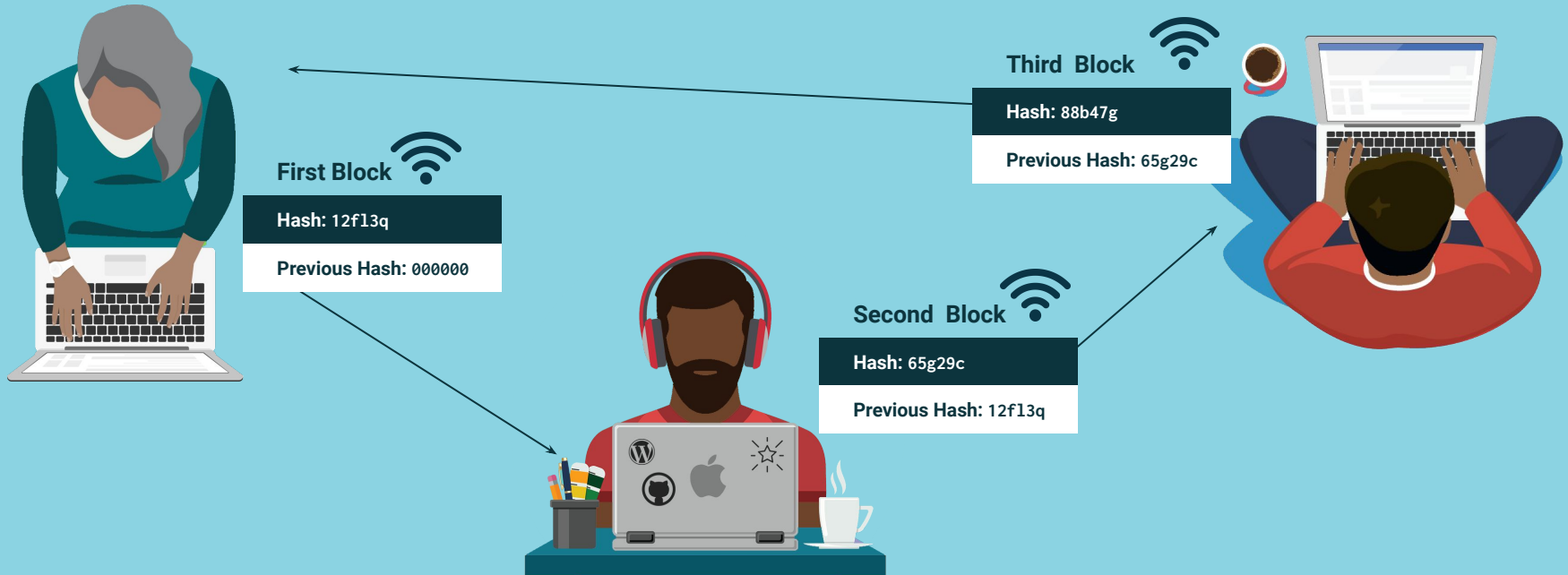
02

A Streamlit application



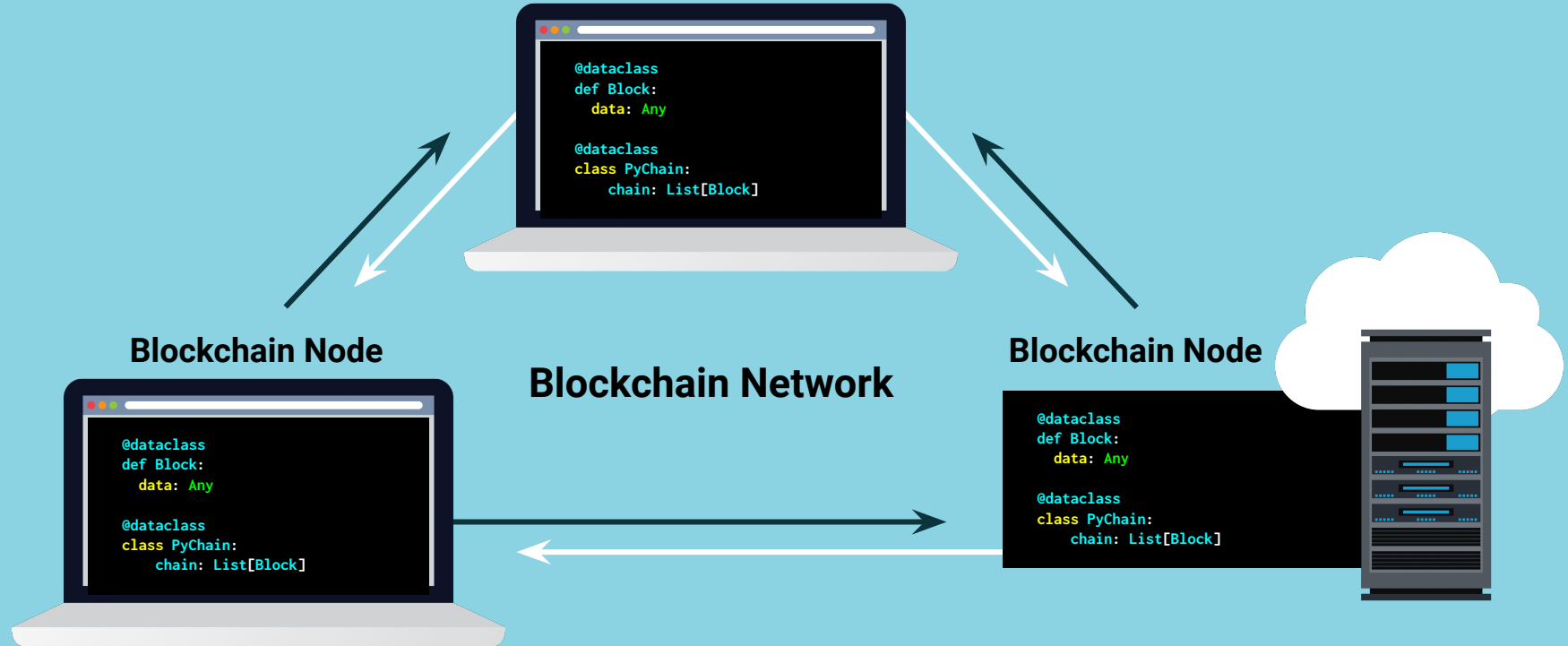
# Blockchain Networks


A network is simply a collection of computers that connect to each other in some way. This connection can occur through the internet, over a local WiFi connection, or even via a physical cable that connects two computers.



# Blockchain Networks

A blockchain network is composed of all the distributed computers, or nodes, that run a copy of the blockchain.





**Blockchain governance:** The logic that's required to maintain the operation, communication, and rules for a blockchain network.



# Components of a Blockchain System

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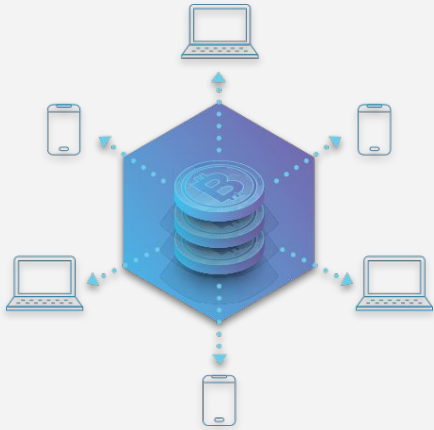
Blockchain governance answers three fundamental questions.

<b>1. What should we do?</b>	The answer determines how copies of the ledger are distributed.
<b>2. Who gets to decide?</b>	The answer determines who gets to add new records to the ledger.
<b>3. How are the deciders chosen and held accountable?</b>	The answer determines how copies of the ledger, maintained on different nodes, are synchronized with each other.

# Components of a Blockchain System

Four types of blockchain networks:

**Public  
blockchain**



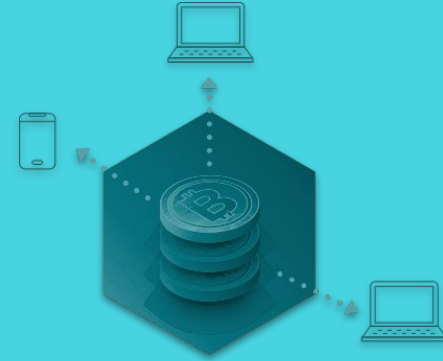
**Semiprivate  
blockchain**



**Private  
blockchain**



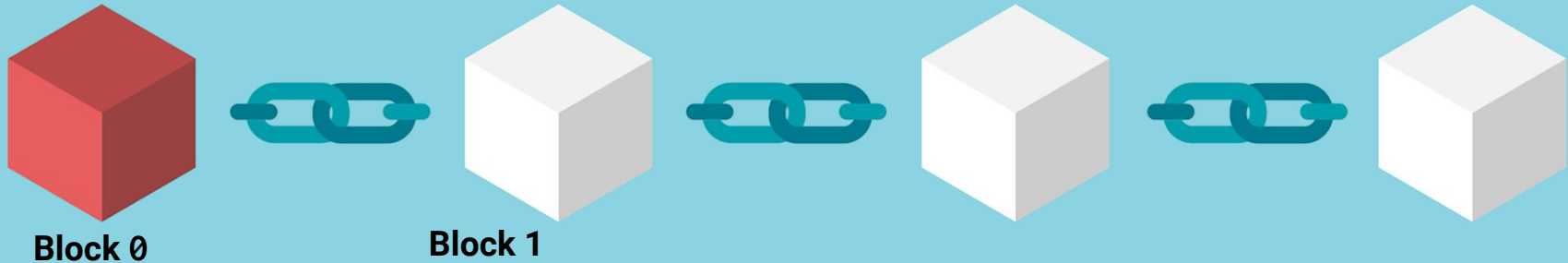
**Consortium  
blockchain**



**Public and private blockchains  
are the two most common types.**

# Public Blockchain

A public blockchain does not restrict access; anyone with an internet connection can send transactions and validate them. Public blockchains are also known as permissionless blockchains.



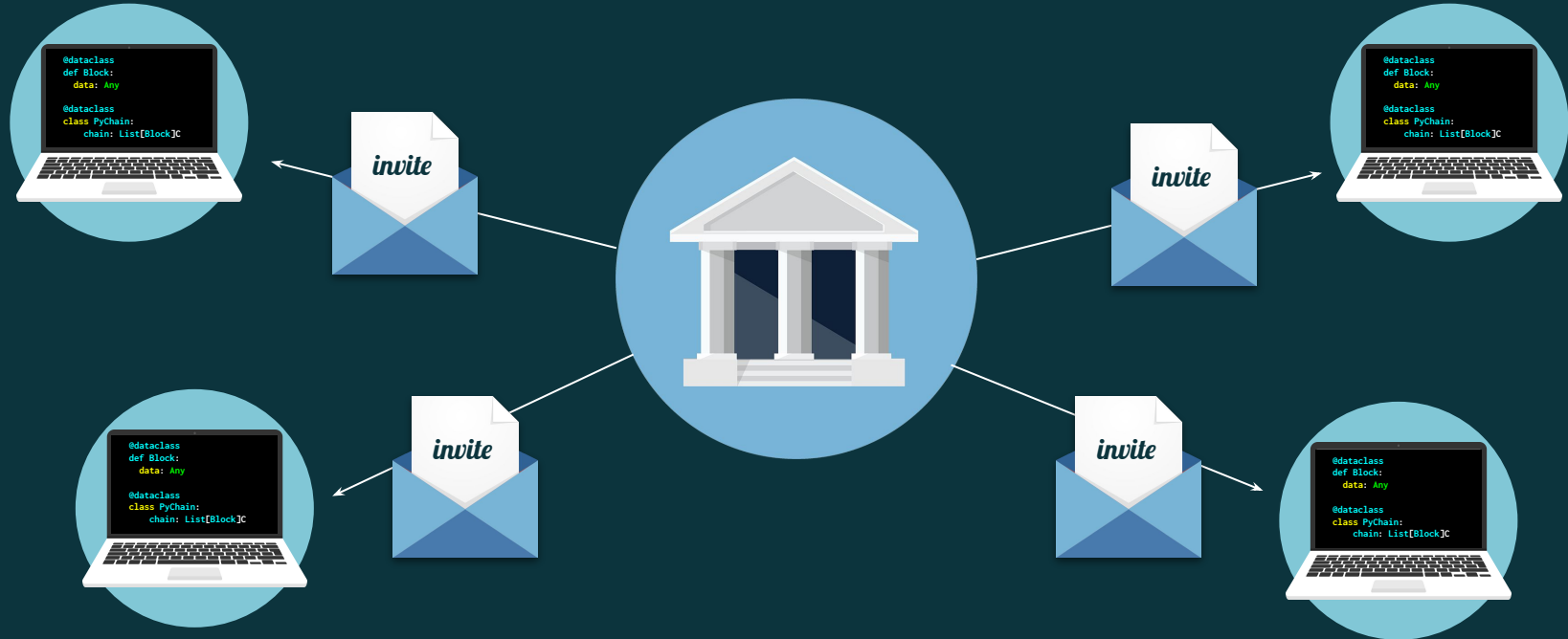
The `prev_hash` attribute contains the hash of Block 0.



Bitcoin and Ethereum are public, permissionless blockchains.

# Private Blockchain

In a private blockchain, users must be invited. Private blockchains are also known as permissioned blockchains. Corporate blockchains tend to be private.





A **semiprivate blockchain** combines features of both public and private blockchains in some way.

# Consortium Blockchain

A consortium blockchain has restricted access, like a semiprivate blockchain, but consists of two or more groups working together for a common purpose.



# Protocol

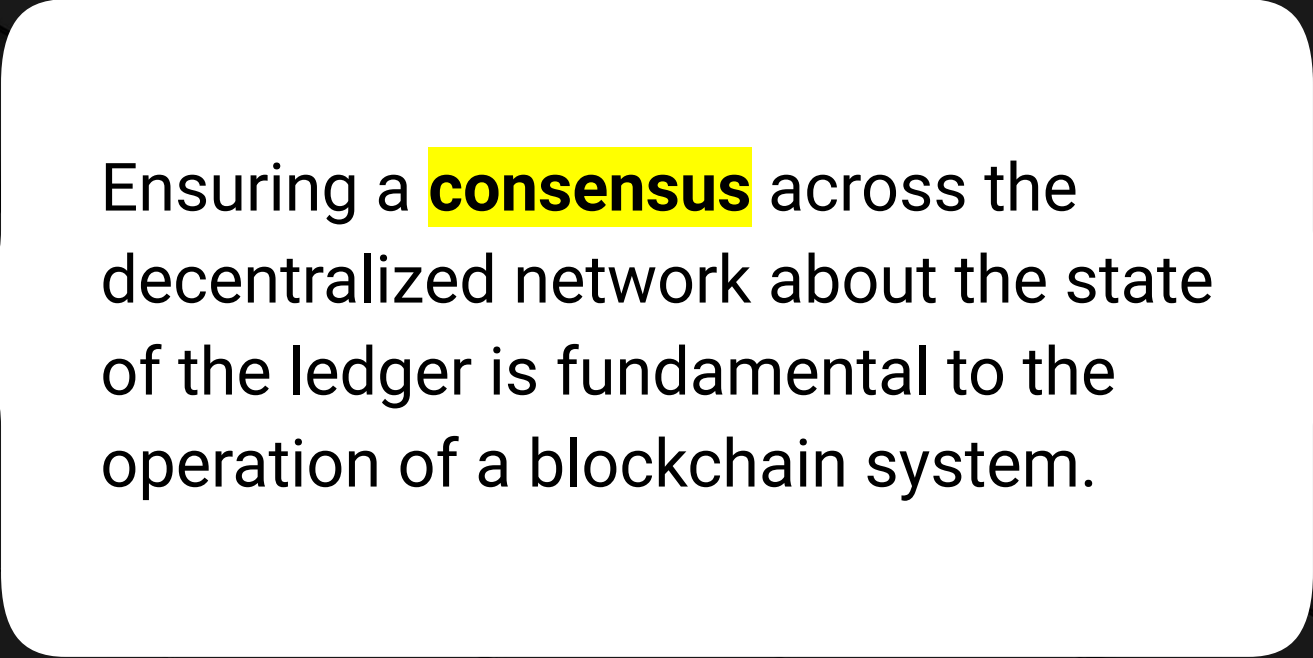
To communicate with each other, the computers in the network use a protocol. A **protocol** is a set of rules that the members of a communication system use to share information with each other.



HTTP is a widely used communication protocol.

Local URL: `http://localhost:8501`

Network URL: `http://192.168.205.109:8501`

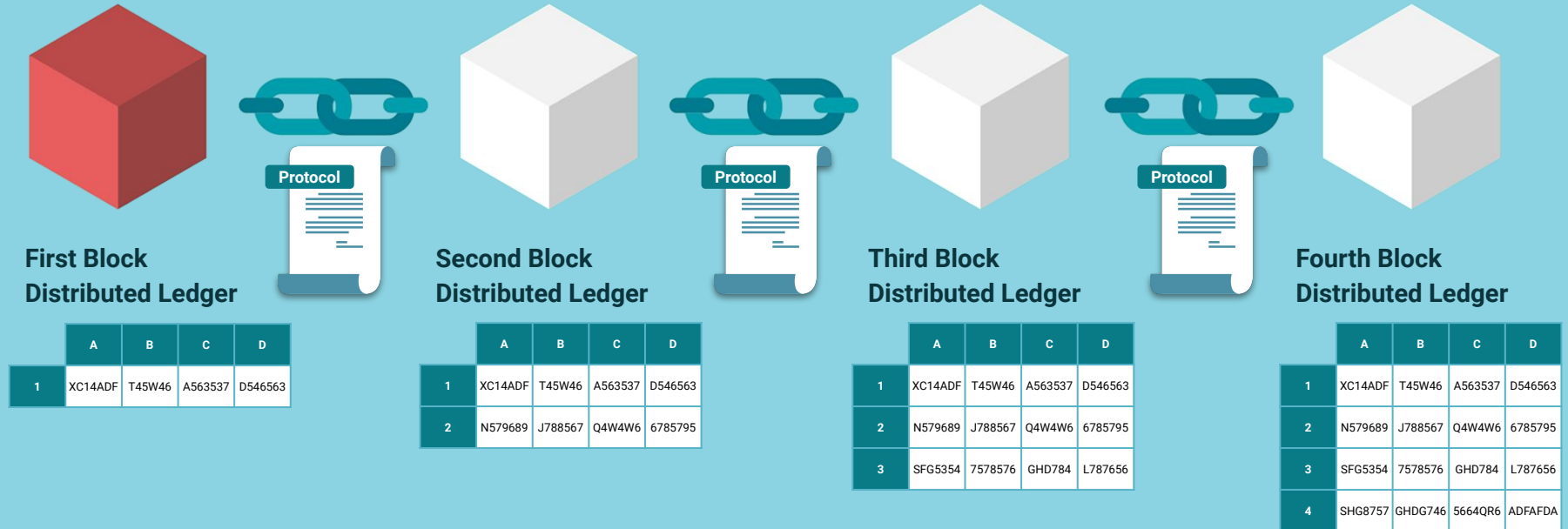


Ensuring a **consensus** across the decentralized network about the state of the ledger is fundamental to the operation of a blockchain system.



# Consensus Protocols

Without consensus, no guarantee would exist that one node's version of the ledger matched any other node's version. Consensus protocols ensure trust in the blockchain system.



# Popular Consensus Mechanisms

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## Proof of Work

Though highly effective, proof of work requires a lot of computing and energy resources.

## Proof of Stake

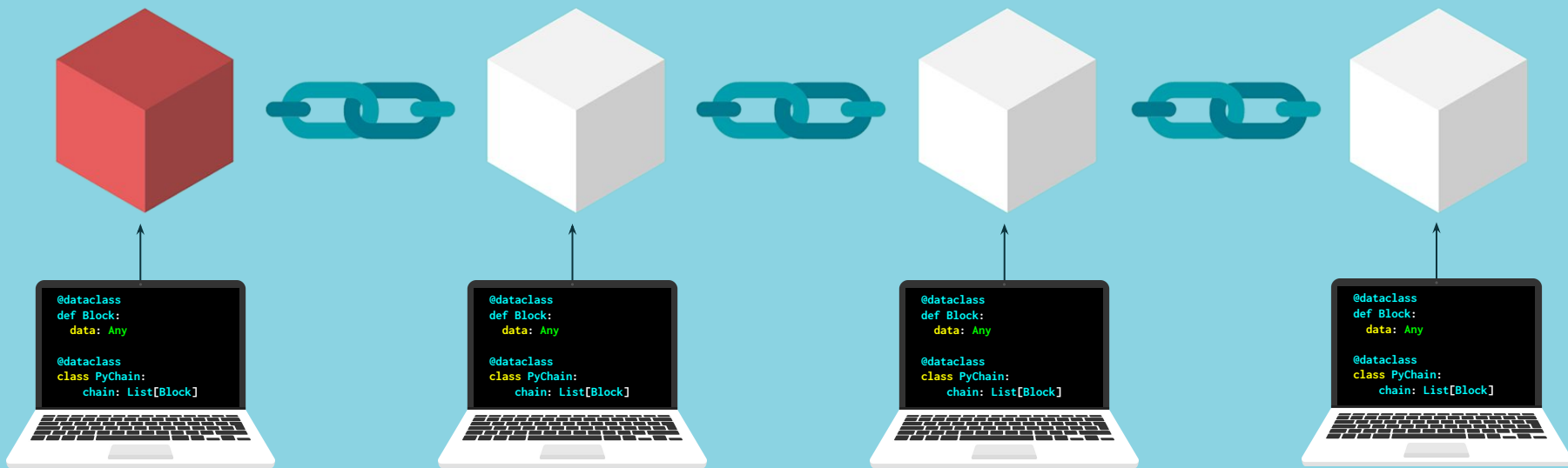
Proof of stake requires less computational energy than proof of work.

# Hash Guesser

# Proof of Work

A computer can quickly record data to a block and add that block to the chain.

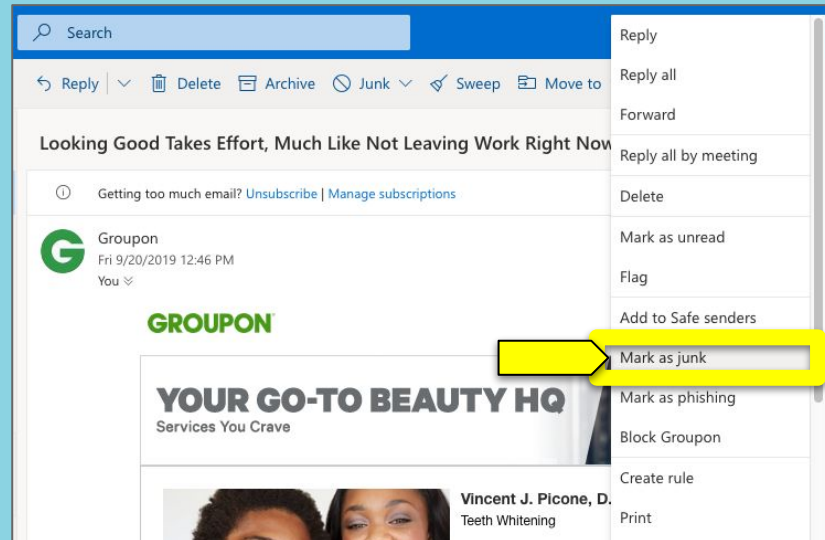
The proof-of-work consensus protocol makes it more difficult to add a block to the chain, which, in turn, makes it harder to cheat the system.



# Hashcash Algorithm

One of the most popular consensus algorithms today, proof of work was originally based on the hashcash algorithm, which was created in the 1990s to combat email spam.

X-Hashcash: 1:20:1303030600:anni@cypherspace.org::McMybZlhxKXu57jd:ckvi



# Hashcash Algorithm

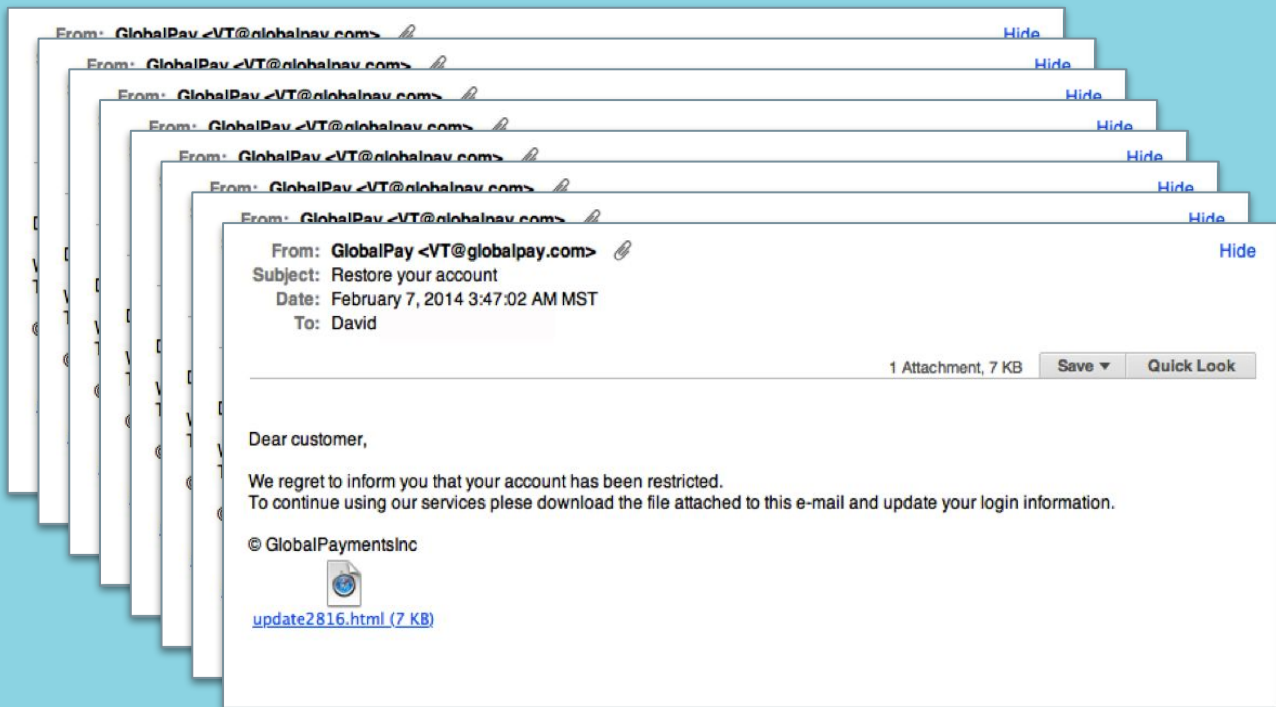
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The original use case for hashcash was email.  
Hashcash requires a computer to solve a computational problem before sending an email.

```
X-Hashcash: 1:20:1303030600:anni@cypherspace.org::McMybZIhxKXu57jd:ckvi
```

# Hashcash Algorithm

Now, imagine that you're a spammer who wants to send millions of emails every day. This would require a significant amount of energy, which is expensive.



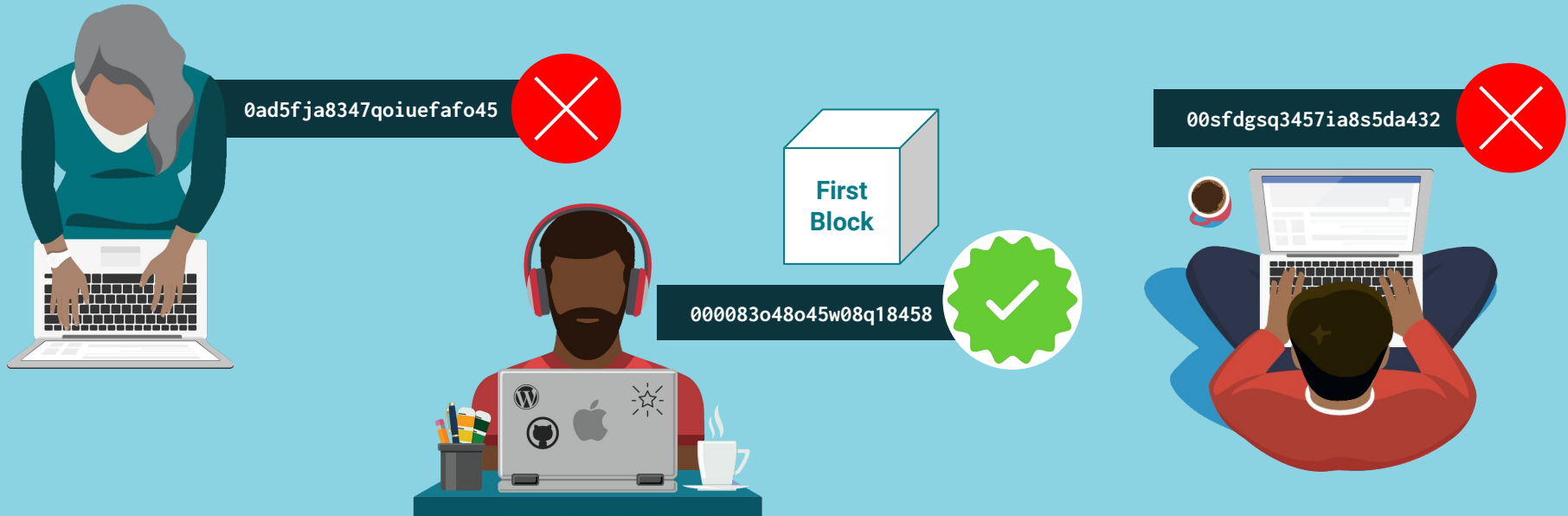


**The hashcash algorithm allows authorized users to use the system without a problem and makes it expensive for malicious users to hack the system. Blockchain applies this same concept.**



# Hashcash Algorithm

In a blockchain, adding a block to the chain involves a guessing game for the participants. Specifically, the algorithm chooses a random number. Then, each participant guesses a number until someone guesses correctly. The first participant to guess the correct number gets to add a block to the chain.





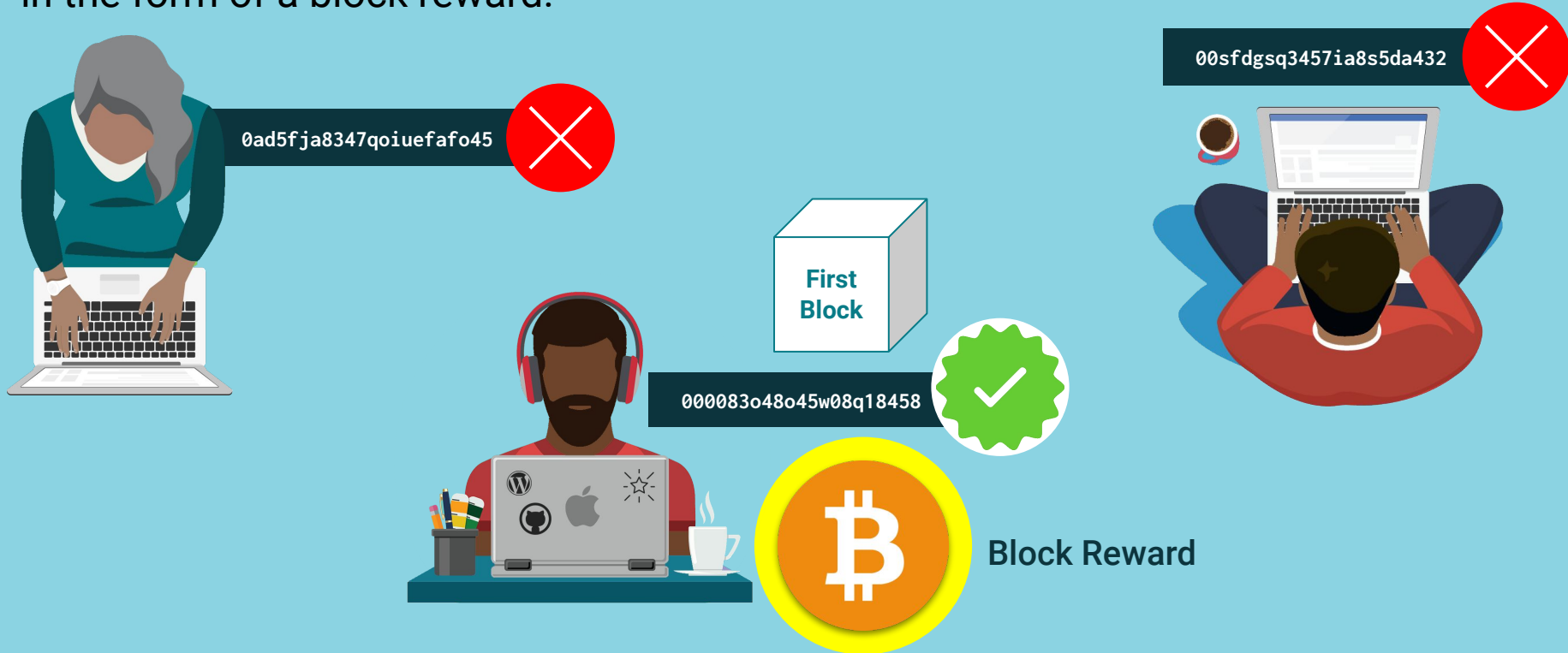
**The node that completes the work first wins the privilege of adding a new data block to the chain.**

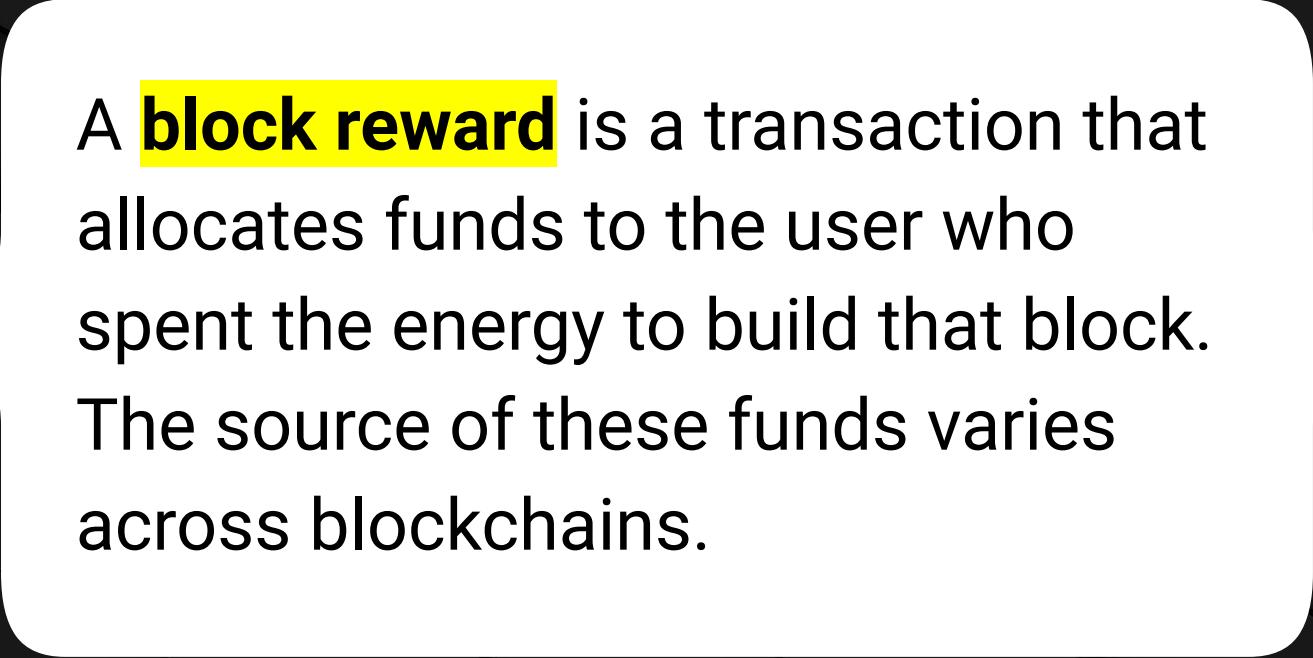


**Why is adding a new block to the chain considered a privilege?**

# Block Reward

Because the person who adds the block receives compensation for their efforts in the form of a block reward.





A **block reward** is a transaction that allocates funds to the user who spent the energy to build that block. The source of these funds varies across blockchains.

# Block Reward

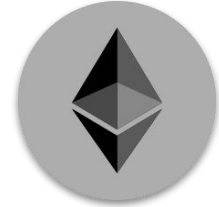
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Bitcoin

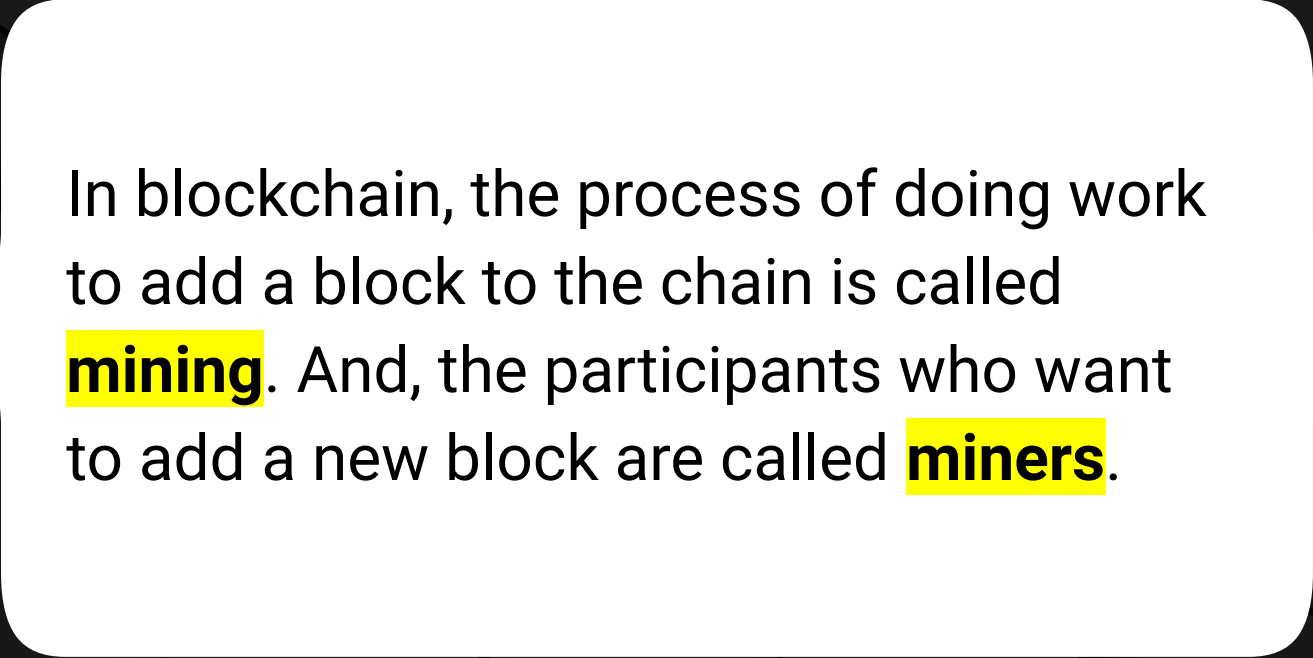


In the Bitcoin blockchain, the funds are allocated by the chain itself.

Ethereum



The block reward on the Ethereum blockchain, is determined by the price the participants in the transaction are willing to pay in fees to the miner.



In blockchain, the process of doing work to add a block to the chain is called **mining**. And, the participants who want to add a new block are called **miners**.

# Proof of Work Process

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At a high level, the proof of work process is as follows:

01

The system sets the difficulty of the work that's required to add a block to the chain. The difficulty determines how much effort, or computational power, will be required to complete the necessary work.

02

The participants compete to be the first to finish the work.

03

The first to finish gets to add a record to the ledger.



# Proof of Work Process

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The proof-of-work algorithms that blockchains like Bitcoin and Ethereum require miners to generate a cryptographic hash for the previous block on the chain. The hash contains a specific pattern determined by the algorithm.

Proof of work requires miners to find a set of inputs to include in their blocks that results in a specific pattern in the block hash.

The blockchain system has a pattern that usually requires a certain number of zeros at the beginning of the block hash.

```
00003fa996ced47773f2dea29cce9b11f951e6dafa321a84ac7d32791c3b4660
```



# Instructor Demonstration

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**Generate the Correct Hash Pattern**

# Questions?





# Time to Code



## Add Hashing to a Block

Suggested Time:

---

20 minutes

# Questions?





# Time to Code

## Integrate Proof of Work Into PyChain

Suggested Time:

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20 minutes



## Activity: Dynamic Difficulty

In this activity, you will test the integration of the proof-of-work consensus protocol into the PyChain application.

Suggested Time:

20 minutes



**Time's Up! Let's Review.**

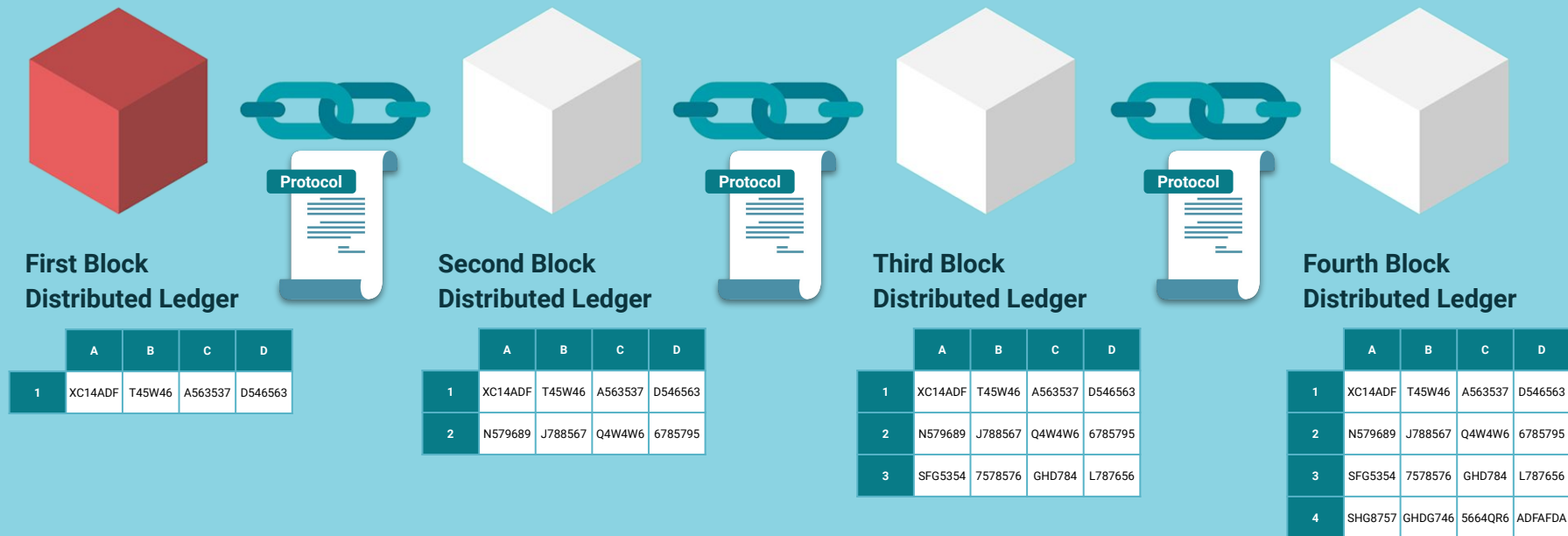




# Proof-of-Work Validation

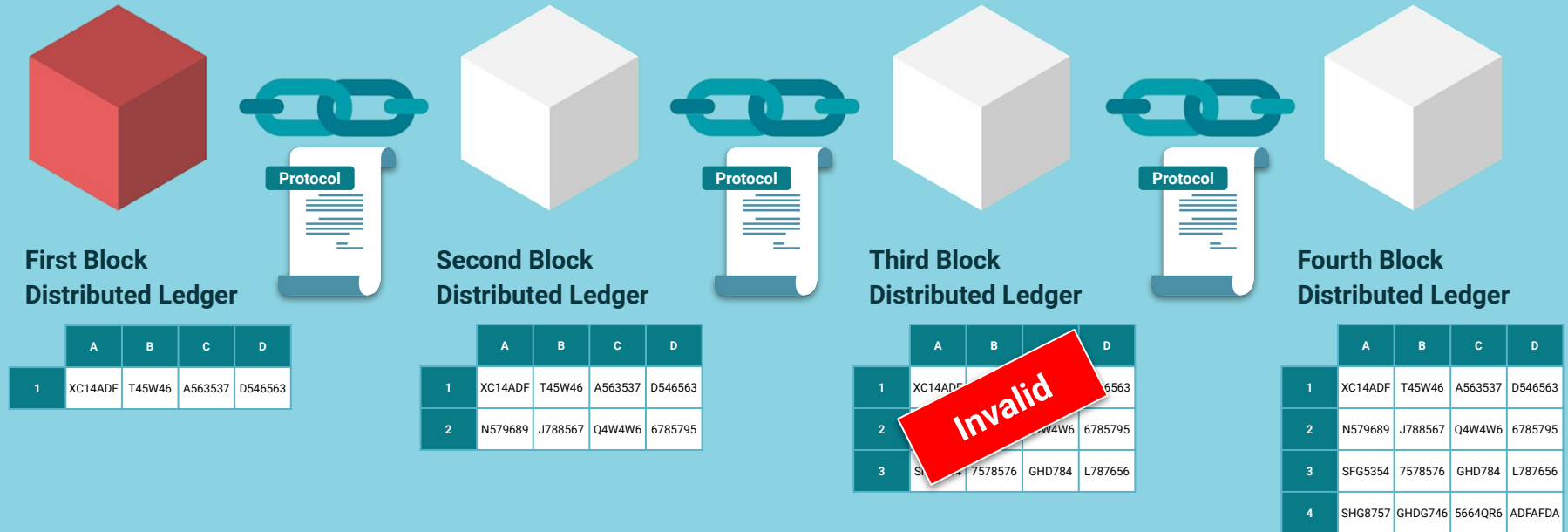
# Proof-of-Work Validation

Part of the goal of the proof-of-work consensus protocol is to prevent nodes from syncing to an invalid copy of the ledger.



# Proof-of-Work Validation

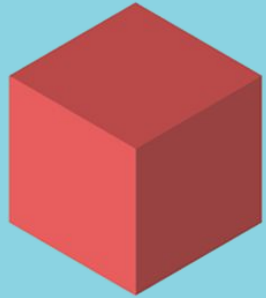
There's a chance that the miner was a bad actor and altered the state of one of the preceding blocks.



Or, the miner could claim to have found the right nonce value to generate a hash that matches the requirement, but in reality, they have not done the work.

# Proof-of-Work Validation

The blockchain is validated by adding cryptographic links between all the blocks in the ledger through their hashes.



First Block

Data: "Good Day"
Previous Hash: 000000
Hash: 12f13q



Second Block

Data: "Thursday"
Previous Hash: 12f13q
Hash: d340kc



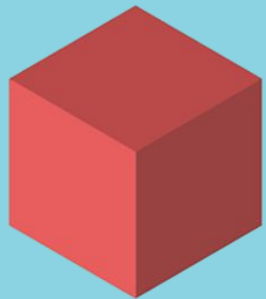
Third Block

Data: "Fingerprint"
Previous Hash: d340kc
Hash: 1m12ep



# Proof-of-Work Validation

It's possible to manually validate the entire chain by calculating the hash of a block, and then checking if the `prev_hash` attribute value in the next block matches the current block's hash.



First Block

Data: "Good Day"
Previous Hash: 000000
Hash: 12f13q



Second Block

Data: "Thursday"
Previous Hash: 12f13q
Hash: d340kc



Third Block

Data: "Fingerprint"
Previous Hash: d340kc
Hash: 1m12ep



# Proof-of-Work Validation

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Steps for validating the PyChain ledger:

01

Hash the first block in the chain.

02

Access the `prev_hash` attribute value from the next block.

03

Compare the two hashes.

04

Repeat Steps 1 through 3 for each block in the chain until every block's `prev_hash` value has been evaluated.



If all comparisons result in matches, the entire blockchain is valid. Otherwise, it's invalid.



# Instructor Demonstration

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## Validate the Chain



# Questions?





# Activity: Validating the Blockchain

In this activity, you will use Streamlit to test the validation functionality associated with the PyChain.

Suggested Time:

20 minutes



**Time's Up! Let's Review.**

*The  
End*