Week 4 - Solana Jargon, Programming model, Tokens [23 Aug 2024]

> **Timing** - Every Friday 8:00pm to 10:00pm IST
> Class Slides - Programs, Accounts and the Token Program (100xdevs.com)
> Class Video - Take your development skills from 0 to 100 and join the 100xdevs community
> Assignment - Programs, Accounts and the Token Program (100xdevs.com)
> - Token 22 with metadata (100xdevs.com)

> **Syllabus** - Notion – The all-in-one workspace for your notes, tasks, wikis, and databases. (100xdevs.com)

Goal of the Session

1. **Introduction to Solana and Its Advantages Over Bitcoin and Ethereum**
    - **Understanding Solana's Purpose**: Explore why Solana was introduced and how it aims to improve upon the limitations of Bitcoin and Ethereum.
    - **Comparative Analysis**:
        - **Bitcoin**: Primarily a digital currency, focusing on decentralization and security.
        - **Ethereum**: Enhances Bitcoin's functionality by introducing smart contracts.
        - **Solana**: Further expands capabilities by offering a high-performance blockchain, supporting thousands of transactions per second, with a unique architecture that optimizes for scalability.
2. **Architecture of Solana**
    - **Accounts on Solana**: Explanation of the various types of accounts on Solana:
        - **Wallet Accounts**: Used to store and manage cryptocurrency.
        - **Data Storage Accounts**: Store various types of data on-chain, enabling more complex applications.
    - **Scalability and Performance**: How Solana's architecture allows for millions of accounts and high transaction throughput.
3. **Setting Up the Solana Development Environment**

- **Installing Solana CLI**: Step-by-step instructions on how to install the Solana Command Line Interface (CLI) locally to interact with the blockchain and deploy smart contracts.

4. **Data Storage: Web2 vs. Solana**
    - **Web2 Data Storage**: Overview of how data is traditionally stored in centralized servers and databases.
    - **Solana Data Storage**: Understanding how data is stored on the blockchain in Solana smart contracts, emphasizing the decentralized nature of storage.
5. **Building Smart Contracts on Solana**
    - **Data Persistence in Smart Contracts**: Discuss the necessity of data storage in smart contracts (e.g., user data, first names, last names) and how it's handled in Solana.
    - **Creating Your Own Token**:
        - **JavaScript**: Instructions on how to create tokens using JavaScript.
        - **Rust/Python/Go**: Guidance on creating tokens using Rust, Python, or Go, highlighting the versatility and support for multiple programming languages on Solana.
6. **Solana's Token Program: An Overview**
    - **Token 2022 Program**: Explanation of the Token 2022 program, its features, and how it expands the functionality and utility of tokens on the Solana blockchain.

Beyond Bitcoin

The Limitations of Bitcoin

- Bitcoin primarily serves as a decentralized currency.
- It was not designed to support complex applications or diverse use cases.

The Rise of Alternative Blockchains

- **Post-2012 Developments**: Various blockchains emerged, each tailored for specific purposes, such as lending protocols or decentralized exchanges.
- **Challenges Faced**:
    - **Fragmentation**: Each blockchain operated independently with its own set of miners and consensus mechanisms.
    - **Cold Start Problem**: New blockchains struggled to gain traction and security, unable to match Bitcoin's network size and robustness.

Ethereum: A Revolutionary Solution

- Ethereum introduced the concept of smart contracts, allowing developers to build decentralized applications (dApps) directly on the Ethereum network.
- **Advantages of Ethereum**:
  - **No Cold Start Problem**: Developers could leverage Ethereum's existing decentralized network, avoiding the initial growth challenges faced by standalone blockchains.
  - **Flexibility and Innovation**: Enabled a wide range of applications, from finance to gaming, all on a single, secure blockchain.

▼ Example: Counter Contract in Solidity

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract Counter {
    uint public count;

    // Constructor to initialize count
    constructor() {
        count = 0;
    }

    // Function to increment the count
    function increment() public {
        count += 1;
    }

    // Function to decrement the count
    function decrement() public {
        require(count > 0, "Count cannot be negative");
        count -= 1;
    }

    // Function to get the current count
    function getCount() public view returns (uint) {
        return count;
    }
}
```

Solana: A New Frontier

- **Smart Contracts vs. Programs**: What Ethereum calls `smart contracts`, Solana refers to as `programs`.

- Solana offers similar capabilities to Ethereum but with significantly faster transaction speeds and scalability, high throughput and low latency.
- The design and operation of Solana's programs differ from traditional blockchains, providing a distinct approach to building and running decentralized applications.

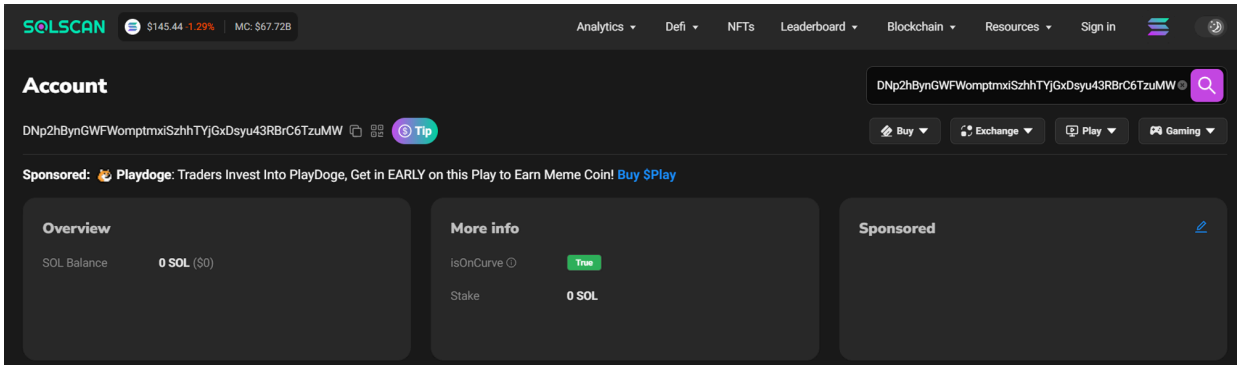
Accounts in Solana

What is an Account?

- In Solana, an account is a data structure that includes a public-private key pair (using the `ed25519` elliptic curve).
- **Types of Accounts**:
  - **Wallet Accounts**: These accounts represent user wallets that can hold **lamports** (Solana's native currency).

    ▼ Example: Wallet Account [Only Lamports]

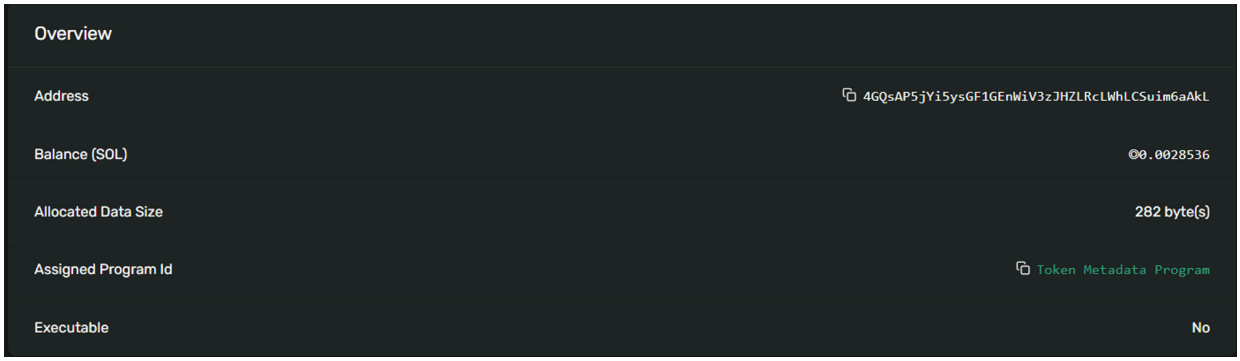
    Account DNp2hBynGWFWomptmxiSzhhTYjGxDsyu43RBrC6TzuMW | Solscan

  - **Data Accounts**: These accounts store data on the blockchain and can be used for various decentralized applications.

    ▼ Example: Data Account [Data and Lamports]

    Transaction History | 4GQsAP5jYi5ysGF1GEnWiV3zJHZLRcLWhLCSuim6aAkL | Solana

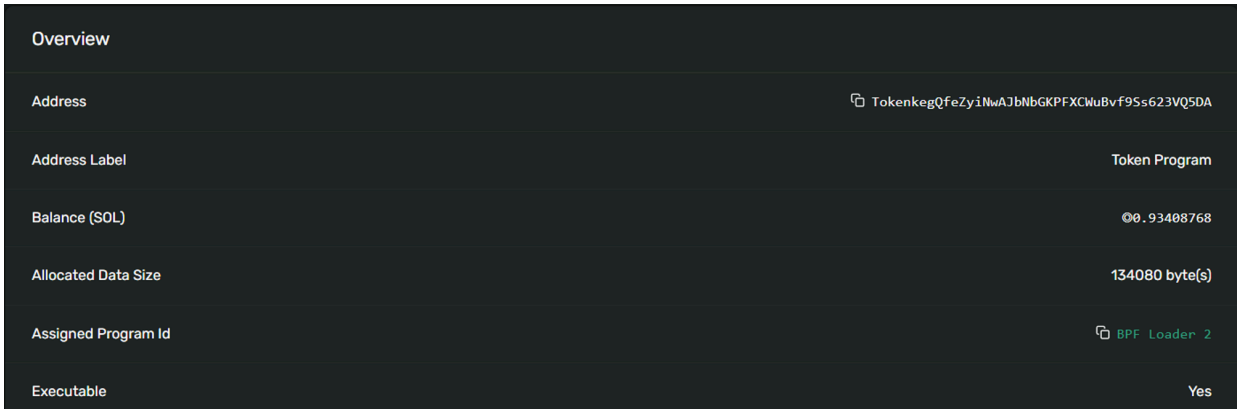
    

  - **Program Accounts**: These are special accounts that store executable code, allowing smart

contracts (known as "programs" in Solana) to run on the blockchain.

▼ Example: Program Account [Data, Lamports and Executable code]

Transaction History | TokenkegQfeZyiNwAJbNbGKPFXCWuBvf9Ss623VQ5DA | Solana



Rent on Solana

- **Purpose of Rent**: To prevent the blockchain from being clogged with inactive or unnecessary data, Solana charges rent for storing data.
  - **Rent Calculation**: Rent is based on the storage size and the duration the account remains on the blockchain.
  - **Rent Exemption**: If an account maintains a balance above a certain threshold, it becomes "rent-exempt," meaning it does not incur further rent charges. The rent paid is refundable when the account is closed.

💡 What is Rent on Solana and How to Calculate it | QuickNode

Efficient Storage Management

- **Incentivizing Minimal Storage**: The rent model encourages users to store only the necessary data, reducing blockchain bloat.
- **Removing Inactive Accounts**: Accounts that fail to pay the required rent are eventually removed from the ledger, ensuring efficient use of blockchain resources.

Calculating Rent-Exempt Threshold

- **Methods to Calculate**:
  1. **Solana CLI**: Command-line interface tools.
  2. **Solana Web3.js Library**: JavaScript library for interacting with the Solana blockchain.

3. **Anchor's Space Constraint**: A framework-specific approach for calculating space requirements for accounts.

Install Solana CLI

MacOS & Linux

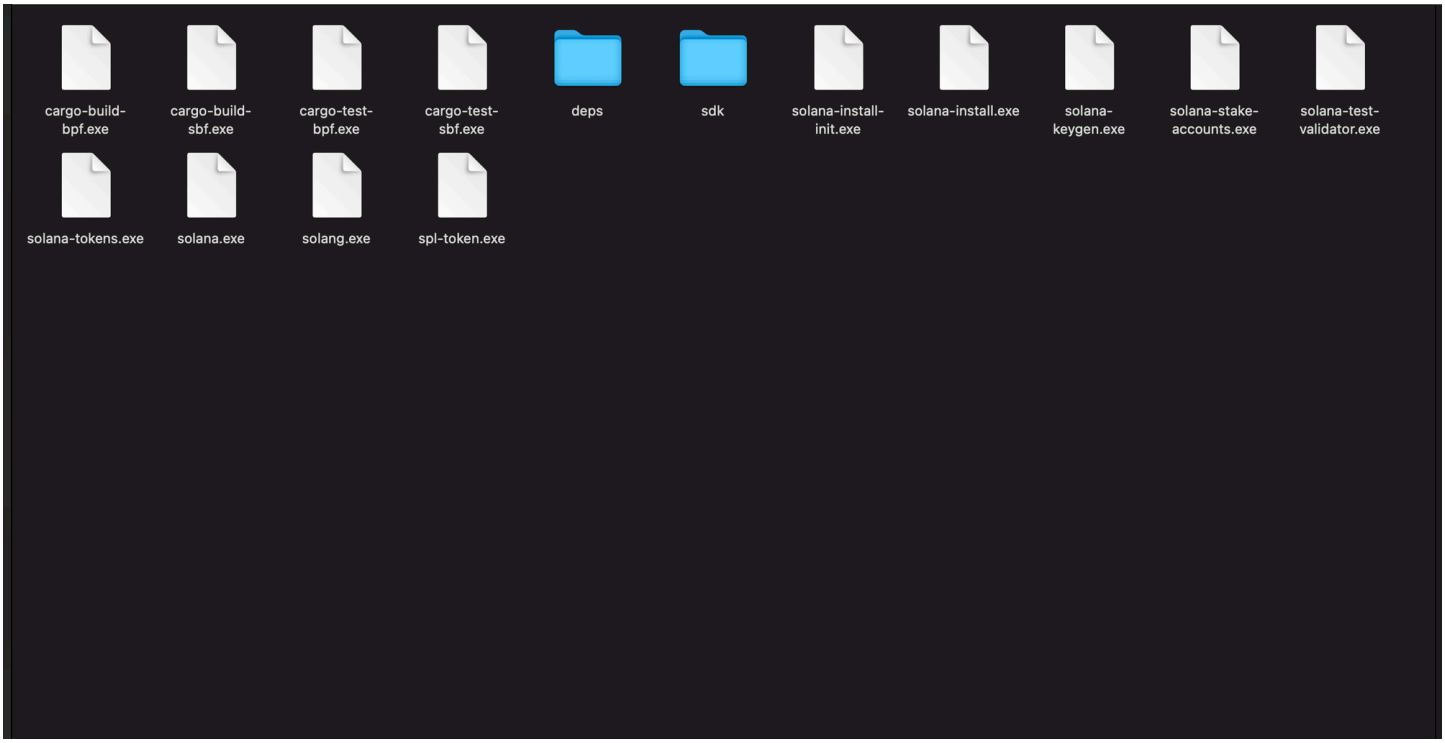
The below commands run for WSL as well.

> 💡 Install the Solana CLI | Solana Validator (solanalabs.com)

Windows

Download the highlighted folder from - https://github.com/solana-labs/solana/releases

Unzip and you should see all the .exe files



Confirm by running commands

▼ Get Solana version

```
solana --version
```

▼ Create your own keygen

```
solana-keygen new
```

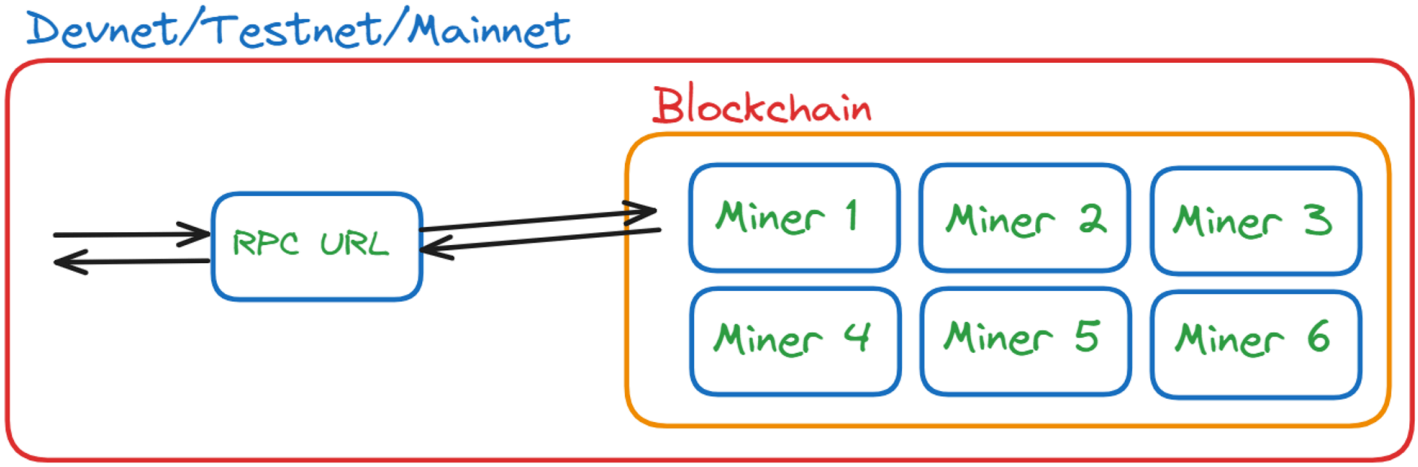
▼ Get your Solana address

```
solana address
```

▼ Get your config file

```
solana config get
```

RPC URL, Testnet, Devnet, and Mainnet



What is an RPC URL?

- RPC (Remote Procedure Call) URLs allow applications like browsers, wallets, and users to interact with the Solana blockchain.
- By sending requests to an RPC URL, you can query the blockchain and perform various operations.
- **How to Use RPC URLs**:
  - **Mainnet**: `https://api.mainnet-beta.solana.com`
  - **Devnet**: `https://api.devnet.solana.com`
  - **Testnet**: `https://api.testnet.solana.com`

> 💡 Clusters and Public RPC Endpoints | Solana

Changing RPC URLs

Use the following commands to set the appropriate RPC URL for your environment:

```
# Set RPC URL for Mainnet
solana config set --url https://api.mainnet-beta.solana.com

# Set RPC URL for Devnet
solana config set --url https://api.devnet.solana.com

# Set RPC URL for Testnet
solana config set --url https://api.testnet.solana.com
```

Solana Networks

- **Mainnet**: The live Solana blockchain where real transactions occur. It's secure and used for deploying production applications.
- **Testnet**: A testing environment that mimics the mainnet but is used for testing applications before deploying them to the mainnet. It does not use real SOL.
- **Devnet**: A development environment similar to the testnet but specifically for developers to experiment and test applications. You can freely request SOL from the Solana Devnet Faucet for testing purposes.

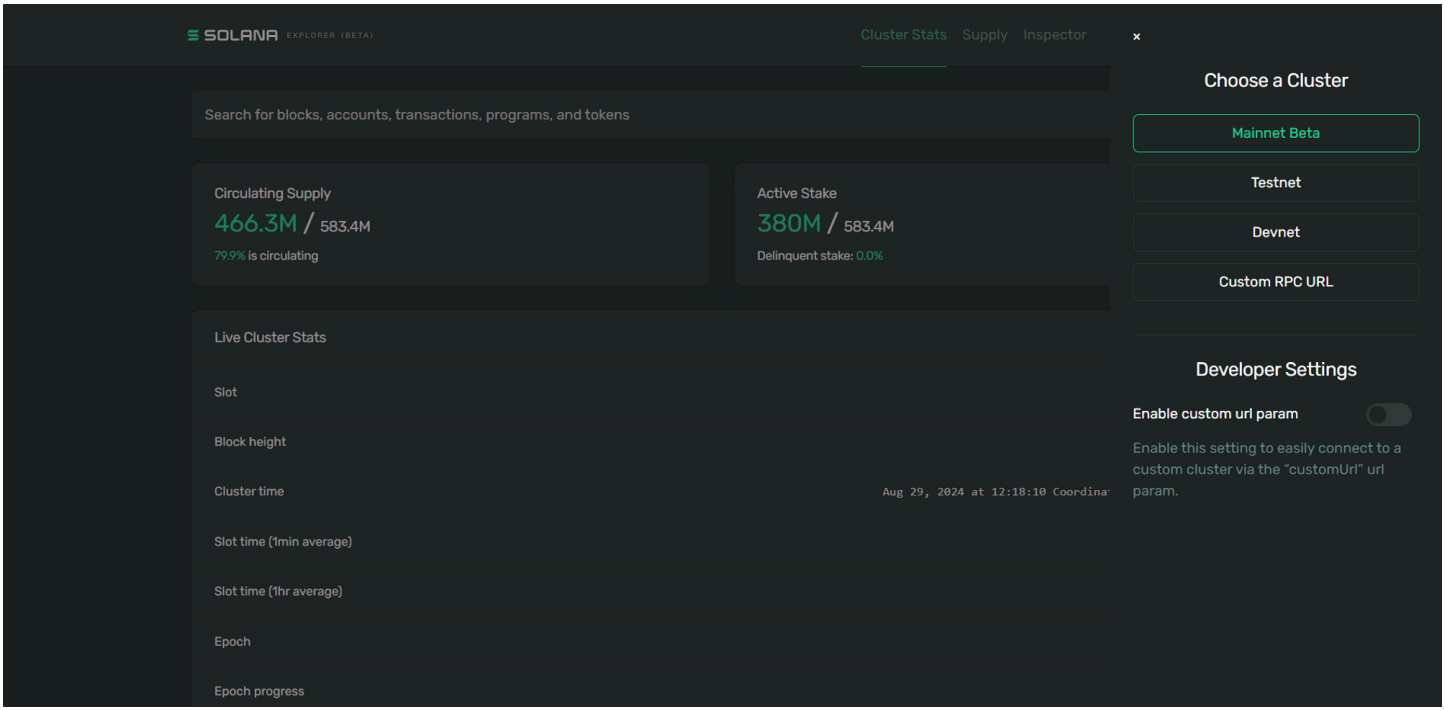
Using Devnet and Testnet

- **Airdrop SOL**: On Devnet, you can use the faucet to receive free SOL for testing.
- **Local Testing**: Use the Solana Test Validator to start a local validator for testing applications without relying on external networks.

```
solana-test-validator
```

Solana Explorer

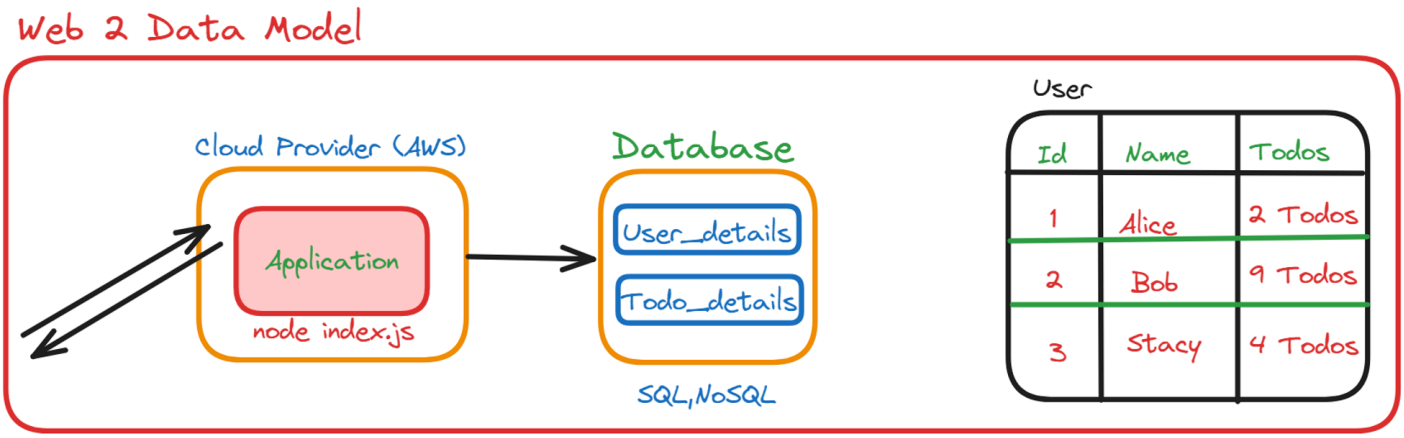
- **Explorer Tool**: You can view transactions, account balances, and more on the Solana blockchain using the Solana Explorer, which supports Devnet, Testnet, Mainnet, and custom RPC URLs.



Web2 Data Model vs. Solana Data Model

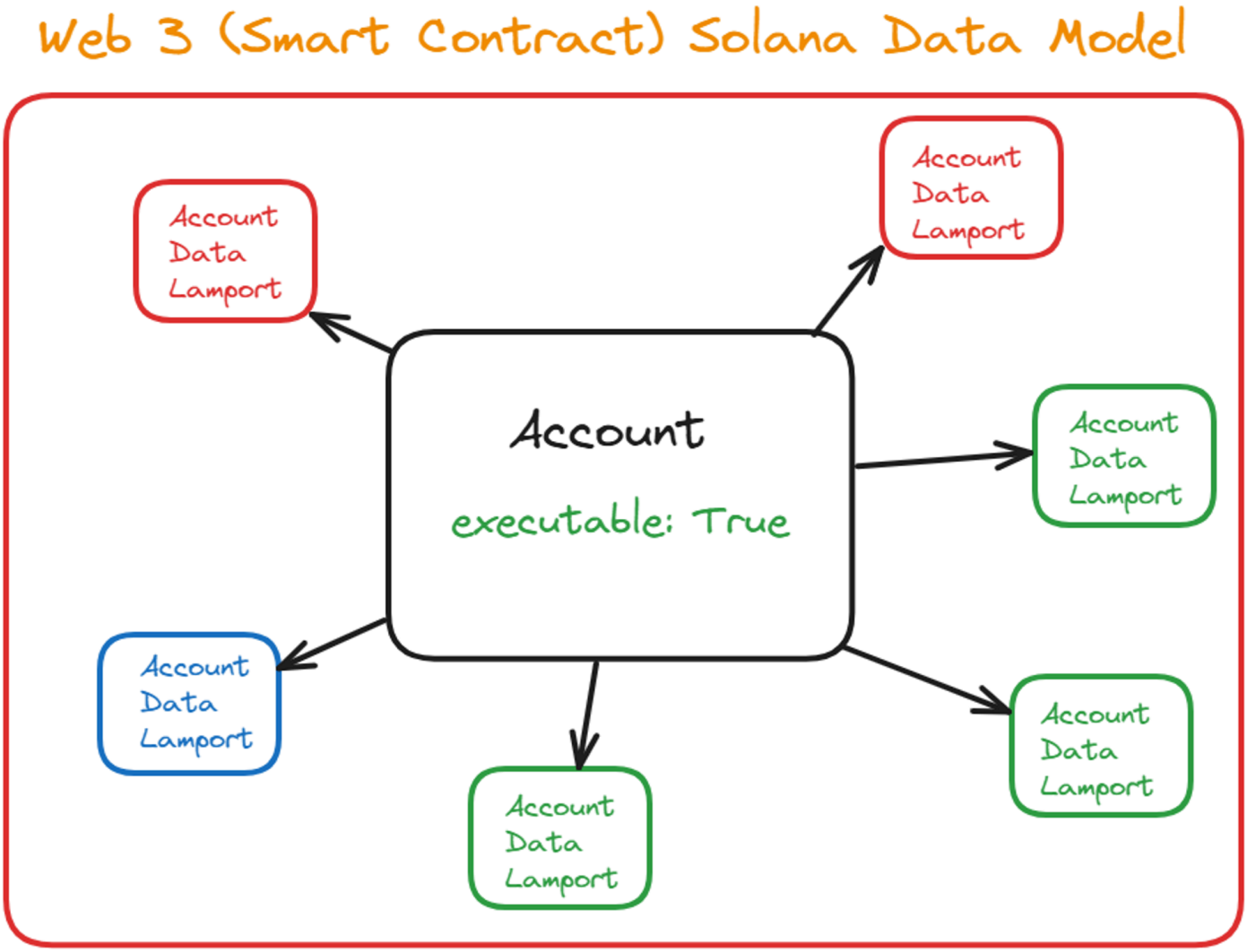
Web2 Data Model

- Applications are typically deployed on cloud providers with backend code and data storage separated.
- **Databases**: Use SQL or NoSQL databases to store user data.
- **Data Management**: Adding or deleting a user involves simply adding or removing a row in the database.



Solana Data Model

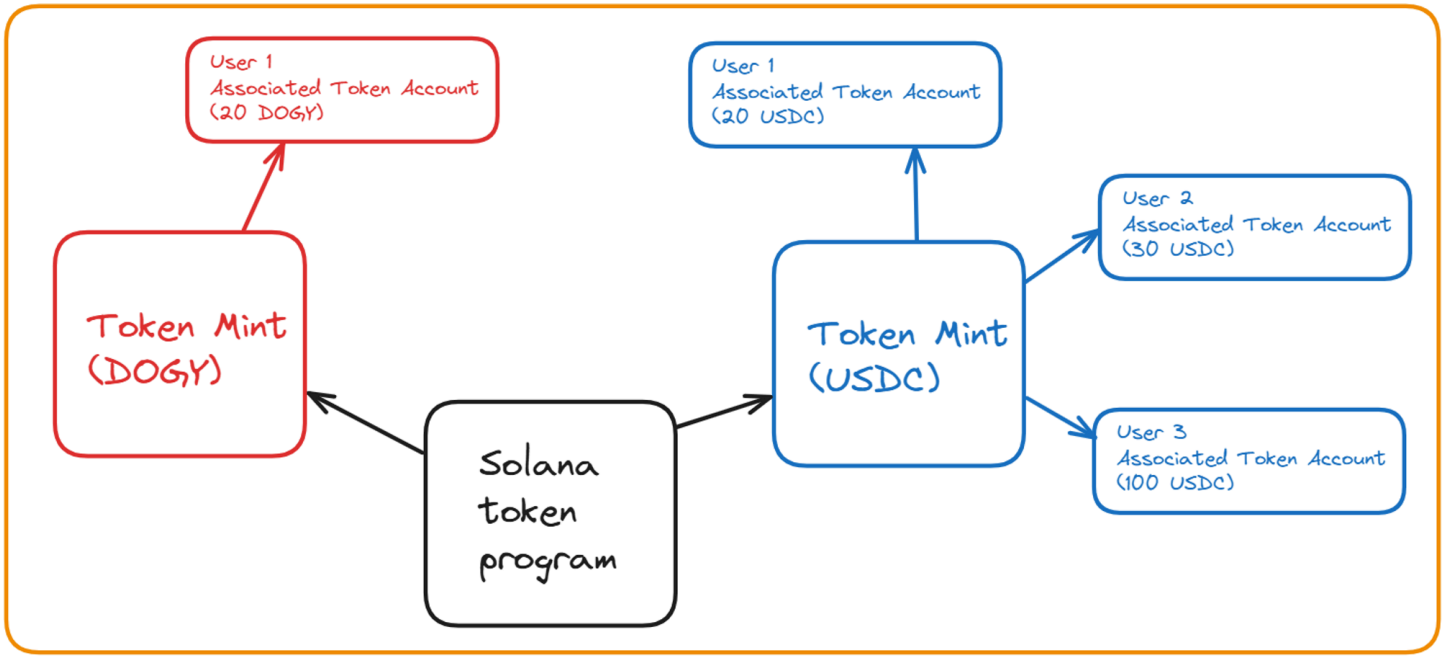
- **Smart Contracts**: In Web3, smart contracts are equivalent to backend applications in Web2. These are deployed on the blockchain.
- **Program Storage**: On Solana, smart contracts (called "programs") are stored in **executable accounts**.
- **Data Storage**: Unlike Ethereum, where data and smart contract code are stored together, Solana separates them:
  - **Data Accounts**: Store data independently from programs.
  - **Executable Accounts**: Store the smart contract code (programs).



Key Differences and Implications

- **User Account Management**:
  - In Solana, each user requires a separate account, which adds complexity compared to simply adding a row in a Web2 database.
  - **User-Paid Fees**: The responsibility for creating and funding these accounts, including paying for data rent, is delegated to the user.
  - **Decentralized Fees**: Users pay the fees for their individual accounts, not the program itself. If an account is closed, any remaining rent is refunded to the user.

Token Program on Solana



Creating Tokens: Ethereum vs. Solana

- **Ethereum**:
  - To create a token, you must deploy your own smart contract.
  - Ethereum provides a standard template (ERC-20), but each token requires its own contract to be deployed on the blockchain.
- **Solana**:
  - Solana simplifies this process with a **single, pre-deployed Token Program**.
  - Instead of deploying a new contract, you only need to create a token account under this program.
  - This significantly reduces complexity and deployment costs.

Understanding Tokens

- Tokens represent one of the primary use cases of blockchain technology, acting as digital assets or currencies that can be transferred or traded on the blockchain.
  - **Examples**: USDC and USDT are popular stablecoins that have found significant market adoption. These tokens do not have their own blockchain; instead, they operate as smart contracts on existing blockchains like Ethereum and Solana.
- **Why Use Existing Blockchains?**
  - Tokens like USDC and USDT leverage the security and infrastructure of established blockchains such as Solana and Ethereum. This allows them to function without maintaining their own blockchain or miners.

- The **Token Program** is essentially a mapping from an account to a number, representing the balance of tokens held by an account.

> 💡 Explore various tokens and their market data on CoinMarketCap.

Solana's Token Program

- **Centralized Token Program**:
  - Solana engineers recognized the importance of tokens and created a dedicated **Token Program**.
    - This program is pre-deployed on the Solana blockchain, simplifying token creation.
- **Mint Accounts**:
  - When creating a token on Solana, you establish a **mint account** under the Token Program.
  - A mint account functions like a bank for your token, overseeing its supply but without executing any code. It does not run transactions or logic on its own; instead, it is responsible for managing the minting and overall supply of tokens.
- **Associated token account:**
  - Associated Token Account is a token account whose address is deterministically derived using the owner's address and the mint account's address.

    ▼ When you created an `associated token account` , you actually created a PDA.
    - https://github.com/solana-labs/solana-program-library/blob/master/associated-token-account/program/src/lib.rs#L71
    - JS - https://github.com/solana-labs/solana-program-library/blob/ab830053c59c9c35bc3a727703aacf40c1215132/token/js/src/state/mint.ts#L171

      > 💡 Program derived accounts (PDAs) -Programming on Solana | Program Derived addresses and Cross Program Invocation - YouTube

> 💡 Solana program library: solana-labs/solana-program-library: A collection of Solana programs maintained by Solana Labs (github.com)

Creating a Token using CLI

▼ Create a new CLI wallet, you can continue with your wallet as well

```
solana-keygen new
```

▼ Set the RPC URL

```
# Set RPC URL for Devnet
solana config set --url https://api.devnet.solana.com
```

▼ Airdrop yourself some SOL

```
solana airdrop 2
```

▼ Check your balance

```
solana balance
```

▼ Create token mint

```
spl-token create-token
```

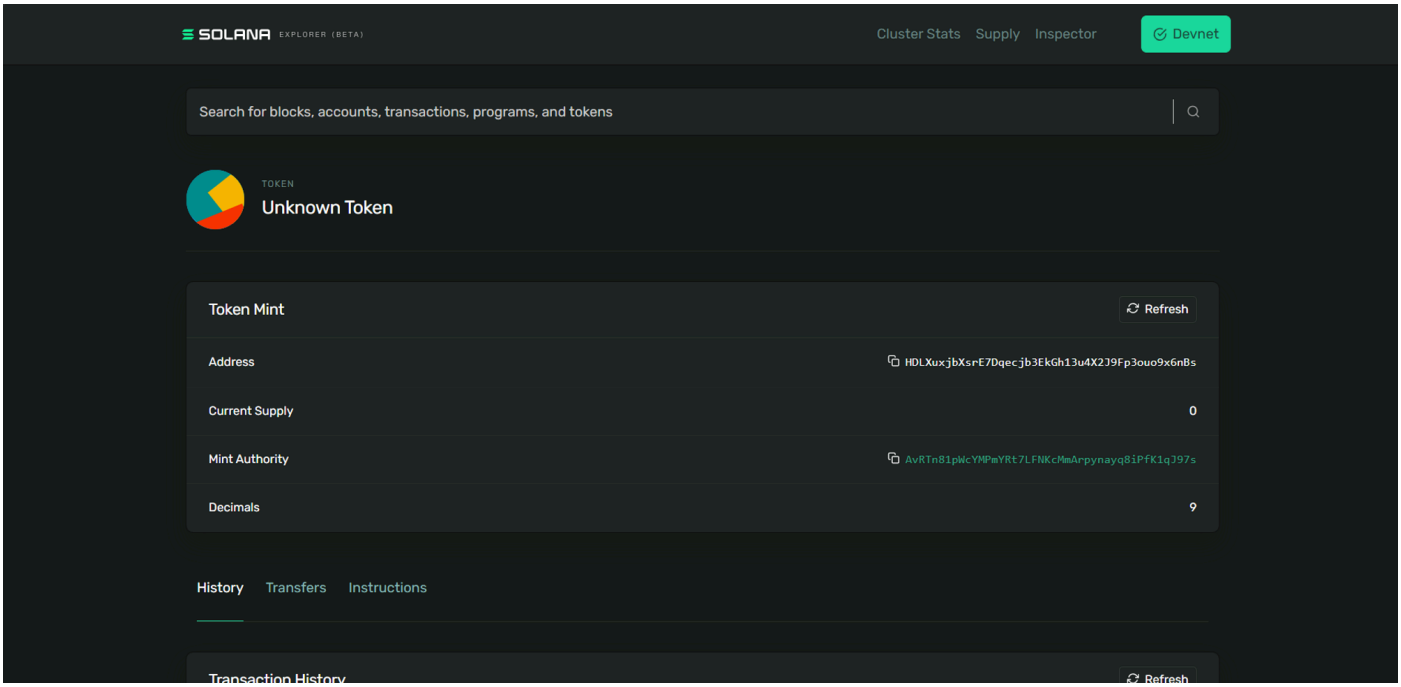
▼ Will get an output something like this,

```
Creating token HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs under program TokenkegQfeZyiNwAJbNbGKPFXCWuBvf9Ss623VQ5DA

Address:  HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs
Decimals:  9

Signature: 2DGKrjBha4FP236J3K8EwDxiNs8EAK28yDhN7h3fU6A2RYNJM4J7r27p1qfT2njUqwcytJWR4A4BZDGV2FAYniHJ
```

Decimals: 1 coin can be broken down in 10^9 parts. If the decimal is 0, it creates a non-fungible token which cannot be broken in parts and sent.

▼ Verify token mint on chain

Transaction History | HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs | Solana

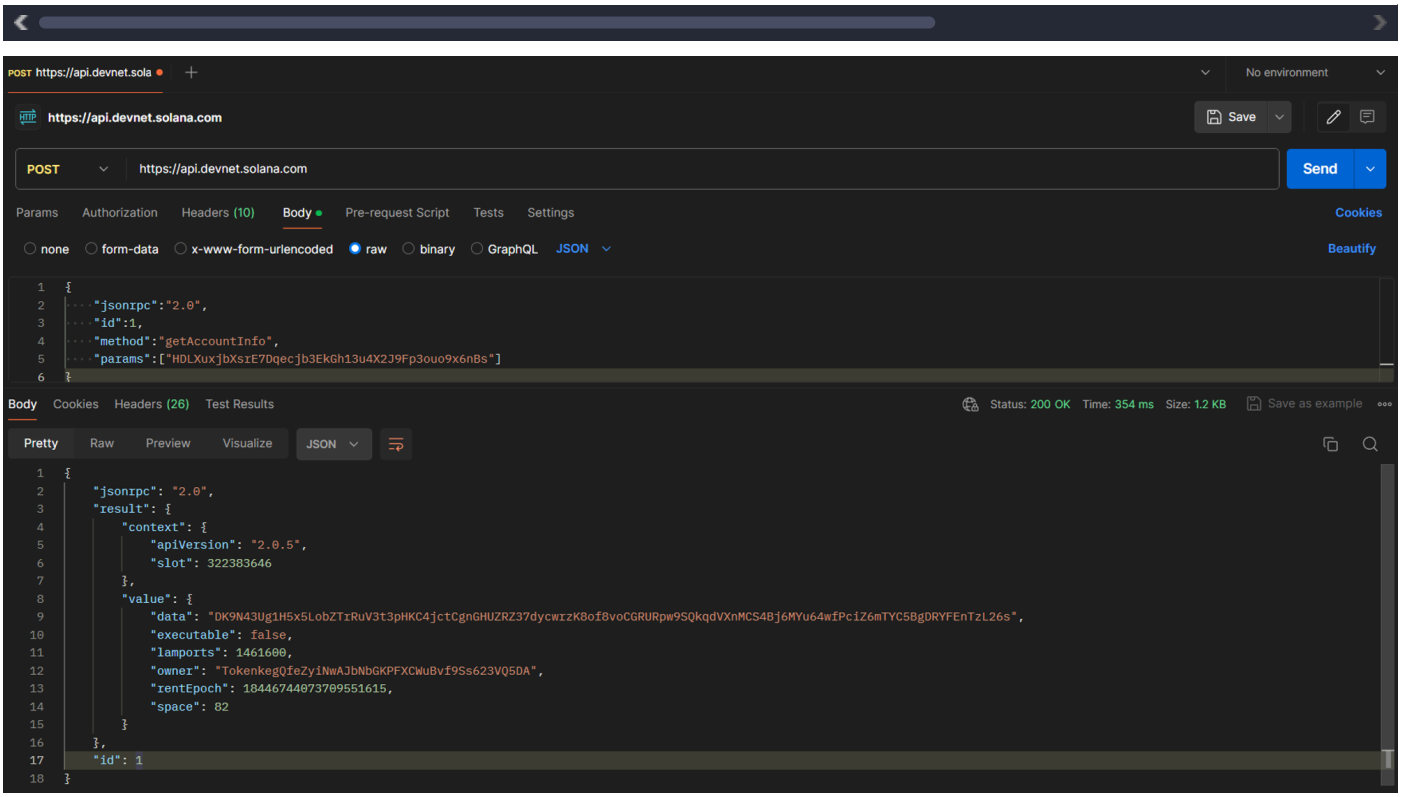


Postman Request

```
{
    "jsonrpc":"2.0",
    "id":1,
    "method":"getAccountInfo",
    "params":["HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs"]
}
```

Postman Response

```
{
    "jsonrpc": "2.0",
    "result": {
        "context": {
            "apiVersion": "2.0.5",
            "slot": 322383646
        },
        "value": {
            "data": "DK9N43Ug1H5x5LobZTrRuV3t3pHKC4jctCgnGHUZRZ37dycwrzK8of8voCGRURpw9SQkqd\
            "executable": false,
            "lamports": 1461600,
            "owner": "TokenkegQfeZyiNwAJbNbGKPFXCWuBvf9Ss623VQ5DA",
            "rentEpoch": 18446744073709551615,
            "space": 82
        }
    },
    "id": 1
}
```



> 💡 Explore Solana program library: solana-labs/solana-program-library: A collection of Solana programs maintained by Solana Labs (github.com)

▼ Check the supply of the token

```
spl-token supply HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs
```

▼ Create an `associated token account`

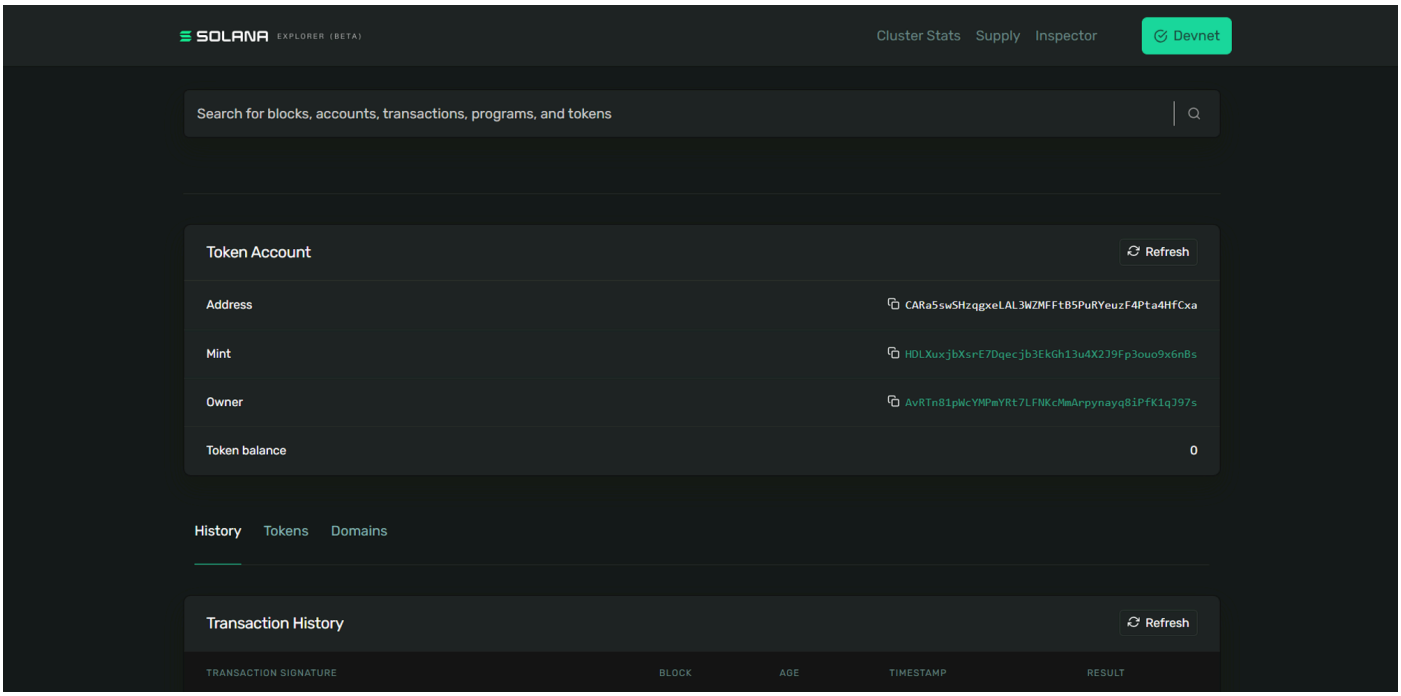
```
spl-token create-account HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs
```

Output:

Created an `associated token account` - `CARa5swSHzqgxeLAL3WZMFFtB5PuRYeuzF4Pta4HfCxa` for the `mint address` - `HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs`

```
Creating account CARa5swSHzqgxeLAL3WZMFFtB5PuRYeuzF4Pta4HfCxa

Signature: 3DYQya24H5Ds4TVfKDe4pNSFS4Y3XZfF6GJdDbjMNK5vsvLYAyPwWwYNrYNKuXN36FrZC9AFBWugXTyk7ABq9PUM
```

Explore on Solana explorer - Transaction History | CARa5swSHzqgxeLAL3WZMFFtB5PuRYeuzF4Pta4HfCxa | Solana



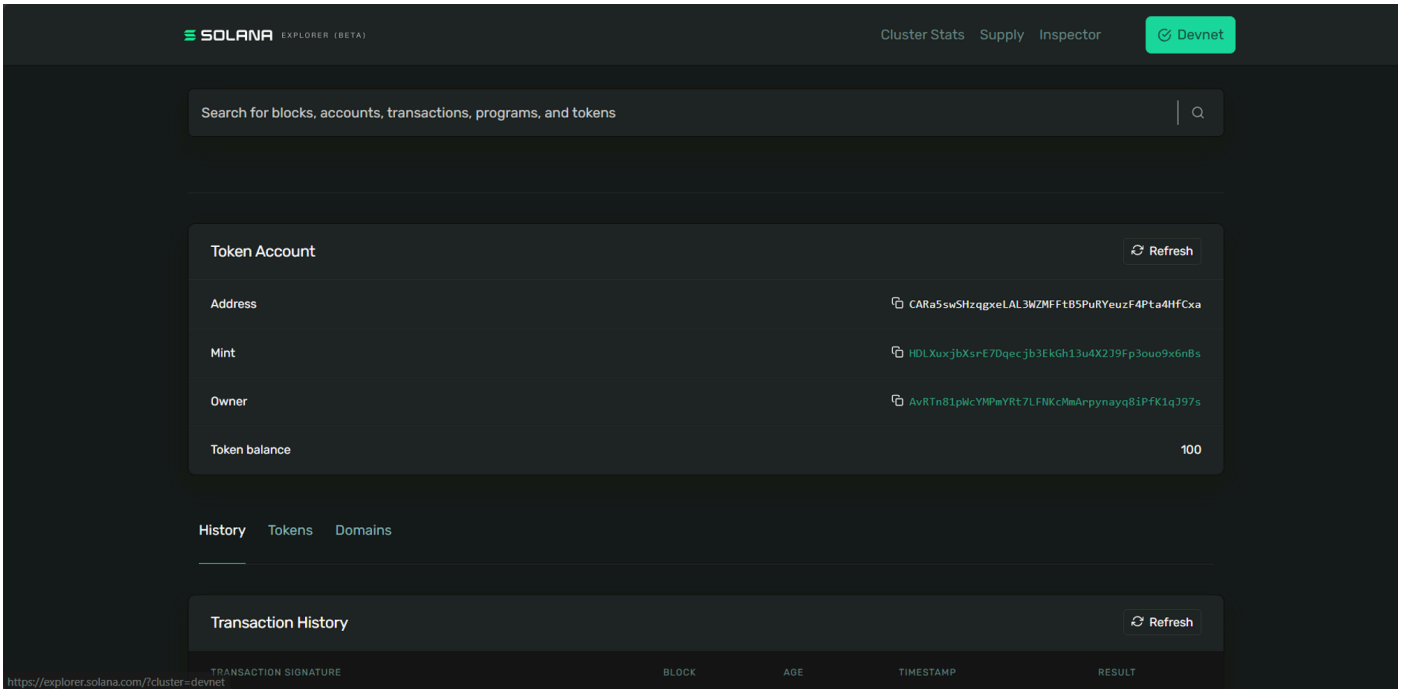
▼ Mint some tokens to yourself

```
spl-token mint HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs 100
```

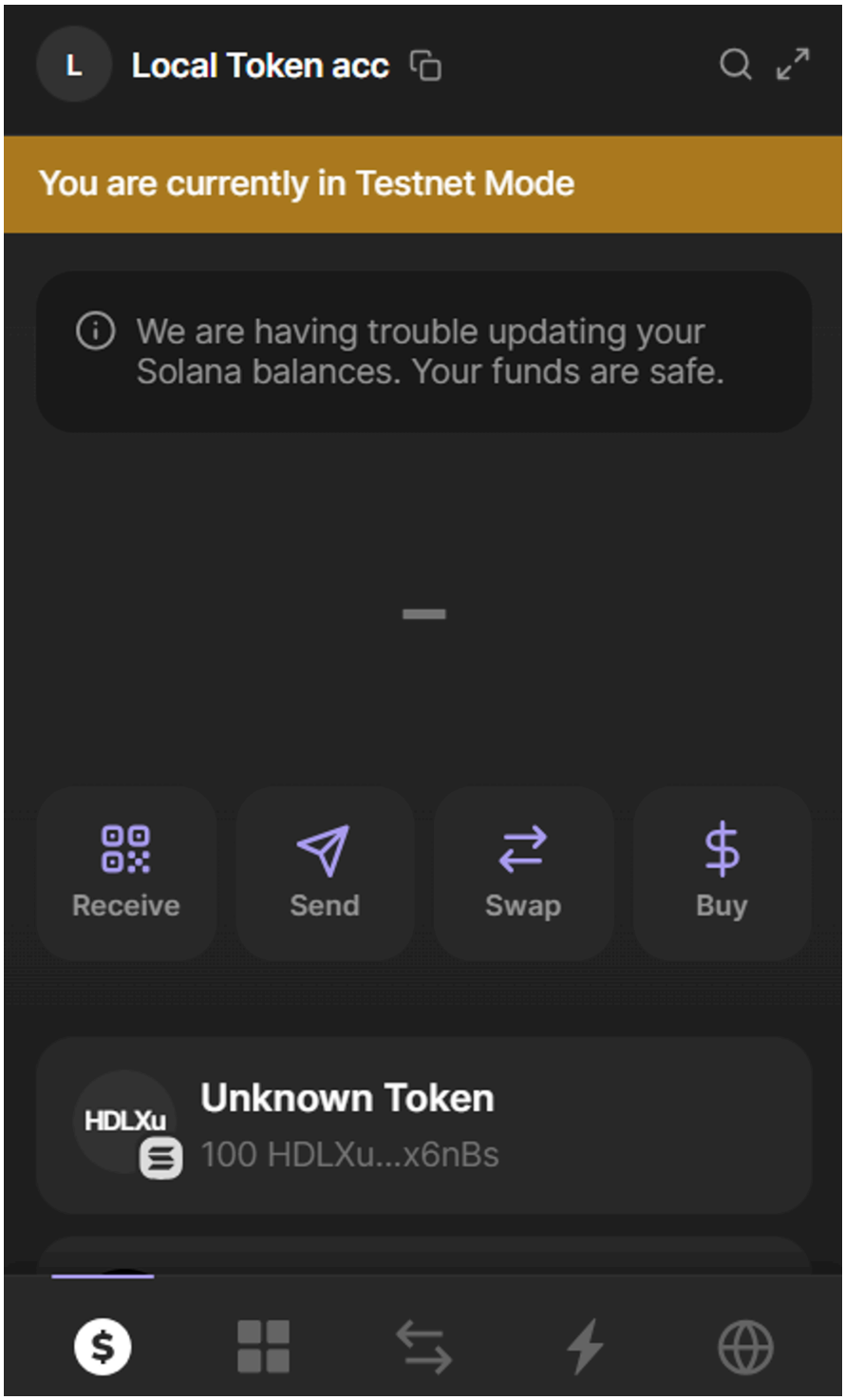
By default, the minted token goes to associated token account - `CARa5swSHzqgxeLAL3WZMFFtB5PuRYeuzF4Pta4HfCxa`

```
Minting 100 tokens
  Token: HDLXuxjbXsrE7Dqecjb3EkGh13u4X2J9Fp3ouo9x6nBs
  Recipient: CARa5swSHzqgxeLAL3WZMFFtB5PuRYeuzF4Pta4HfCxa

Signature: usMZZDdojQfcGYY78LTTxWiQ3kGFD1GMbgcRW8byqhzPtWdVBL1JAijnFBdAnX2UE4GRvoy2qDQa51Y3VcahLAh
```

Explore on - Transaction History | CARa5swSHzqgxeLAL3WZMFFtB5PuRYeuzF4Pta4HfCxa | Solana



▼ Import the token in Phantom and see the balances



Creating a Token using JavaScript

▼ Create a new CLI wallet, you can continue with your wallet as well

```
solana-keygen new
```

▼ Set the RPC URL

```
# Set RPC URL for Devnet
solana config set --url https://api.devnet.solana.com
```

▼ Create an empty JS file

```
npm init -y
touch index.js
```

▼ Install dependencies

```
npm install @solana/web3.js @solana/spl-token
```

▼ Write a function to airdrop yourself some Solana

```
const {Connection, LAMPORTS_PER_SOL, clusterApiUrl, PublicKey} = require('@solana/web3.js');

const connection = new Connection(clusterApiUrl('devnet'));

async function airdrop(publicKey, amount) {
    const airdropSignature = await connection.requestAirdrop(new PublicKey(publicKey), amour
    await connection.confirmTransaction({signature: airdropSignature})
}

airdrop("GokppTzVZi2LT1MSTWoEprM4YLDPy7wQ478Rm3r77yEw", LAMPORTS_PER_SOL).then(signature =>
    console.log('Airdrop signature:', signature);
});
```

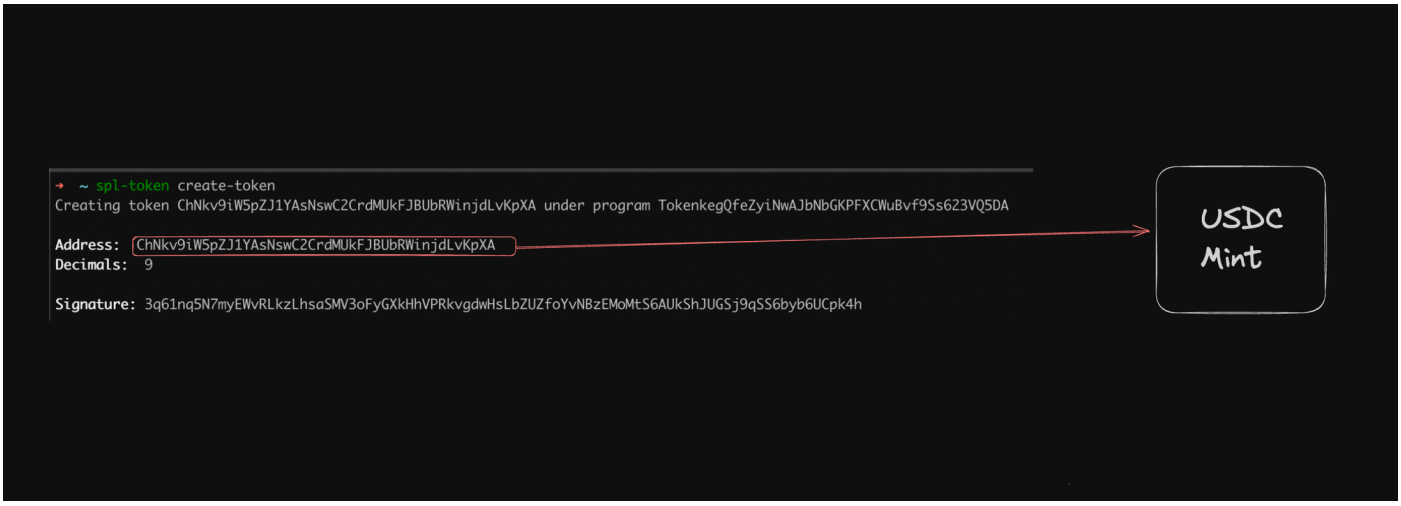
▼ Check your balance

```
solana balance
```

▼ Create token mint

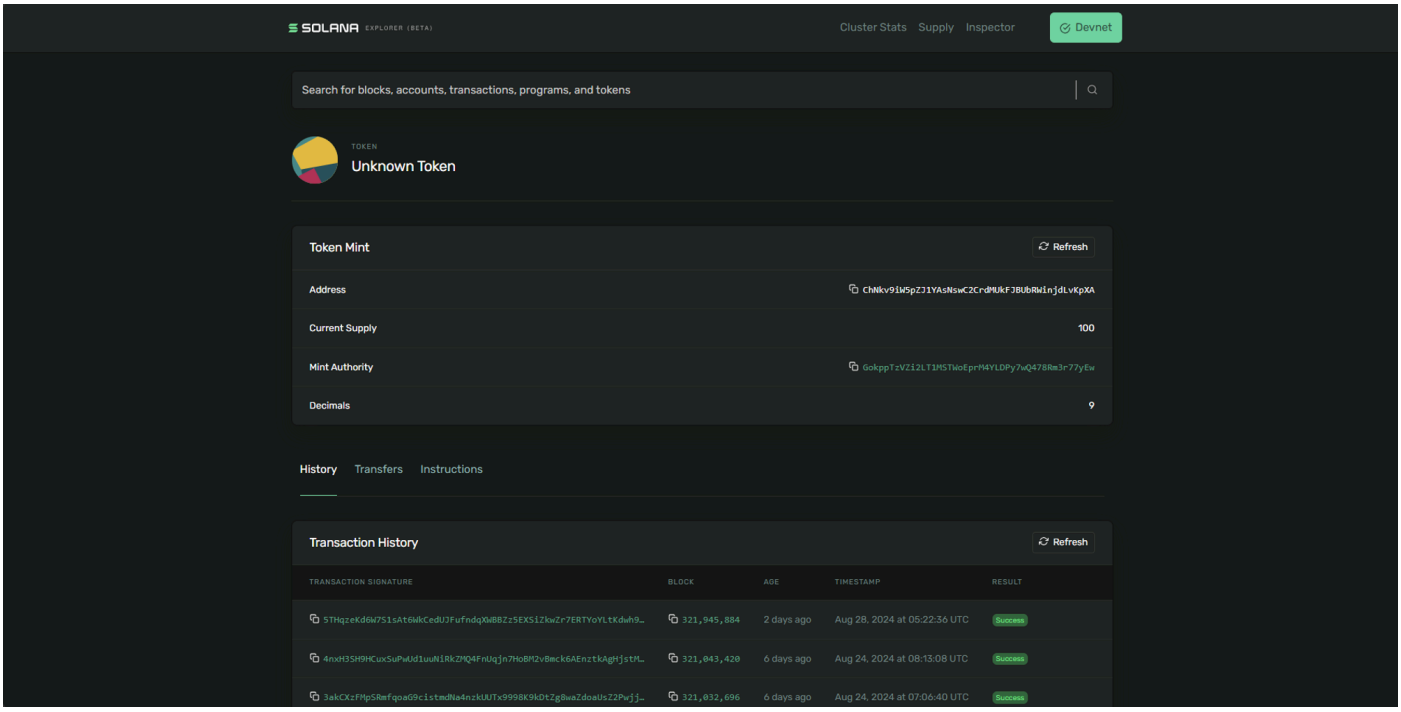
```
const { createMint } = require('@solana/spl-token');
const { Keypair, Connection, clusterApiUrl,  TOKEN_PROGRAM_ID } = require('@solana/web3.js')

const payer = Keypair.fromSecretKey(Uint8Array.from([102,144,169,42,220,87,99,85,100,128,197

const mintAthority = payer;

const connection = new Connection(clusterApiUrl('devnet'));

async function createMintForToken(payer, mintAuthority) {
    const mint = await createMint(
        connection,
        payer,
        mintAuthority,
        null,
        6,
        TOKEN_PROGRAM_ID
    );
    console.log('Mint created at', mint.toBase58());
```

```
    return mint;
}

async function main() {
    const mint = await createMintForToken(payer, mintAthority.publicKey);
}

main();
```



▼ Verify token mint on chain

Transaction History | ChNkv9iW5pZJ1YAsNswC2CrdMUkFJBUbRWinjdLvKpXA | Solana



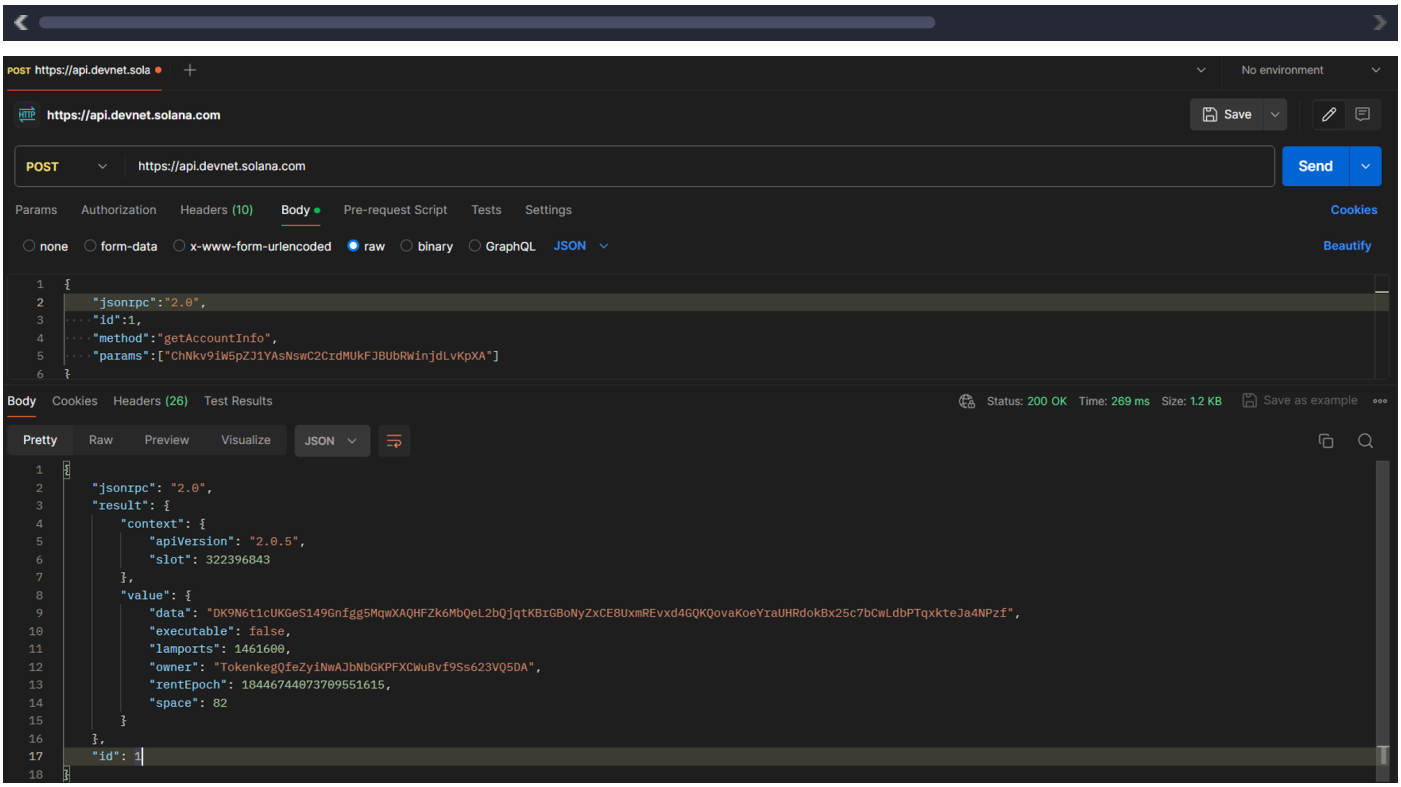
Postman Request

```
{
    "jsonrpc":"2.0",
    "id":1,
    "method":"getAccountInfo",
```

```
    "params":["ChNkv9iW5pZJ1YAsNswC2CrdMUkFJBUbRWinjdLvKpXA"]
}
```

Postman Response


```
{
    "jsonrpc": "2.0",
    "result": {
        "context": {
            "apiVersion": "2.0.5",
            "slot": 322396843
        },
        "value": {
            "data": "DK9N6t1cUKGeS149Gnfgg5MqwXAQHFZk6MbQeL2bQjqtKBrGBoNyZxCE8UxmREvxd4GQKQ
            "executable": false,
            "lamports": 1461600,
            "owner": "TokenkegQfeZyiNwAJbNbGKPFXCWuBvf9Ss623VQ5DA",
            "rentEpoch": 18446744073709551615,
            "space": 82
        }
    },
    "id": 1
}
```

▼ Create an `associated token account` , mint some tokens

```
const { createMint, getOrCreateAssociatedTokenAccount, mintTo } = require('@solana/spl-toker
const { Keypair, Connection, clusterApiUrl,  TOKEN_PROGRAM_ID, PublicKey } = require('@solar

const payer = Keypair.fromSecretKey(Uint8Array.from([102,144,169,42,220,87,99,85,100,128,19
```

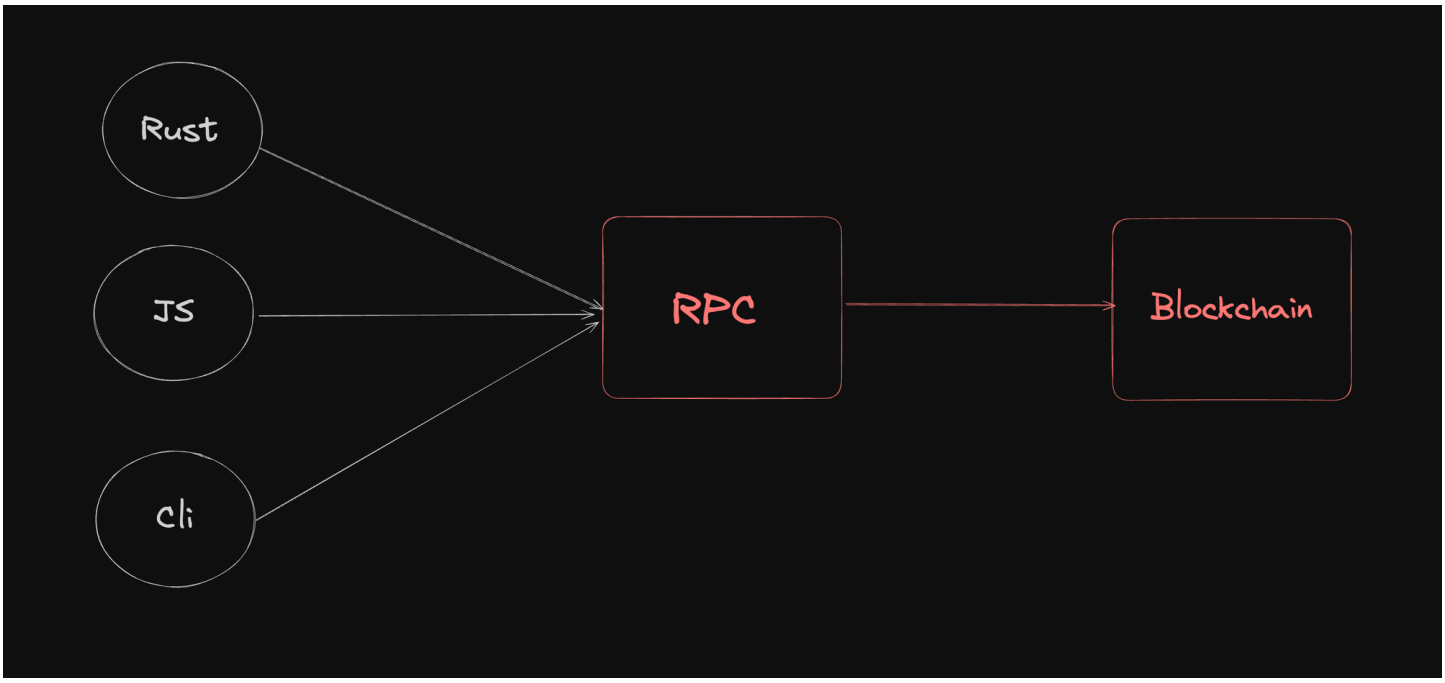
```
const mintAthority = payer;

const connection = new Connection(clusterApiUrl('devnet'));

async function createMintForToken(payer, mintAuthority) {
    const mint = await createMint(
        connection,
        payer,
        mintAuthority,
        null,
        6,
        TOKEN_PROGRAM_ID
    );
    console.log('Mint created at', mint.toBase58());
    return mint;
}

async function mintNewTokens(mint, to, amount) {
    const tokenAccount = await getOrCreateAssociatedTokenAccount(
        connection,
        payer,
        mint,
        new PublicKey(to)
      );

      console.log('Token account created at', tokenAccount.address.toBase58());
      await mintTo(
        connection,
        payer,
        mint,
        tokenAccount.address,
        payer,
        amount
      )
      console.log('Minted', amount, 'tokens to', tokenAccount.address.toBase58());
}

async function main() {
    const mint = await createMintForToken(payer, mintAthority.publicKey);
    await mintNewTokens(mint, mintAthority.publicKey, 100);
}

main();
```

- Check your balance in the explorer
- Import the token in Phantom and see the balances

Equivalent code in rust/python/go

Solana has libraries similar to `@solana/web3.js` in Rust, Python that would let you do the same thing.

In the end, they all are sending requests to an RPC server.



Token 22 program

- A token program on the Solana blockchain, defining a common implementation for fungible and non-fungible tokens.
- The Token-2022 Program, also known as Token Extensions, is a superset of the functionality provided by the Token Program.

> 💡 https://spl.solana.com/token-2022

▼ Create token mint

```
spl-token create-token  --program-id TokenzQdBNbLqP5VEhdkAS6EPFLC1PHnBqCXEpPxuEb
```

▼ Create an `associated token account`

```
spl-token create-account 8fTM5XYRaoTJU9PLUuyakF3EypQ4RXL5HxKtiw2z9pQQ
```

▼ Mint the tokens

```
spl-token mint 8fTM5XYRaoTJU9PLUuyakF3EypQ4RXL5HxKtiw2z9pQQ  100
```

Token 22 with metadata

> Metadata - https://cdn.100xdevs.com/metadata.json

▼ Create a token with metadata enabled

```
spl-token --program-id TokenzQdBNbLqP5VEhdkAS6EPFLC1PHnBqCXEpPxuEb create-token --enable-met
```

▼ Create metadata

```
spl-token initialize-metadata pXfZ6Hg2s78m1iSRVsdzos9TmfkqkQdv5MmQrr77ZQK 100xx 100xxx https
```

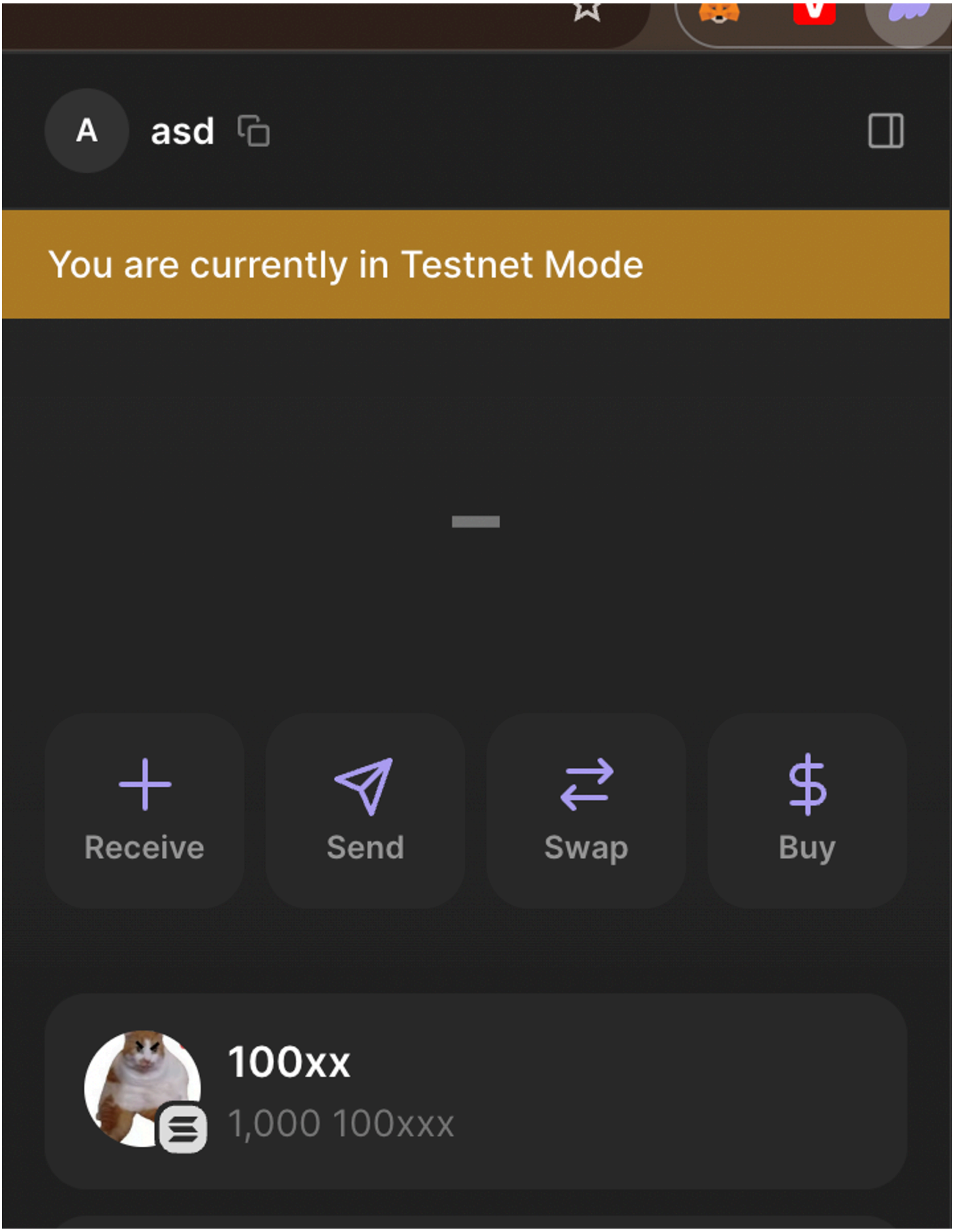
▼ Create `associated token account`

```
spl-token create-account pXfZ6Hg2s78m1iSRVsdzos9TmfkqkQdv5MmQrr77ZQK
```

▼ Mint

```
spl-token mint 1000
```

▼ Check out the token in your wallet


A
asd
You are currently in Testnet Mode
Receive
Send
Swap
Buy
100xx
1,000 100xxx