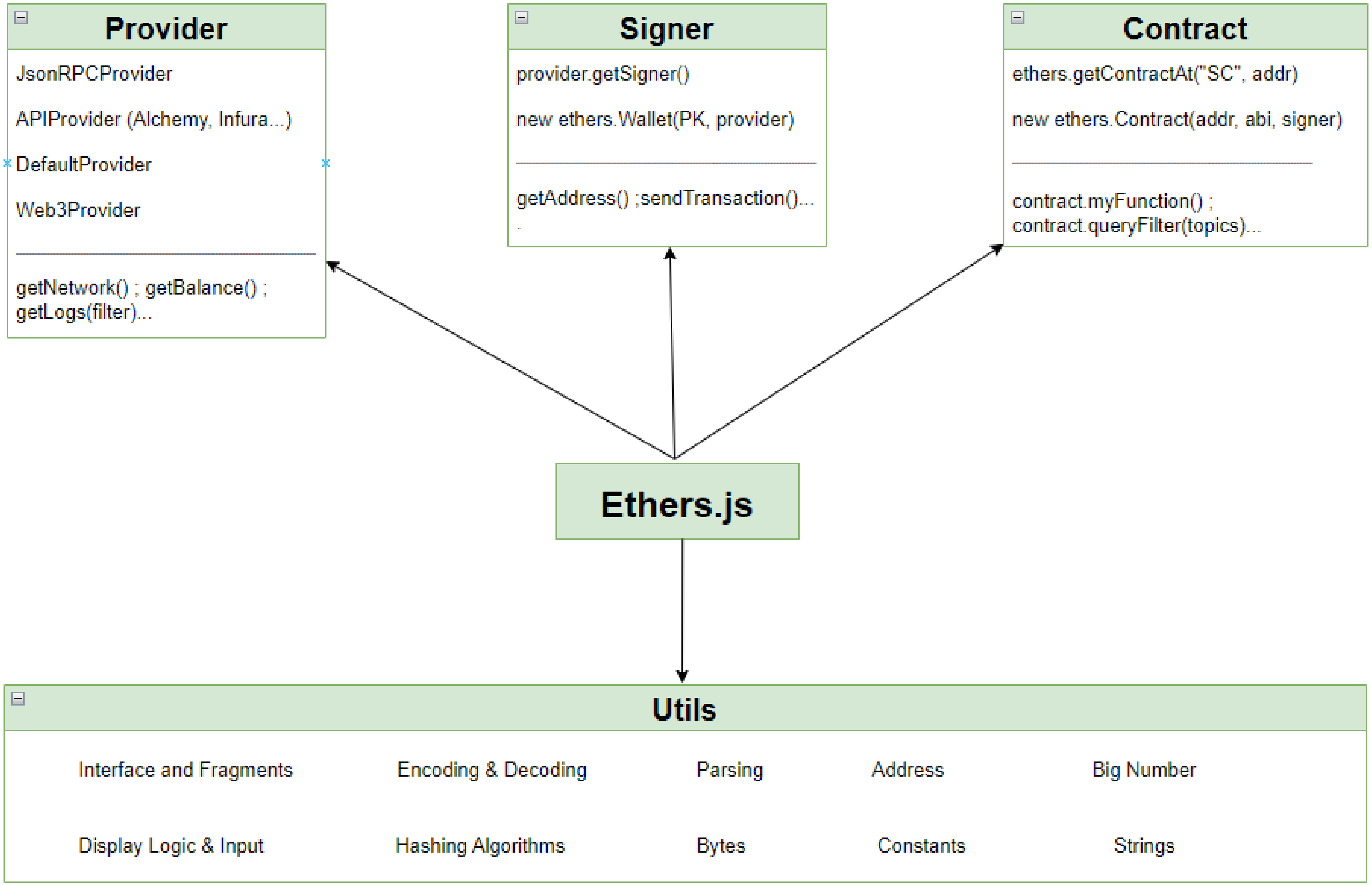
ETHEREUM SMART CONTRACT DEVELOPMENT

Ethers.js – Testing – ERC20 ERC721 – Reentrancy - DAO

Ethers.js

- JavaScript library for interacting with the Ethereum blockchain
- Facilitates the process of calling smart contract functions
- Most important classes: **Provider, Signer and Contract**
- Various utility classes (**Utils**) that facilitates the interaction with the ABI, the treatment of byte, string, address and BigNumber types...
- **Provider:** provides a connection to the Ethereum network - enables read-only access to the Blockchain
- **Signer:** has access to a private key and can sign messages and transactions
- **Contract:** provides a connection to a specific contract on the Ethereum Network



Provider

JsonRPCProvider

APIProvider (Alchemy, Infura...)

DefaultProvider

Web3Provider

getNetwork() ; getBalance() ;
getLogs(filter)...

Signer

provider.getSigner()

new ethers.Wallet(PK, provider)

getAddress() ;sendTransaction()...
.

Contract

ethers.getContractAt("SC", addr)

new ethers.Contract(addr, abi, signer)

contract.myFunction() ;
contract.queryFilter(topics)...

Ethers.js

Utils

Interface and Fragments

Encoding & Decoding

Parsing

Address

Big Number

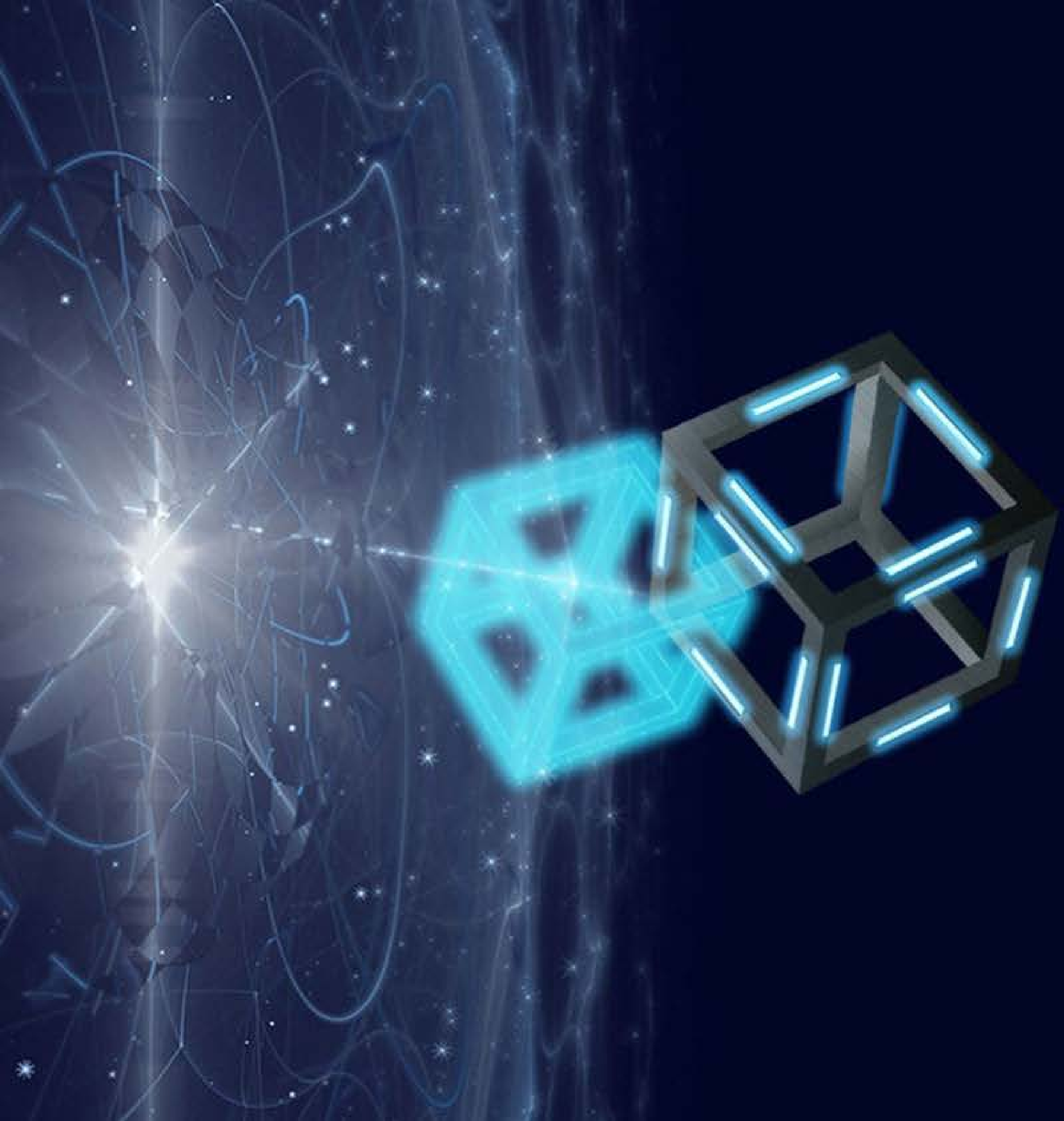
Display Logic & Input

Hashing Algorithms

Bytes

Constants

Strings



Ethers.js - Provider

Ethers.js - Provider

- Enables read-only access the blockchain, a signer provides read/write access

- For a local blockchain like Ganache or Hardhat, use the ***JsonRpcProvider***:
  *provider = new ethers.**JsonRpcProvider**("http://localhost:8545")*

- To connect to a remote blockchain, it is recommended to use a third party provider:
  *provider = new ethers.**AlchemyProvider**((network = "sepolia"), MYAPIKEY)*

- Instead of using a third party provider, you can also use the **defaultProvider**. Ethers.js offers default API keys for free, however, the number of network requests will be very limited:
  *provider = ethers.**getDefaultProvider**((network = "sepolia"))*

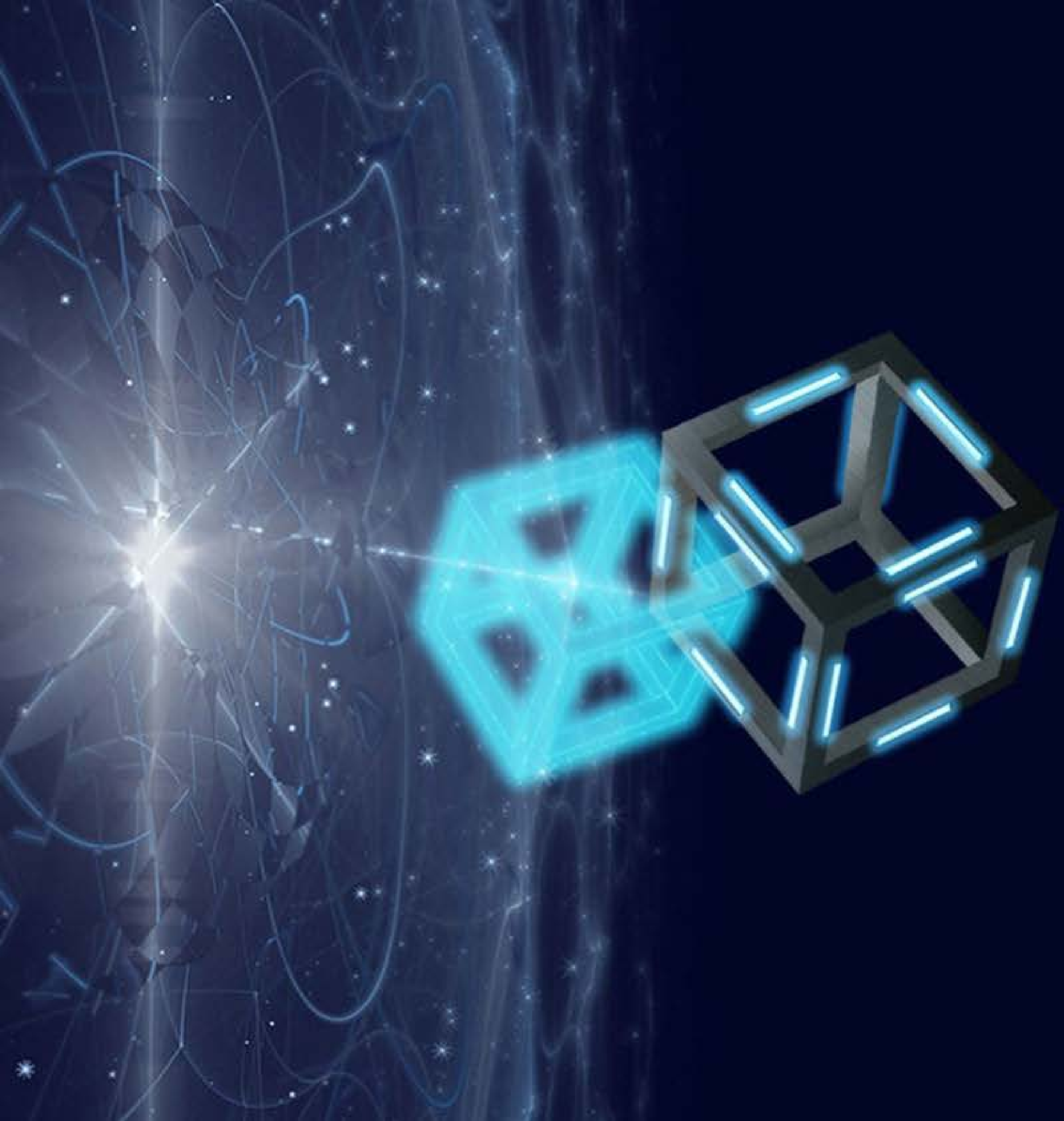
- For web apps that use Metamask (uses Infura internally), use the ***BrowserProvider***:
  *provider = new ethers.**BrowserProvider**(window.ethereum)*

- In Hardhat, we can configure a list of networks in hardhat.config.js – according to the used network, Hardhat injects the correct provider into the **ethers** class, which can be accessed via: *provider = ethers.provider*

Ethers.js - Provider

Properties & methods:

- provider.getNetwork() //details about the currently used network
- provider.getBalance("0x123...")
- provider.getTransactionCount("0x123...")
- provider.getBlockNumber ()
- provider.getGasPrice() //estimation of gas price in wei
- provider.getFeeData() //estimation for maxFeePerGas, maxPriorityFeePerGas
- Various methods to listen to events and to return logs for a provided filter...



Ethers.js - Signer

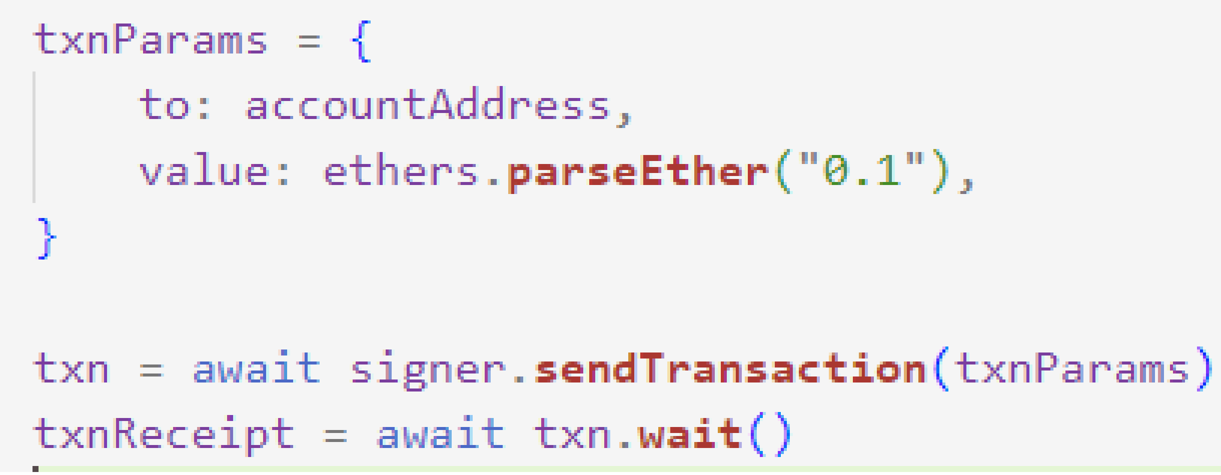
Ethers.js - Signer

- Abstraction of an Ethereum Account. Can be used to sign and send transactions

- **JsonRpcSigner**: connected to a **JsonRpcProvider** (local node) - acquired via:
  *signer = provider.**getSigner()***

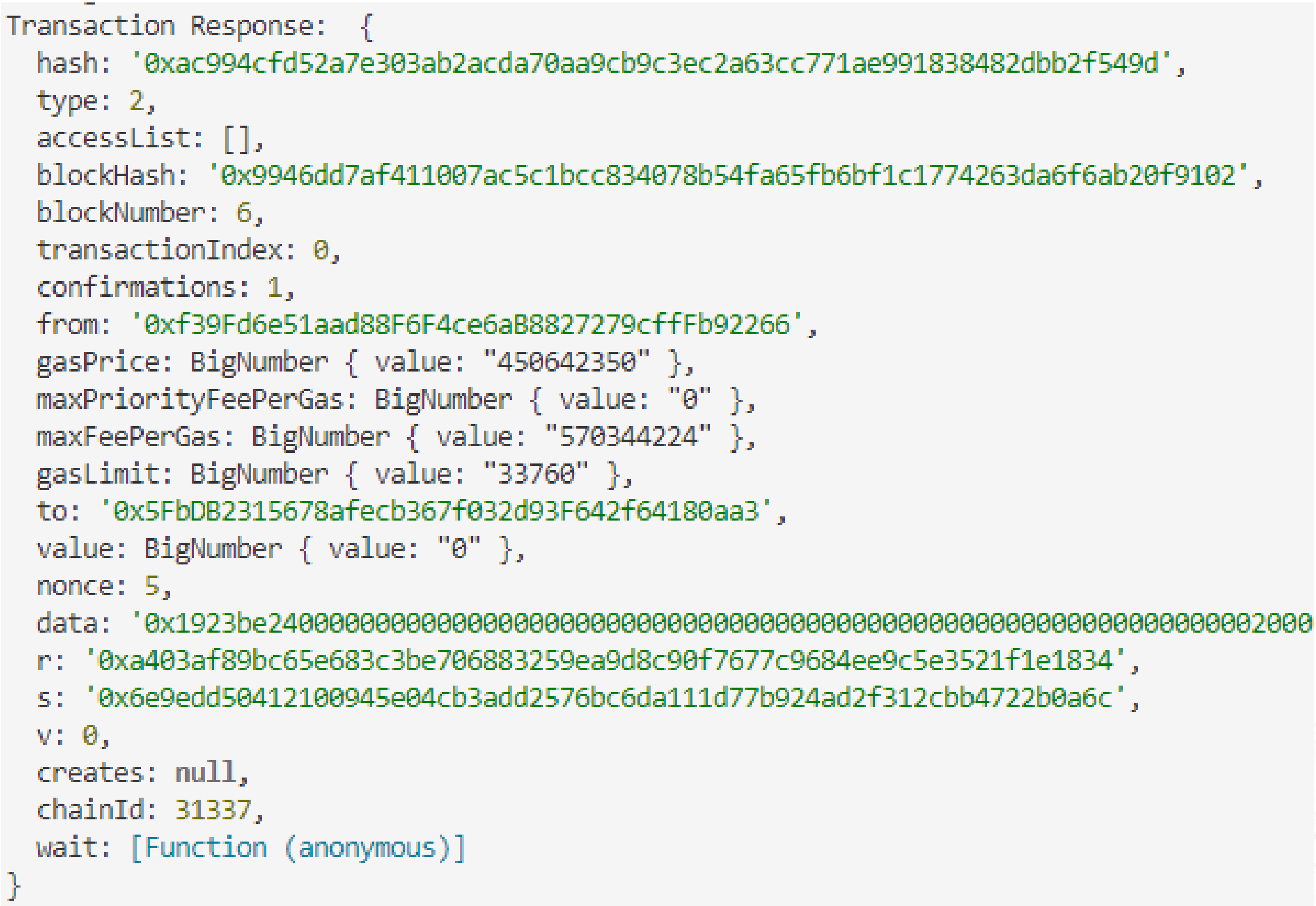
- Wallet: knows its private key and can sign transactions:
  *signer = new ethers.**Wallet**(privateKey , provider)*

Example transaction:



```
txnParams = {
    to: accountAddress,
    value: ethers.parseEther("0.1"),
}

txn = await signer.sendTransaction(txnParams)
txnReceipt = await txn.wait()
```

Ethers.js – Example Transaction

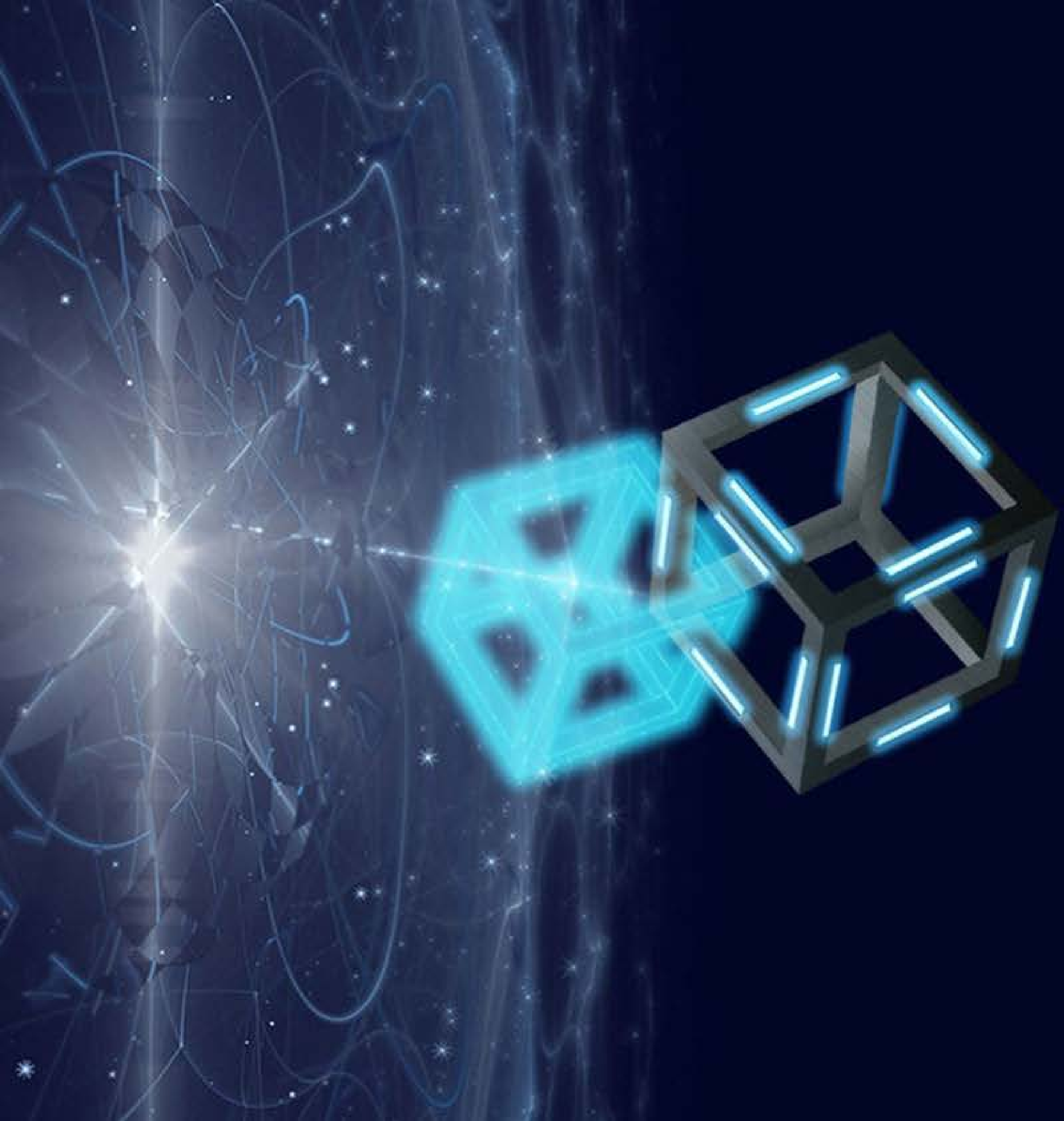


```
Transaction Response:  {
  hash: '0xac994cfd52a7e303ab2acda70aa9cb9c3ec2a63cc771ae991838482dbb2f549d',
  type: 2,
  accessList: [],
  blockHash: '0x9946dd7af411007ac5c1bcc834078b54fa65fb6bf1c1774263da6f6ab20f9102',
  blockNumber: 6,
  transactionIndex: 0,
  confirmations: 1,
  from: '0xf39Fd6e51aad88F6F4ce6aB8827279cffFb92266',
  gasPrice: BigNumber { value: "450642350" },
  maxPriorityFeePerGas: BigNumber { value: "0" },
  maxFeePerGas: BigNumber { value: "570344224" },
  gasLimit: BigNumber { value: "33760" },
  to: '0x5FbDB2315678afecb367f032d93F642f64180aa3',
  value: BigNumber { value: "0" },
  nonce: 5,
  data: '0x1923be2400000000000000000000000000000000000000000000000000000000000002000
  r: '0xa403af89bc65e683c3be706883259ea9d8c90f7677c9684ee9c5e3521f1e1834',
  s: '0x6e9edd50412100945e04cb3add2576bc6da111d77b924ad2f312cbb4722b0a6c',
  v: 0,
  creates: null,
  chainId: 31337,
  wait: [Function (anonymous)]
}
```

Ethers.js - Signer

Properties & methods:

- signer.getAddress()
- signer.getNonce()
- signer.estimateGas(transactionRequest)
- signer.signTransaction(tx)
- signer.sendTransaction(tx)



Ethers.js
Contract, Logs, Events & Filters

Ethers.js - Contract

Used to communicate with a deployed contract. This class needs to know what methods are available and it gets this information from the ABI :

*contract = await ethers.**getContractAt**("HelloWorld", contractAddress)*

*contract = new ethers.**Contract**(contractAddress, abi, signerOrProvider)*

Properties & methods:

- contract.target
- contract.provider
- contract.signer
- contract.connect(signerOrProvider) //new contract instance connected to signer or provider
- *(returnValue1, returnValue22...) = contract.myReadMethod(arg1, arg2...)*
- *txn = contract.myWriteMethod(arg1, arg2...)*

Ethers.js – Events, Logs & Filters

- Logs and filters allow for efficient queries of indexed data and provide low-cost data storage if the data is not required to be accessed on-chain (cannot be accessed by contract)

- Up to 3 event arguments can be indexed (**Topics**) for efficient filtering when a contract emits an event.

Accessing / listening to logs from the provider class:

- *provider.**getLogs**(filter)* //returns an array of logs: data, blockNumber, txnHash...
- *provider.**on**(filter, (log) => { console.log(log)...}* //fromBlock & toBlock are not used

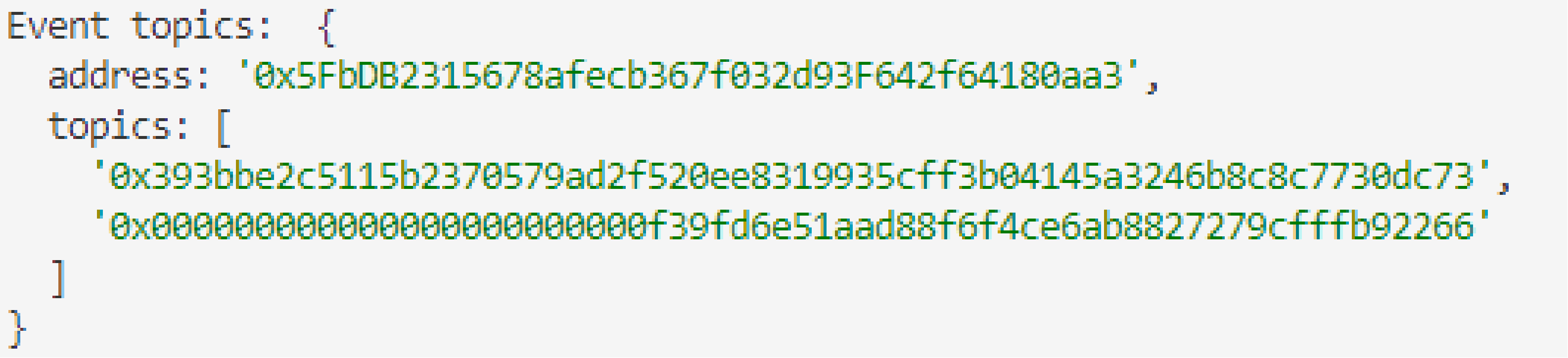
- Properties of the filter object: **fromBlock** (number or “latest”), **toBlock, address, topics**

Ethers.js – Events, Logs & Filters

Accessing / listening to logs from the contract class:

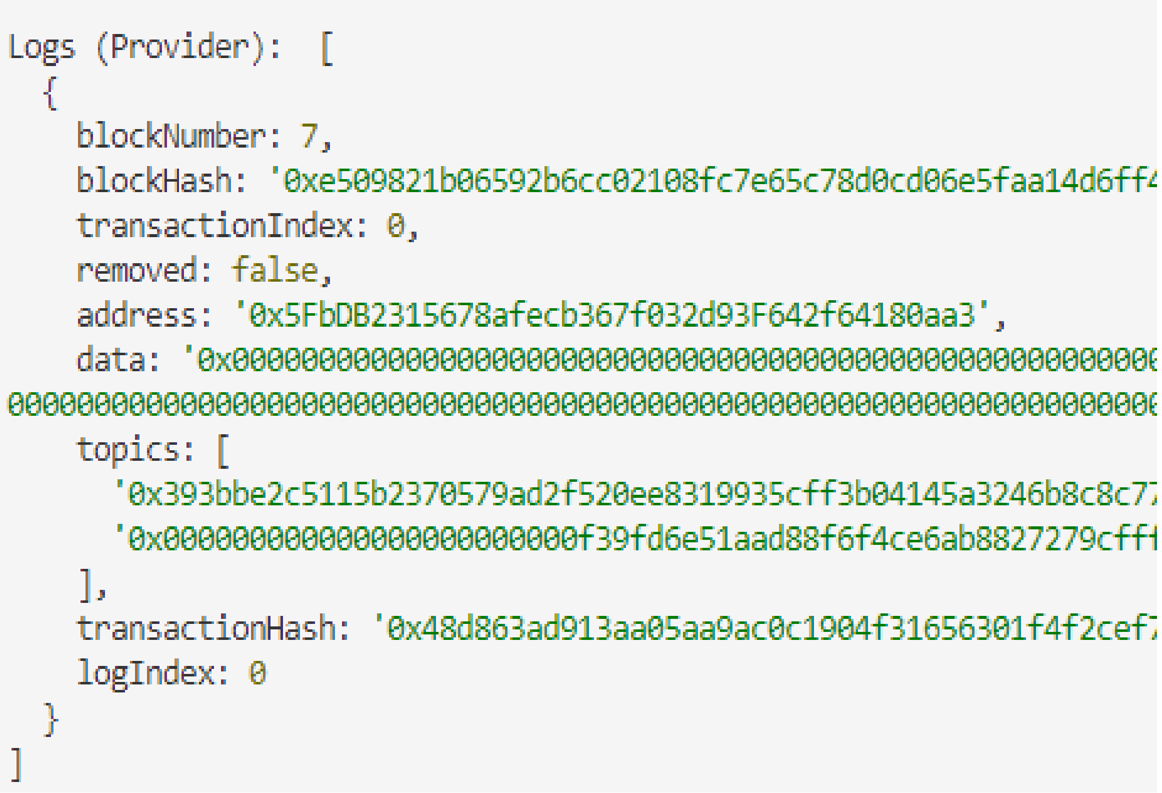
- *myEvents = await contract.**queryFilter**(filter, "latest", "latest")*
- *contract.on(**filter,** (event) => { console.log(event)...}*

// returns a list of topics for a specific Event – null means any match
***filter** = contract.filters.UpdateMessage(someAddress, null, null)*

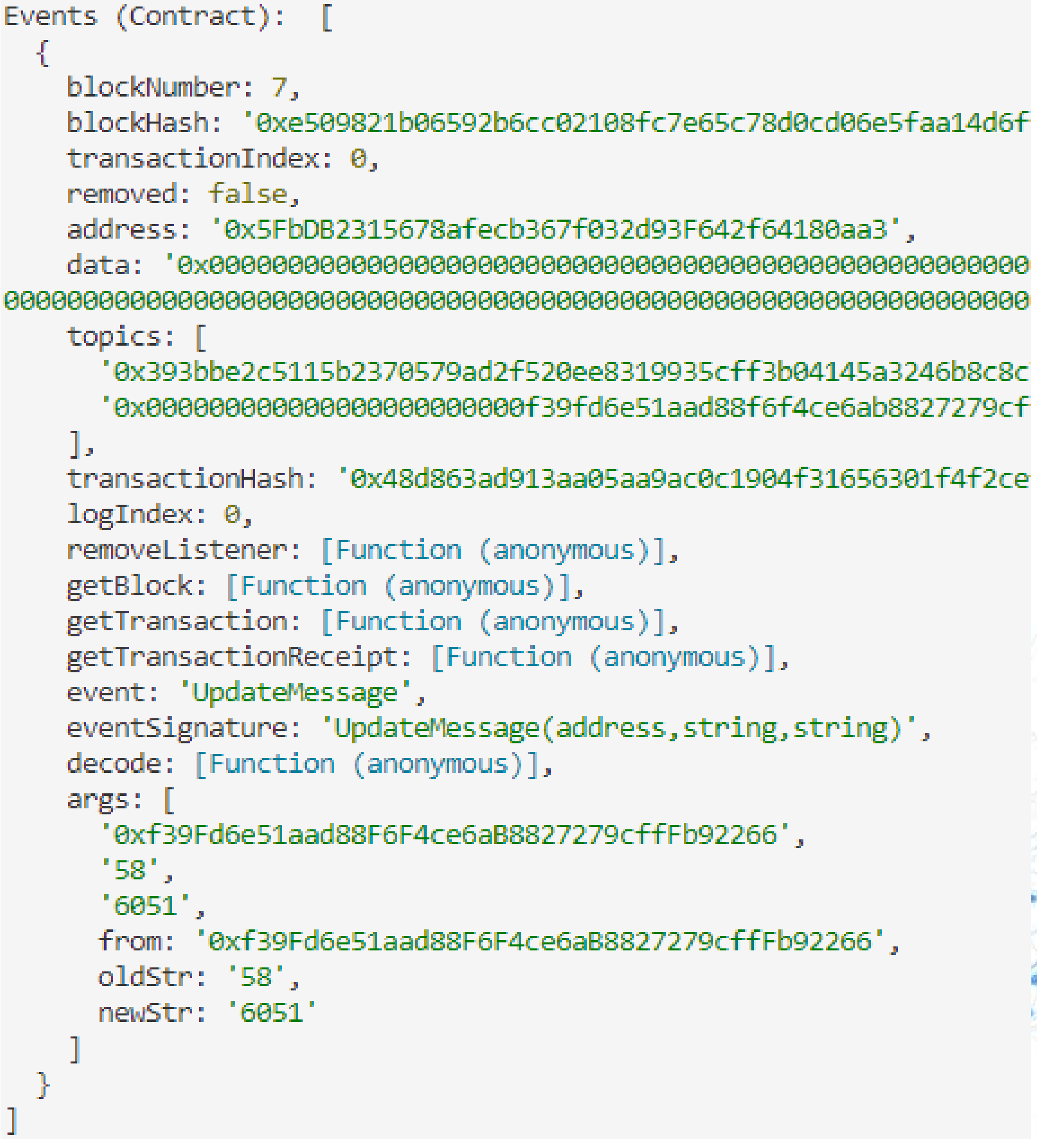


```
Event topics:  {
  address: '0x5FbDB2315678afecb367f032d93F642f64180aa3',
  topics: [
    '0x393bbe2c5115b2370579ad2f520ee8319935cff3b04145a3246b8c8c7730dc73',
    '0x000000000000000000000000f39fd6e51aad88f6f4ce6ab8827279cfffb92266'
  ]
}
```

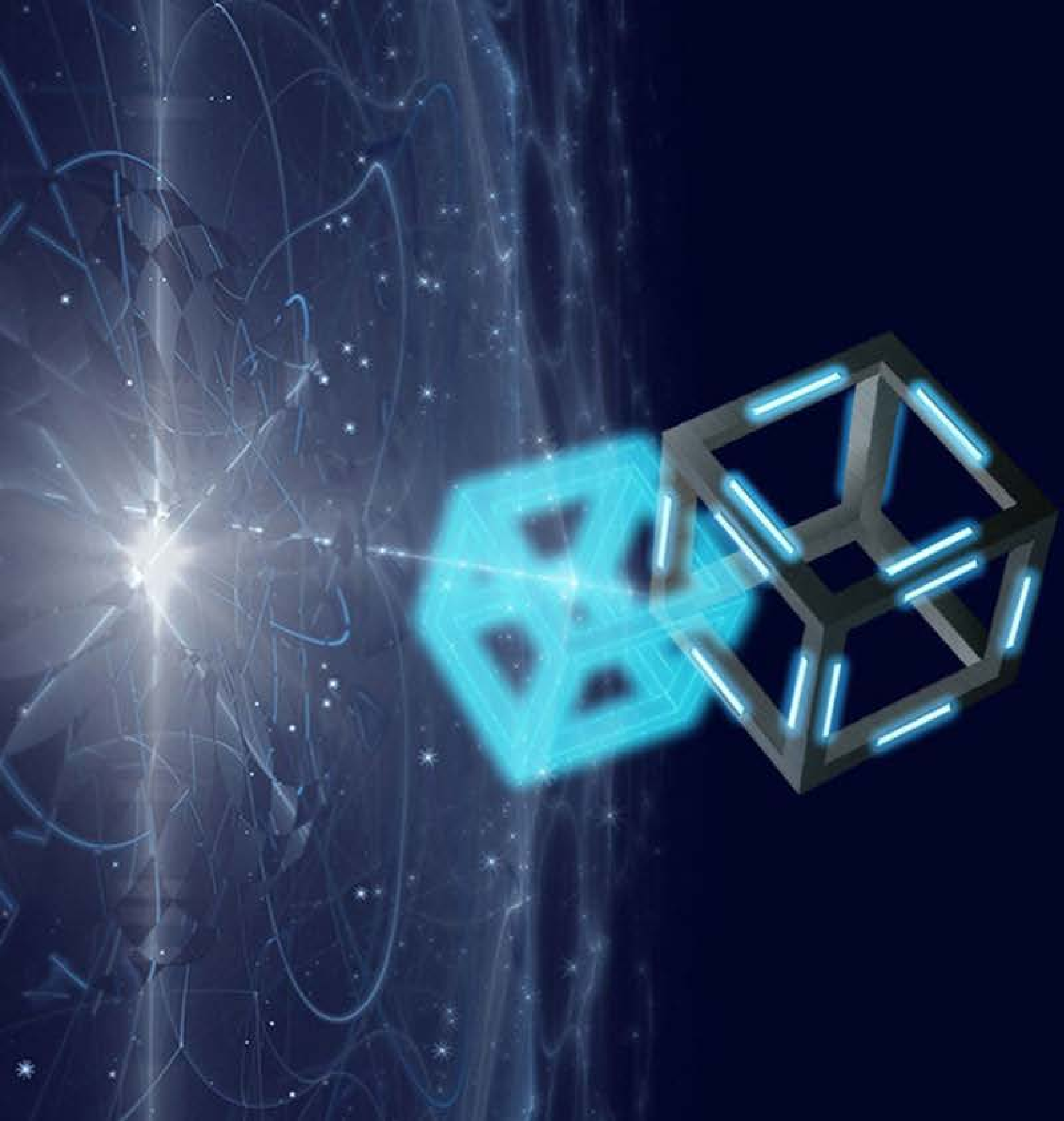
Ethers.js – Logs From Provider & Contract



```
Logs (Provider):  [
  {
    blockNumber: 7,
    blockHash: '0xe509821b06592b6cc02108fc7e65c78d0cd06e5faa14d6ff
    transactionIndex: 0,
    removed: false,
    address: '0x5FbDB2315678afecb367f032d93F642f64180aa3',
    data: '0x0000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000
    topics: [
      '0x393bbe2c5115b2370579ad2f520ee8319935cff3b04145a3246b8c8c7
      '0x000000000000000000000000f39fd6e51aad88f6f4ce6ab8827279cff
    ],
    transactionHash: '0x48d863ad913aa05aa9ac0c1904f31656301f4f2cef
    logIndex: 0
  }
]
```



```
Events (Contract):  [
  {
    blockNumber: 7,
    blockHash: '0xe509821b06592b6cc02108fc7e65c78d0cd06e5faa14d6f
    transactionIndex: 0,
    removed: false,
    address: '0x5FbDB2315678afecb367f032d93F642f64180aa3',
    data: '0x0000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000
    topics: [
      '0x393bbe2c5115b2370579ad2f520ee8319935cff3b04145a3246b8c8c
      '0x000000000000000000000000f39fd6e51aad88f6f4ce6ab8827279cf
    ],
    transactionHash: '0x48d863ad913aa05aa9ac0c1904f31656301f4f2ce
    logIndex: 0,
    removeListener: [Function (anonymous)],
    getBlock: [Function (anonymous)],
    getTransaction: [Function (anonymous)],
    getTransactionReceipt: [Function (anonymous)],
    event: 'UpdateMessage',
    eventSignature: 'UpdateMessage(address,string,string)',
    decode: [Function (anonymous)],
    args: [
      '0xf39Fd6e51aad88F6F4ce6aB8827279cffFb92266',
      '58',
      '6051',
      from: '0xf39Fd6e51aad88F6F4ce6aB8827279cffFb92266',
      oldStr: '58',
      newStr: '6051'
    ]
  }
]
```



Ethers.js - Utils

Ethers.js – Interface

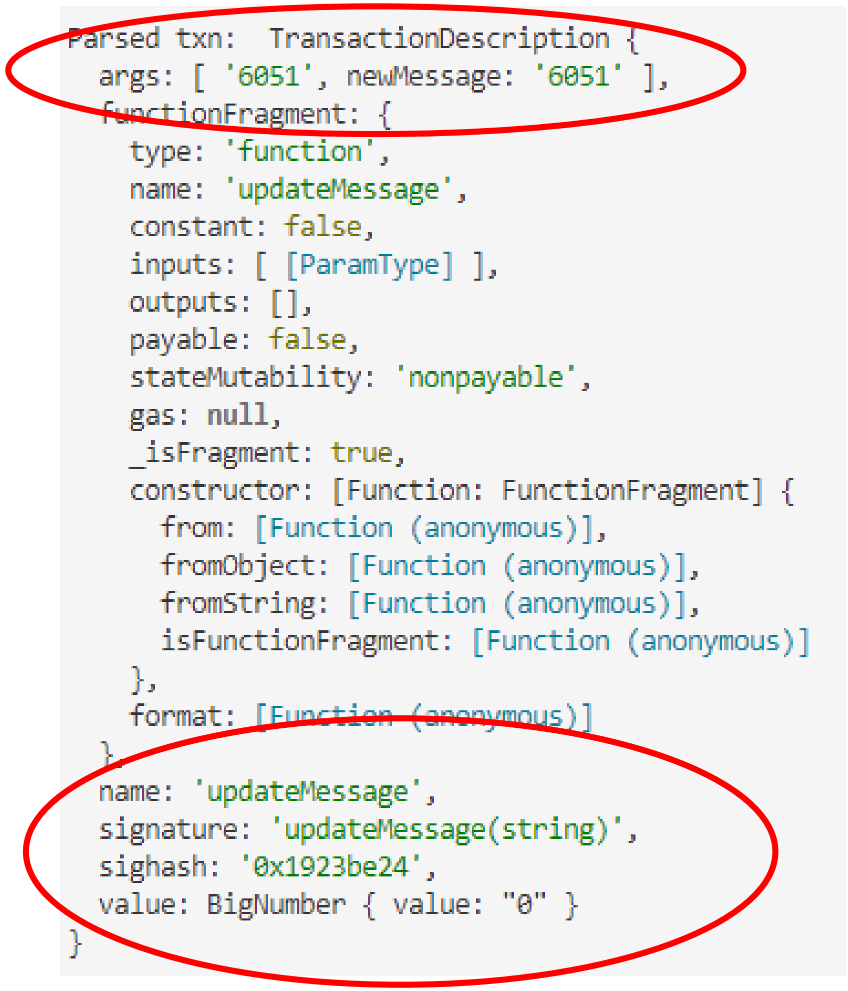
```
iface = new ethers.Interface(["function updateMessage(string newMessage)"])
iface  = new ethers.Interface(contractJson.abi)
```

Encoding & Decoding:

```
encodedFunction = iface.encodeFunctionData("updateMessage", ["test"]) // hex string

// decode provided argument values from txn.data => returns: [ ‘test', newMessage: ‘test' ]
argValues = iface.decodeFunctionData("updateMessage", txn.data)

// get the function selector (4 bytes) => calldata for method call
sigHash = iface.getFunction("updateMessage").selector
```

Ethers.js – ParseTransaction

*parsedTxn = iface.**parseTransaction**({ data: txn.data })*

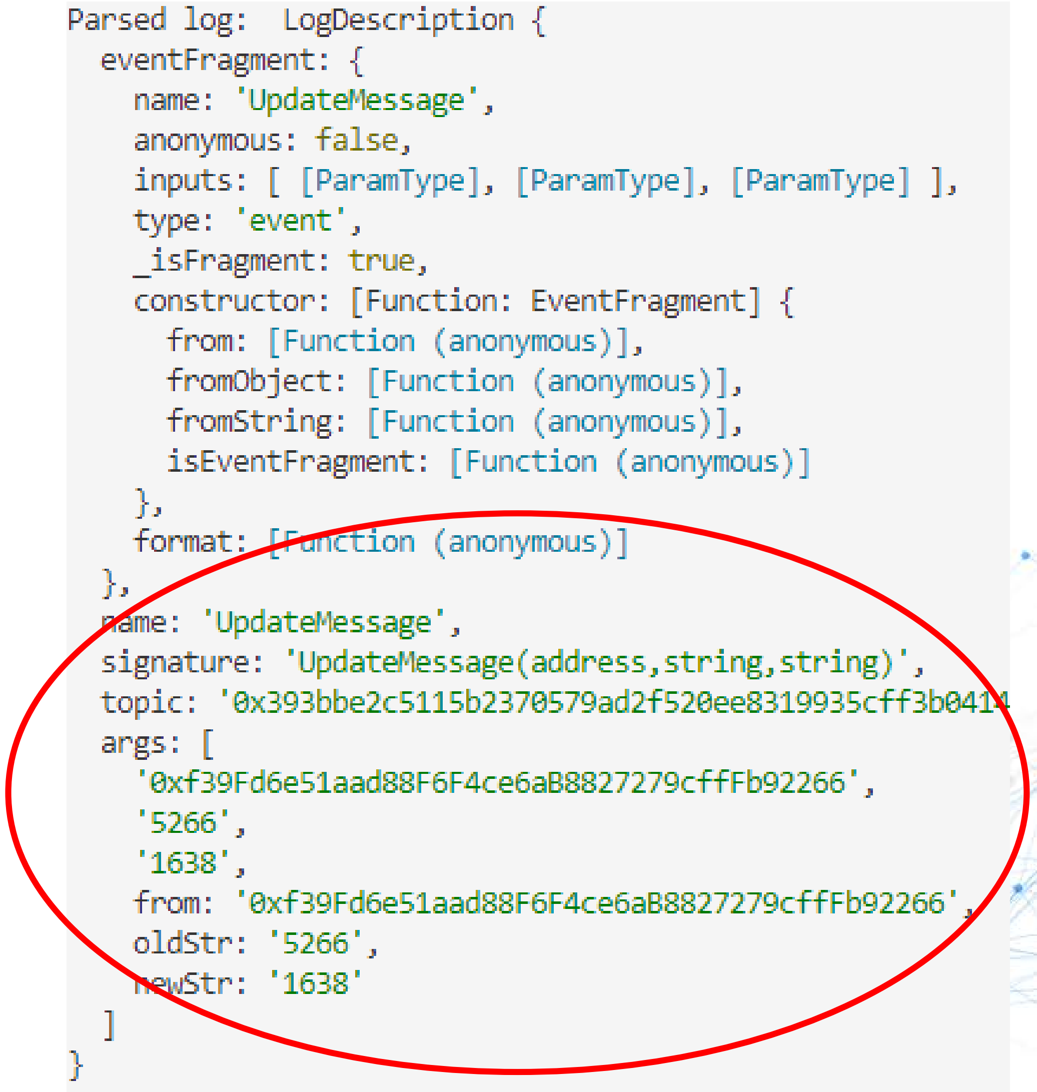


```
Parsed txn:  TransactionDescription {
  args: [ '6051', newMessage: '6051' ],
  functionFragment: {
    type: 'function',
    name: 'updateMessage',
    constant: false,
    inputs: [ [ParamType] ],
    outputs: [],
    payable: false,
    stateMutability: 'nonpayable',
    gas: null,
    _isFragment: true,
    constructor: [Function: FunctionFragment] {
      from: [Function (anonymous)],
      fromObject: [Function (anonymous)],
      fromString: [Function (anonymous)],
      isFunctionFragment: [Function (anonymous)]
    },
    format: [Function (anonymous)]
  },
  name: 'updateMessage',
  signature: 'updateMessage(string)',
  sighash: '0x1923be24',
  value: BigNumber { value: "0" }
}
```

Ethers.js – ParseLog

topics = ["0x393...", "0x749..."]

*log = iface.**parseLog**({ data: txnRec.logs[0].data, topics })*



```
Parsed log:  LogDescription {
  eventFragment: {
    name: 'UpdateMessage',
    anonymous: false,
    inputs: [ [ParamType], [ParamType], [ParamType] ],
    type: 'event',
    _isFragment: true,
    constructor: [Function: EventFragment] {
      from: [Function (anonymous)],
      fromObject: [Function (anonymous)],
      fromString: [Function (anonymous)],
      isEventFragment: [Function (anonymous)]
    },
    format: [Function (anonymous)]
  },
  name: 'UpdateMessage',
  signature: 'UpdateMessage(address,string,string)',
  topic: '0x393bbe2c5115b2370579ad2f520ee8319935cff3b0414
  args: [
    '0xf39Fd6e51aad88F6F4ce6aB8827279cffFb92266',
    '5266',
    '1638',
    from: '0xf39Fd6e51aad88F6F4ce6aB8827279cffFb92266',
    oldStr: '5266',
    newStr: '1638'
  ]
}
```

Ethers.js – Address & Byte Manipulation

Address:

- *ethers.getAddress("0x8ba1f...")* // return checksum address
- *ethers.computeAddress(publicOrPrivateKey)*

Byte manipulation:

// converts DataHexString to a Uint8Array

ethers.getBytes("0x1234") // Uint8Array [18, 52]

// converts a number to Hex

ethers.toBeHex(1) // 0x01

Ethers.js – BigInt

Allows mathematical operations on numbers of any magnitude.

- *let n1 = 10n*
- *let n2 = BigInt("0x32") // 50n*

- *let n3 = n1 + 20n // 30n*
- *let n4 = Number(n1) + 20*

Conversion:

- let myHexString = n1.toString(16) *// 0x10*

Ethers.js – Display Logic & Input

formatUnits formats a BigInt to a string, which is useful when displaying a balance:

ethers.**formatUnits**(value [, unit = "ether"]) ⇒ string (in wei)

```
ethers.formatUnits(oneGweiBigInt, "gwei") // '1'
ethers.formatUnits(oneGweiBigInt, 9) // '1‘
ethers.formatUnits(oneGweiBigInt, 0) // '1000000000 ‘
ethers.formatEther(oneGweiBigInt) // '0.000000001'
```

parseUnits parses a string representing ether, into a BigInt in wei:

ethers.**parseUnits**(value [, unit = "ether"]) ⇒ BigInt (in wei)

```
ethers.parseUnits("12", "gwei") // 12000000000n
ethers.parseUnits("12", 9)  // 12000000000n
ethers.parseEther("12") // 12000000000000000000n
```

Ethers.js – Strings & Hashing Algorithms

User provides string data in frontend => convert to bytes32 => send to smart contract

this is much cheaper than working with strings in smart contracts

- *ethers.encodeBytes32String("hello")* // convert string to a bytes32
- *ethers.decodeBytes32String("0x68656c6c6f000...")* // convert bytes32 to string

- *ethers.toUtf8Bytes("hello")* // convert string to UTF8 byte array [104, 101, ...]
- *ethers..toUtf8String(new UintArray([104, 101, 108, 108, 111]))* // convert UTF8 byte array to string

Hashing Algorithms:

- *ethers.keccak256("0x1234")* // Keccak256 of hex string : HexString32
- *ethers.id("UpdateMessage(address,string,string)")* // event topic : HexString32

Ethers.js – Transactions & Constants

Transaction parameters: hash, to, from, nonce, data, value, gasLimit ,
maxFeePerGas, maxPriorityFeePerGas, v, r, s

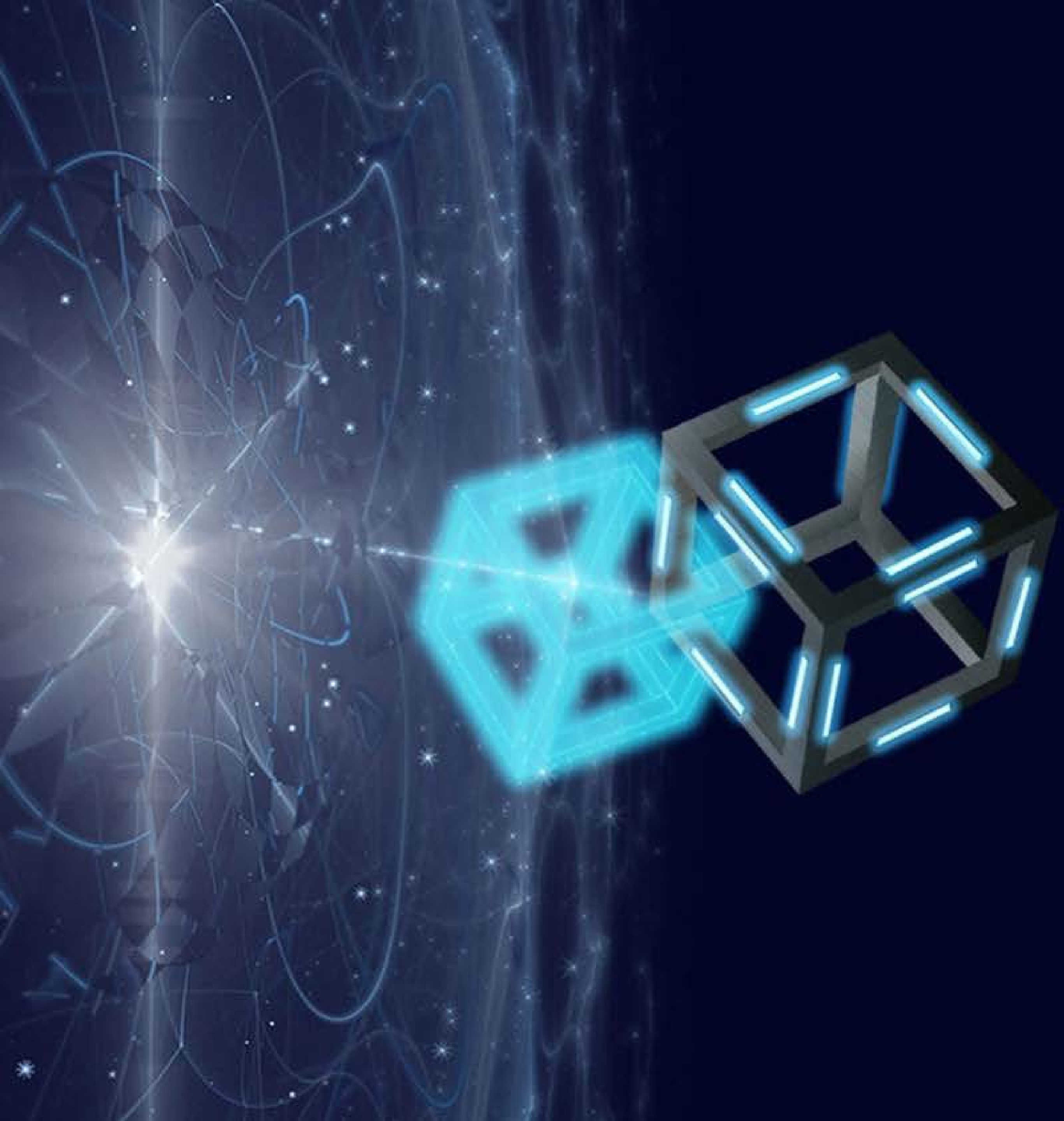
```
txnParams = {   to: account2Address,
                value: ethers.utils.parseEther("1.0"),
                data: encodedFunction  }
```

```
ethers.Transaction.from(txnParams).unsignedSerialized // hexString : 0xf88c0a...
ethers.Transaction.from(txnSerialized) // { to:... , value:... , data:... }
```

Constants:

ethers.ZeroAddress ⇒ Address (20 bytes)

etherss.WeiPerEther ⇒ BigInt



Metamask RPC API

Metamask RPC API

- Metamask uses Infura (third party node provider) to connect to the blockchain
- Metamask communicates with the blockchain (full node) via JSON RPC
- Metamask is compatible with any blockchain that exposes an Ethereum-compatible JSON RPC API (interface between client and full node)
- For example, to retrieve the account balance, MetaMask can make a HTTP request to a full node, invoking the ***eth_getBalance*** RPC function with my address as a parameter
- A web app can interact with Metamask via the ***window.ethereum*** object. This API allows websites to request user accounts, read data from the blockchains, sign a transactions

Metamask RPC API

A DAPP needs to do the following:

- Detect the Ethereum provider injected by Metamask (**window.ethereum**)
- Verify if the DAPP is already connected with one or more accounts managed by MetaMask and return those accounts
- Display all accounts that are managed by MetaMask and return the selected ones
- Detect network and account changes

Metamask RPC API

Submitting RPC requests to Ethereum via MetaMask:

```
window.ethereum.request(object)
```

Get a list of all MetaMask accounts that are already connected with the DAPP:

```
accounts = await window.ethereum.request({ method: 'eth_Accounts' })
```

Enable a DAPP on Metamask (select account(s) in popup):

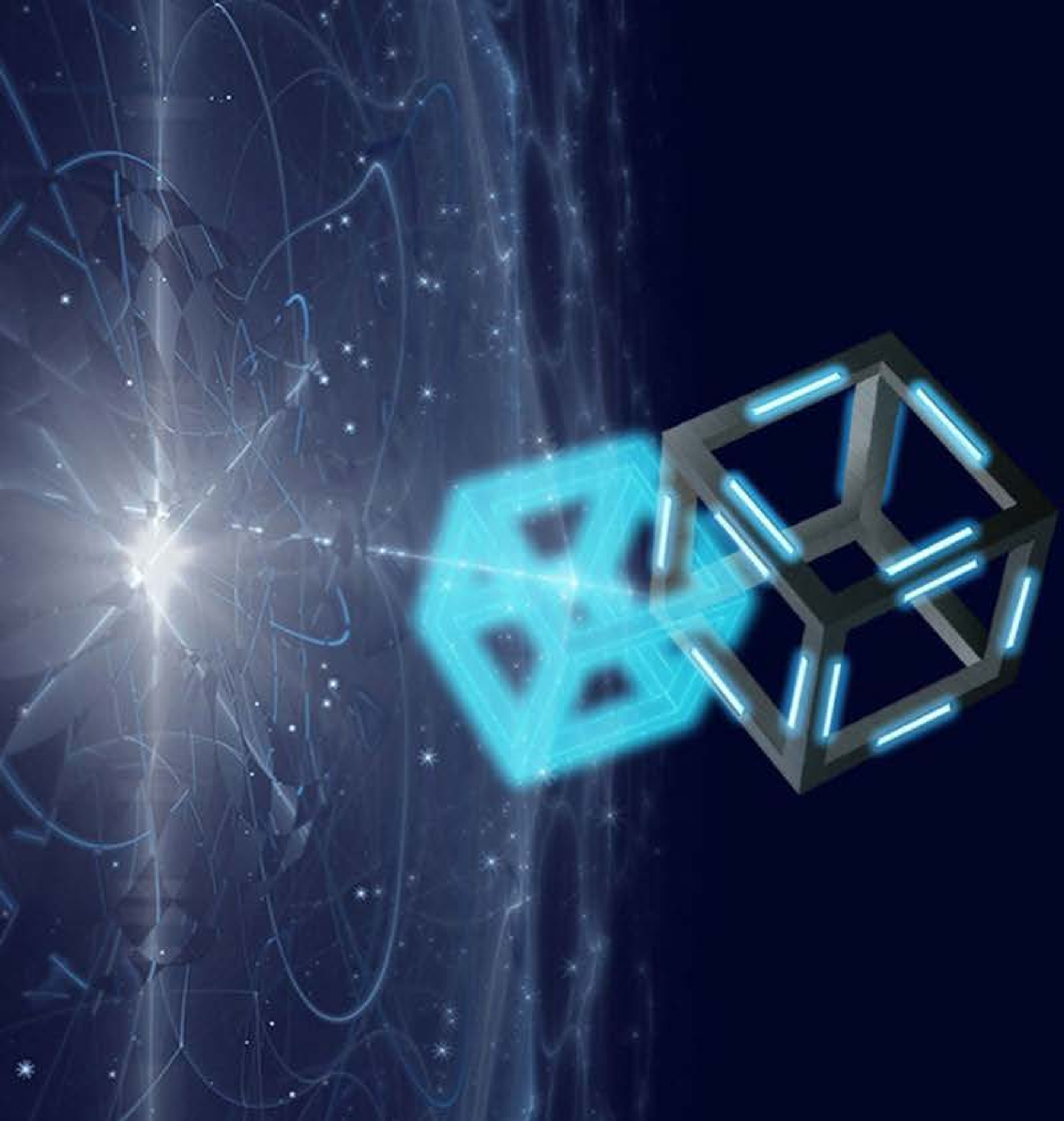
```
accounts = await window.ethereum.request({ method: 'eth_requestAccounts' })
```

React if the user changes the network or account:

```
window.ethereum.on('accountsChanged', function (accounts) { // reload page... })
window.ethereum.on('chainChanged', function (chainId) { // reload page... })
```

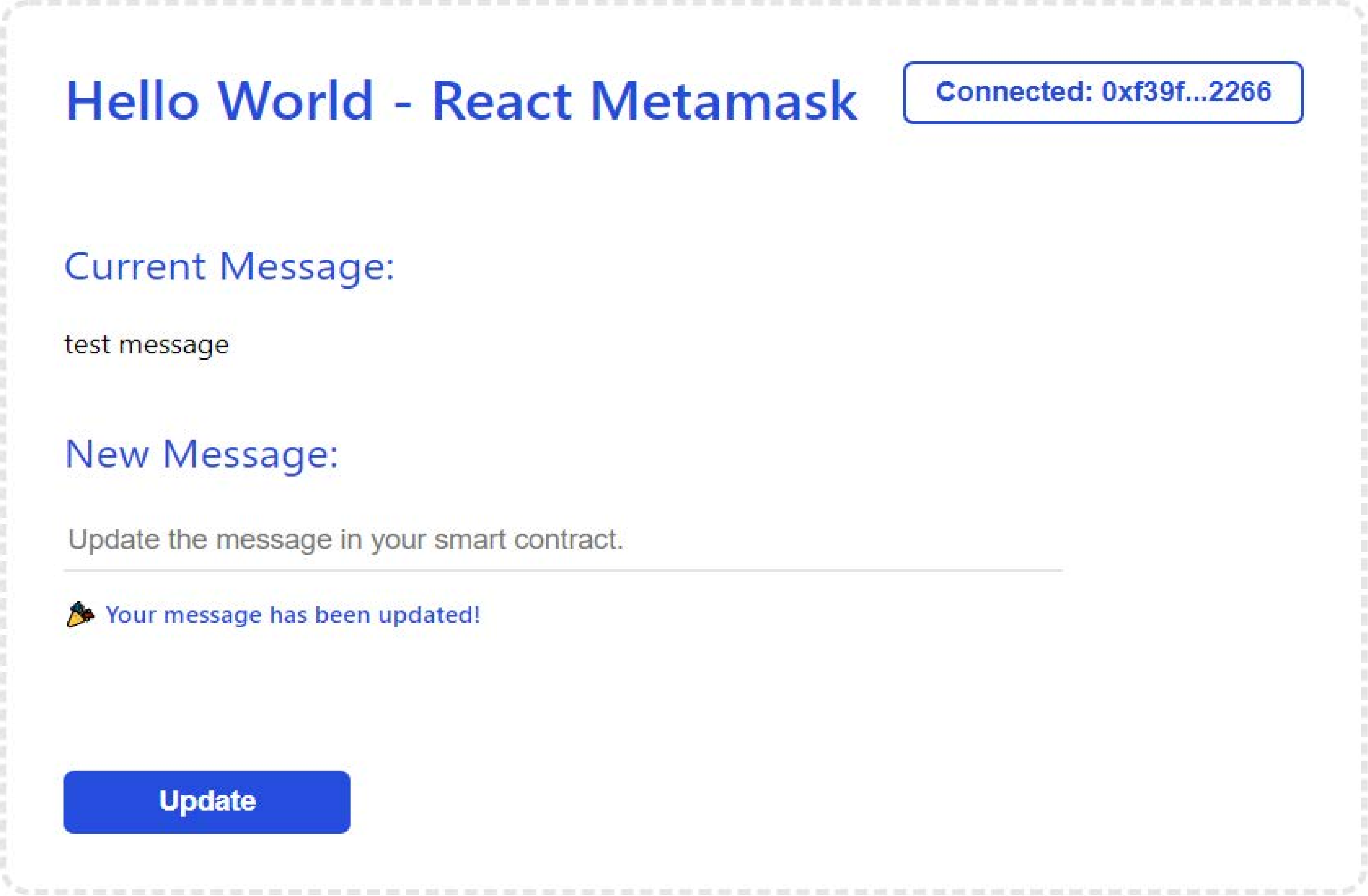
Metamask RPC API – Send Transaction

```
const txnParameters = {
  gasPrice: '0x09184e72a000', // customizable by user during MetaMask confirmation.
  to: '0x123...', // required except during contract publications.
  from: myAddress, // must match user's active address.
  value: '0x0', // only required to send ether
  data: '0x7f746573743200000000000000000...'
};

const txHash = await window.ethereum.request({
  method: 'eth_sendTransaction',
  params: [txnParameters],
});
```



React DAPP Project

React Web App Using Ethers.js



Hello World - React Metamask

Current Message:

test message

New Message:

Update the message in your smart contract.

🎉 Your message has been updated!

React Web App Using Ethers.js

Requirements:

- Create a React application (javascript-swc) : ***npm create vite@latest app-name*** => npm install => npm run dev
- Retrieve accounts from Metamask and allow the app to be connected to one or more accounts: ***request({method: "eth_requestAccounts"...***
- Whenever the app starts, verify if there are already any connected accounts: ***request({method: "eth_accounts"...***
- Retrieve the current message value and display it in the UI
- Allow the message to be updated from the UI by sending a transaction to Metamask: ***request({method: "eth_sendTransaction"...***
- Update the UI when the transaction has been mined and the message value has been updated on the blockchain: ***contract.on("UpdateMessage“...***

React Web App Using Ethers.js - Exercise

Exercise – interact.js:

- Add the provider
- Export the contract
- Get already connected Metamask accounts => ***eth_accounts*** and log a message whenever the network or an account changes => ***accountsChanged & chainChanged*** in **getCurrentWalletConnected**()
- Get all addresses from metamask => ***eth_requestAccounts*** in connectWallet()
- Return the initial message from the contract in **loadCurrentMessage**()
- In **updateMessage**() : encode the function we want to call ; set up transaction parameters => transactionParameters : to, from, data ; send the transaction using Metamask => ***eth_sendTransaction*** , return txHash

React Web App Using Ethers.js - Exercise

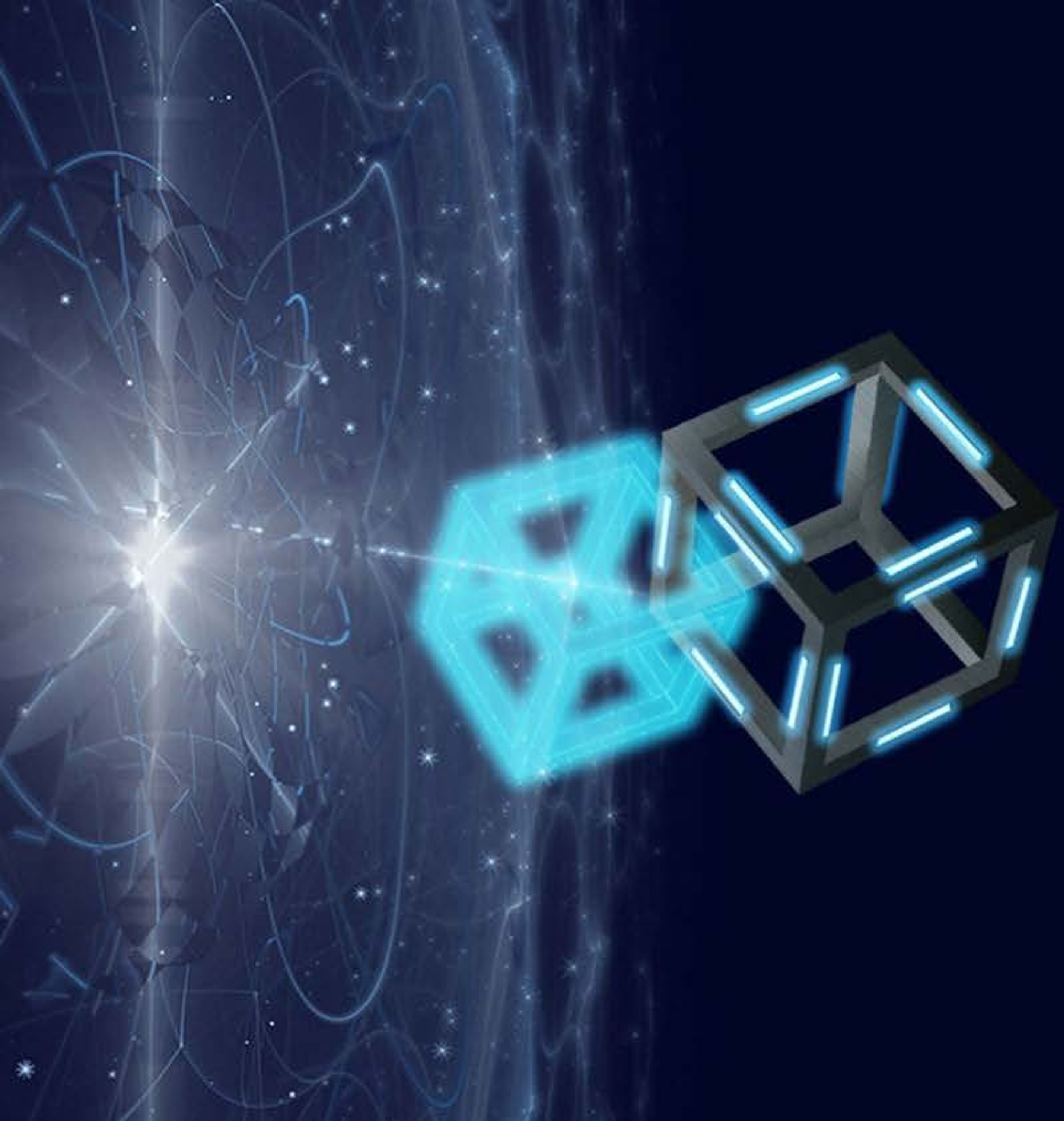
Exercise – HelloWorld.js:

- In ***useEffect()*** : load current message ; verify if a Metamask address is already connected with the app and retrieve the address and status

- In ***addSmartContractListener()*** : listen to the ***UpdateMessage*** event => setMessage, setNewMessage & setStatus

- In ***connectWalletPressed()*** : connect to Metamask and update the states

- In ***onUpdatePressed(*)** : call ***updateMessage*** and update the state



ERC20 Tokens & OpenZeppelin

ERC20 Tokens

- A Tokens can represent virtually anything in Ethereum: reputation points, skills of a character in a game, financial assets, a fiat currency like USD, an ounce of gold, real estate...
- ERC20 is the technical standard for fungible tokens on the Ethereum blockchain. Fungible means interchangeable or equal
- Use cases of ERC20 tokens: medium of exchange, currency, voting rights, staking...
- An ERC20 tokens is created by deploying a smart contract that adheres to the ERC20 standard
- Examples for ERC20 Tokens: USDC, USDT, BNB, DAI, MAKER

ERC20 Standard 1/2

Required functions & events of the ERC20 standard:

- ***totalSupply()*** → ***uint256*** : The total number of tokens that will ever be issued
- ***balanceOf(address account)*** → ***uint256*** : The account balance of a token owner's account
- ***transfer(address recipient, uint256 amount)*** → ***bool*** : Transfers a specified number of tokens to a specified address
- ***transferFrom(address sender, address recipient, uint256 amount)*** → ***bool*** : Transfers a specified number of tokens from a specified address to the specified recipient

ERC20 Standard 2/2

Required functions & events of the ERC20 standard:

- ***approve(address spender, uint256 amount) → bool*** : Allows a spender to withdraw a specified number of tokens from the caller's account
- ***allowance(address owner, address spender) → uint256*** : Returns the remaining number of tokens that spender will be allowed to spend on behalf of owner
- ***Transfer(from, to, value)*** : An event triggered when a transfer is successful
- ***Approval(owner, spender, value)*** : An event triggered when the allowance of a spender is modified by a call to **approve()** - value is the new allowance.

OpenZeppelin

- A library of modular, reusable, secure smart contracts for the Ethereum network
- Minimize risk by using battle-tested smart contracts and libraries for Ethereum

- Docs: https://docs.openzeppelin.com/contracts/4.x
- Code: https://github.com/OpenZeppelin/openzeppelin-contracts/tree/master/contracts

Provided contracts:

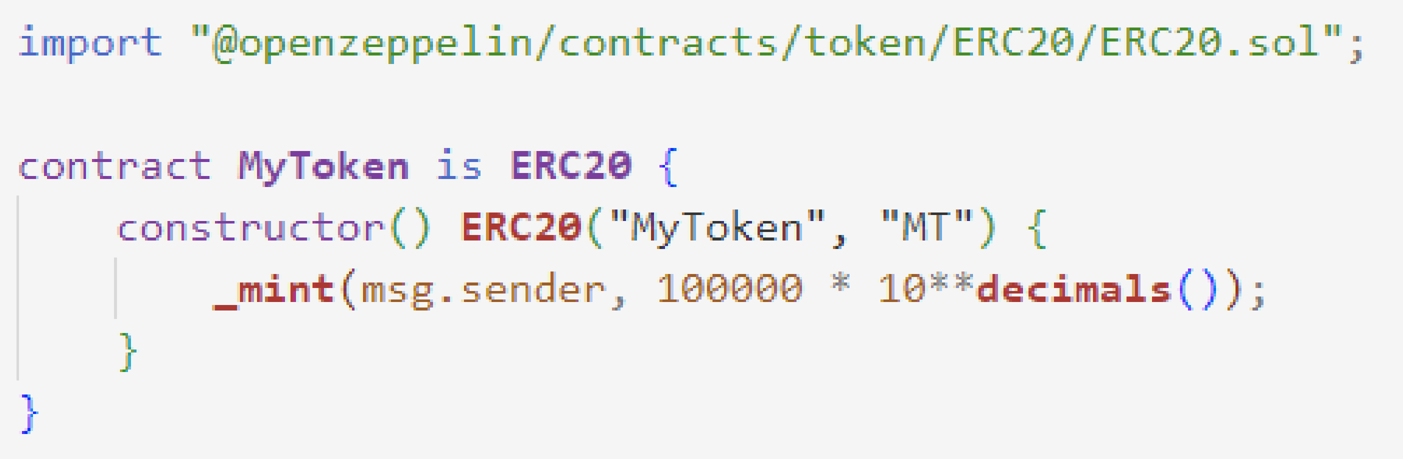
- Tokens: ERC20, ERC721, ERC1155
- Access control: ownership, role-based access control
- Governance, cryptography, math, security, multicall...

OpenZeppelin

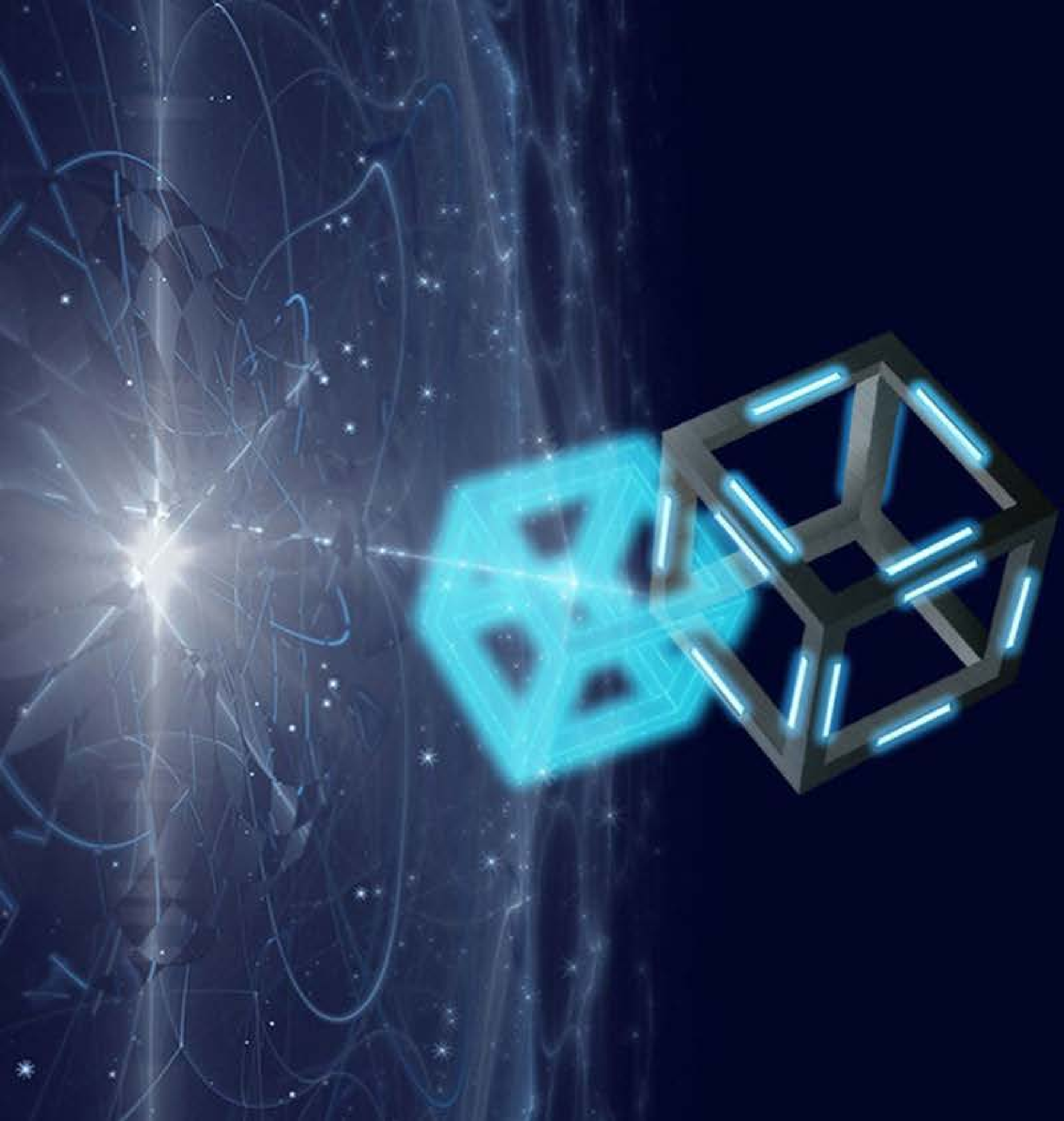
Installation:

npm install @openzeppelin/contracts

Usage:



```
import "@openzeppelin/contracts/token/ERC20/ERC20.sol";

contract MyToken is ERC20 {
    constructor() ERC20("MyToken", "MT") {
        _mint(msg.sender, 100000 * 10**decimals());
    }
}
```



ERC20 Token Project

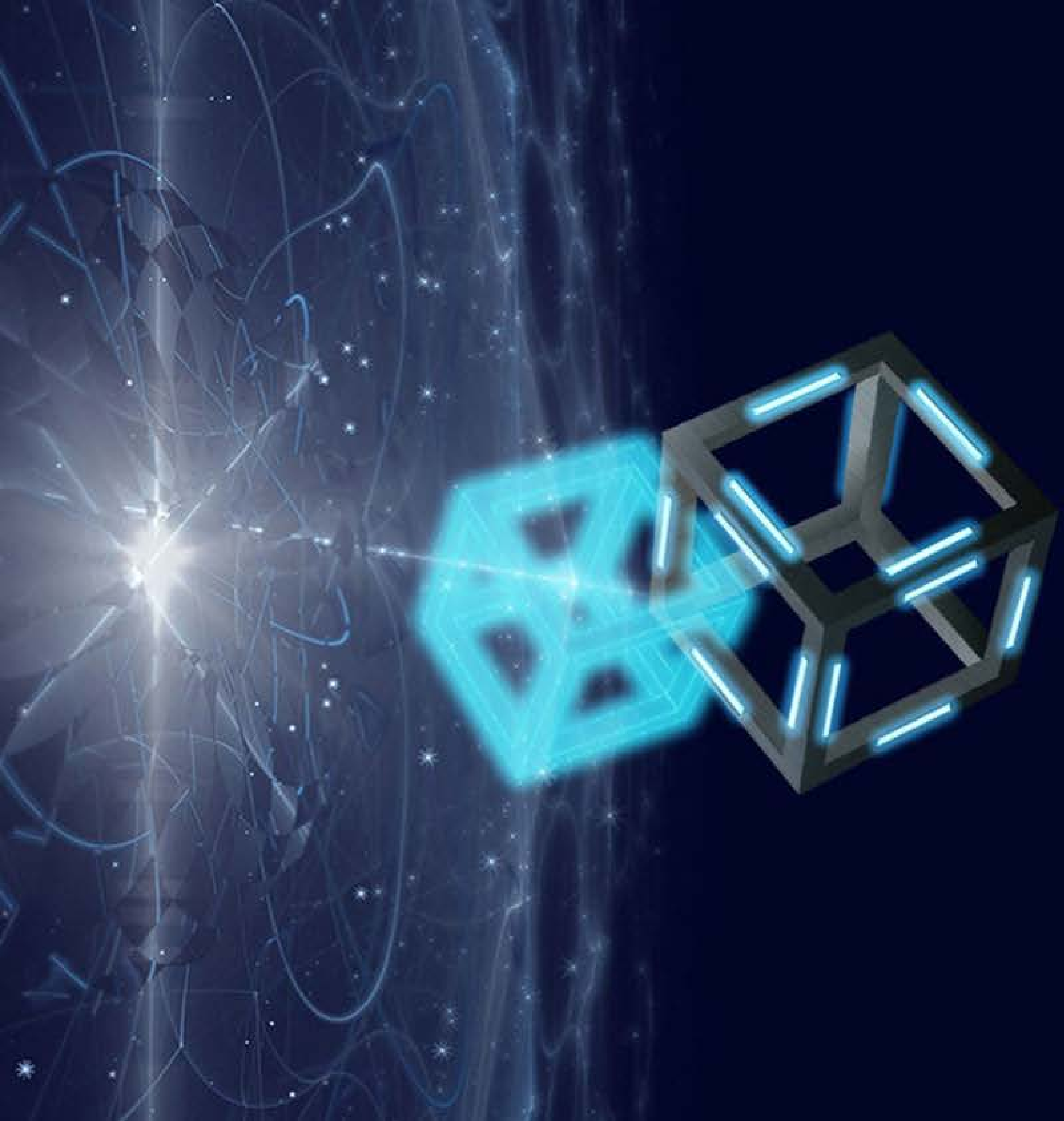
ERC20 Token Project - Requirements

- Create an ERC20 Token with the name: ***MyToken*** and the symbol: ***MT***
- During deployment, mint 100.000 MT's to the contract deployer
- The token must provide the following properties, functions and events:
  - totalSupply()
  - balanceOf(address account)
  - transfer(address recipient, uint256 amount)
  - transferFrom(address sender, address recipient, uint256 amount)
  - approve(address spender, uint256 amount)
  - allowance(address owner, address spender)
  - Transfer(from, to, value) Event
  - Approval(owner, spender, value) Event
- Deploy the contract to the Sepolia testnet
- Import the token into Metamask and send some tokens to a different address

ERC20 Token Project - Exercise

Write a script that performs the following tasks on a local Hardhat node:

- Display the MT balance of the deployer account
- Transfer 1000 MT's from the deployer account to another Hardhat account
- Display the MT balance of the second account
- Allow the second account to spend up to 50 MT's from the deployer account
- Display how many tokens the second account can spend on behalf of the deployer account



Testing Smart Contracts

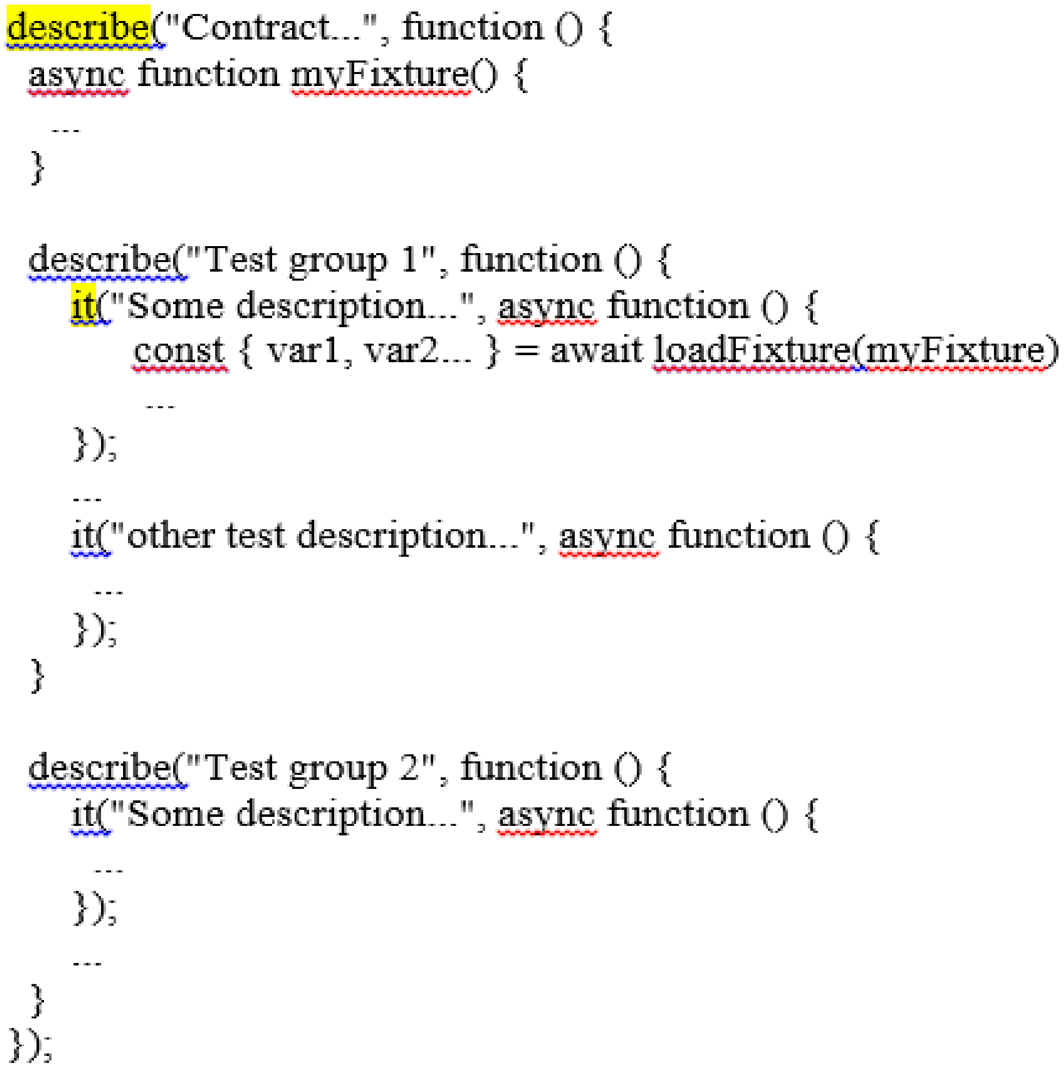
Testing Smart Contracts

Tests are executed on the Hardhat network. Mocha is used as the test runner and Chai as assertion library. Additionally, custom Hardhat-Chai matchers and the Hardhat Network Helper plugins are used.

Running the tests:

- npx hardhat test test/my-tests.js
- npx hardhat test
- npx hardhat coverage
- REPORT_GAS=true (GitBash) ; $env:REPORT_GAS='true' (Powershell) & npx hardhat test

Basic Structure of a Test File



```
describe("Contract...", function () {
 async function myFixture() {
   ...
 }

 describe("Test group 1", function () {
     it("Some description...", async function () {
           const { var1, var2... } = await loadFixture(myFixture)
             ...
     });
     ...
     it("other test description...", async function () {
       ...
     });
 }

 describe("Test group 2", function () {
     it("Some description...", async function () {
       ...
     });
     ...
 }
});
```

Hardhat Chai Matchers

This plugin adds Ethereum-specific capabilities to the Chai assertion library:
https://www.chaijs.com/api/bdd/

Installation:

- npm install --save-dev @nomicfoundation/hardhat-toolbox (already installed)

Usage:

- Add the following to hardhat.config.js:
  - require("@nomicfoundation/hardhat-toolbox")
- Add the following to the test file:
  - const { expect } = require(“chai")
  - const { anyValue } = require("@nomicfoundation/hardhat-chai-matchers/withArgs")

Hardhat Chai Matchers

Numbers:

- *expect(**await** token1.totalSupply()).to.**eq**(1_000_000)*
- *expect(await token2.totalSupply()).to.eq(ethers.parseEther("1"))*
- *expect(await token2.totalSupply()).to.eq(10n ** 18n)*

Reverted transactions (reverted, revertedWith & revertedWithCustomError):

- ***await** expect(token.transfer(address0, 10)).to.be.**reverted***
- *await expect(token.transfer(address0, 10)).to.be.**revertedWith**("some message...")*
- *await expect(myToken.transfer(address0, 10)).to.be.*
  ***revertedWithCustomError**(myToken, "InvalidTransferValue").withArgs(0)*

The first argument must be the contract that defines the error. If the error has arguments, the .withArgs matcher can be added

Hardhat Chai Matchers – Events & Balances

Events:

- *await expect(token.transfer(address, 100)).to.**emit**(myToken, "Transfer").**withArgs**(100)*

Assert how a transaction affects the ETH balance of a specific address:

- *await expect(mySigner.sendTransaction({ to: receiver, value: 1000 }))*
  *.to.**changeEtherBalance**(sender, -1000)*

Assert how a transaction affects the ERC20 token balance of a specific address:

- *await expect(myToken.transfer(receiver, 1000))*
  *.to.**changeTokenBalance**(myToken, sender, -1000)*

Hardhat Network Helpers

- ➢ Functions for quick and easy interaction with the Hardhat Network
- ➢ Facilitates the manipulation of account attributes (balance, nonce...)

Usage:

```
const { loadFixture, setBalance } = require("@nomicfoundation/hardhat-network-helpers")
```

Set the balance for the given address:

- ➢ *await setBalance(someAddress, 100)*

Return the timestamp of the latest block:

- ➢ *await time.latest()*

Hardhat Network Helpers

Mine a new block whose timestamp is newTimestamp:

- *await helpers.time.increaseTo(newTimestamp)*

Take a snapshot of the state of the blockchain at the current block:

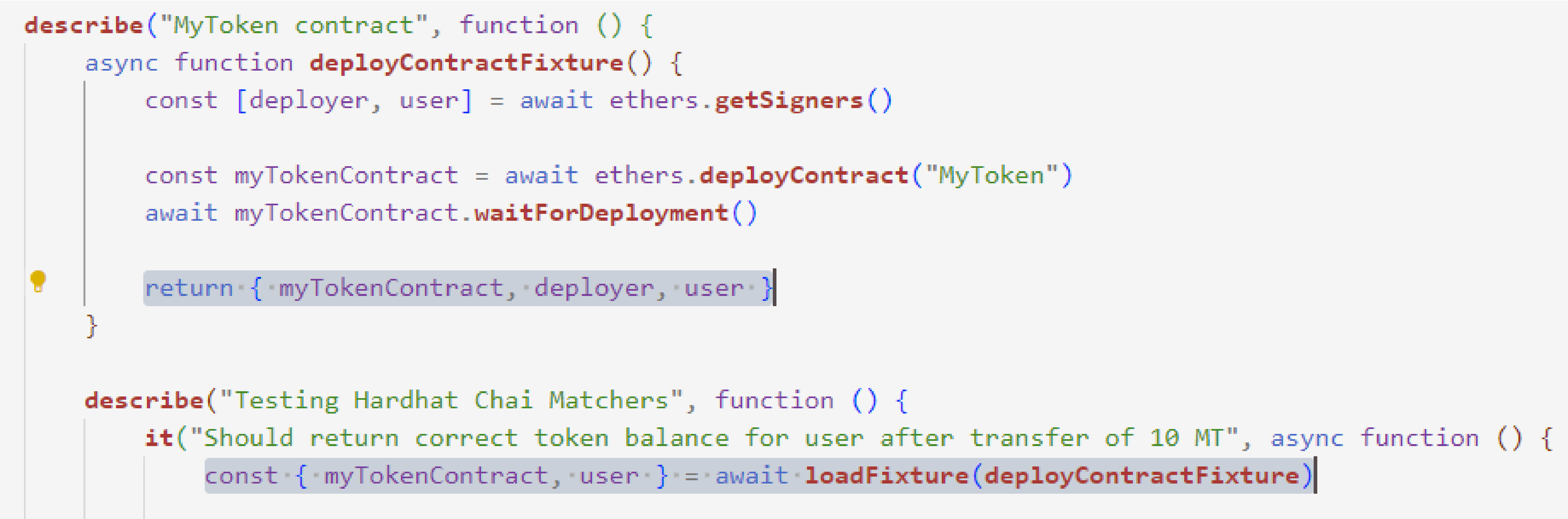
- *const snapshot = await takeSnapshot()*

After doing some changes, you can restore to the state of the snapshot:

- *await snapshot.restore()*

Fixtures - loadFixture

The first time ***loadFixture*** is called, the code is executed (and the contract(s) are deployed). In subsequent calls, the initial network state (after contract deployment) is restored from a snapshot. This is much faster than deploying the contracts each time the fixture is executed.

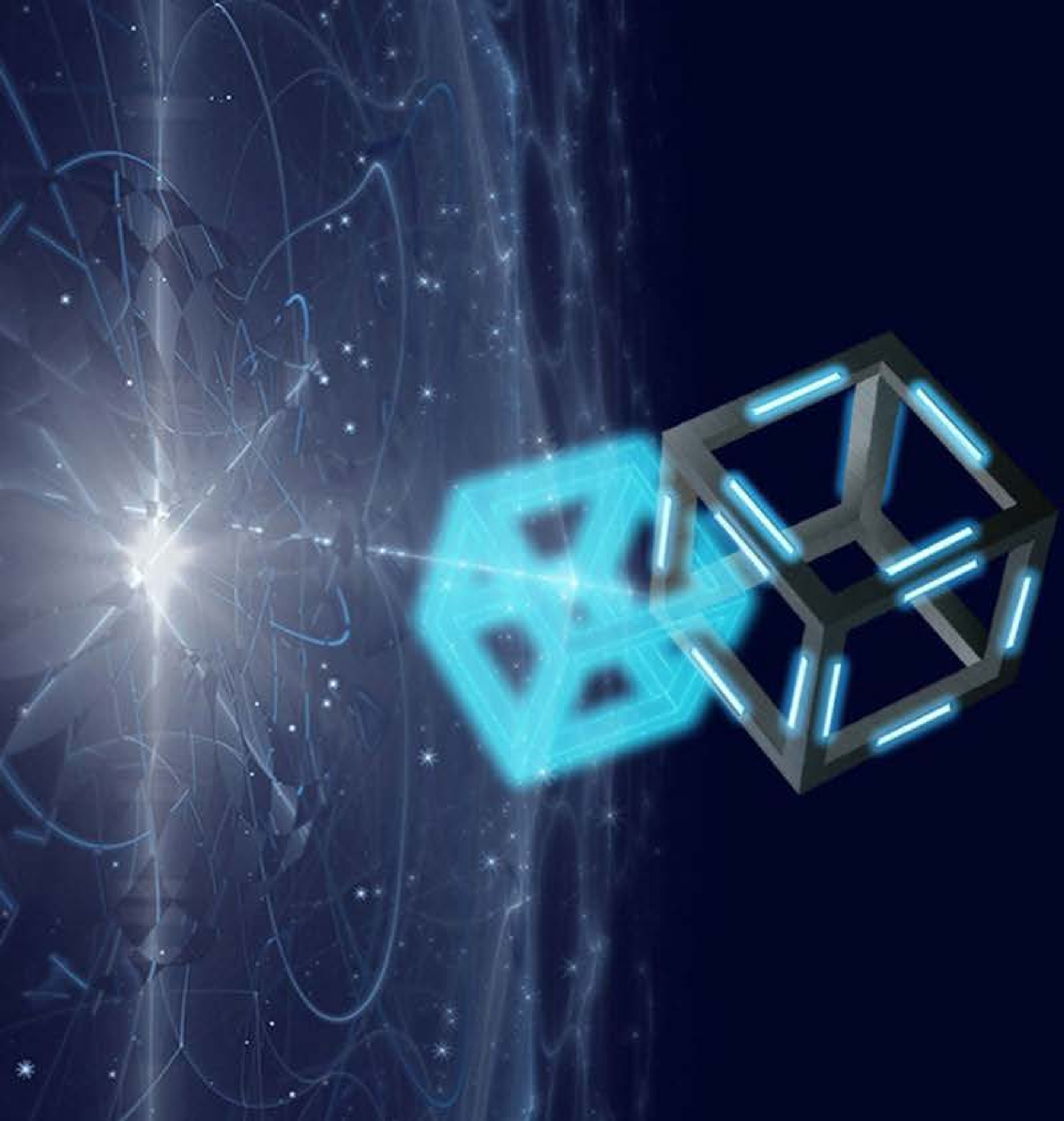


```
describe("MyToken contract", function () {
    async function deployContractFixture() {
        const [deployer, user] = await ethers.getSigners()

        const myTokenContract = await ethers.deployContract("MyToken")
        await myTokenContract.waitForDeployment()

        return { myTokenContract, deployer, user }
    }

    describe("Testing Hardhat Chai Matchers", function () {
        it("Should return correct token balance for user after transfer of 10 MT", async function () {
            const { myTokenContract, user } = await loadFixture(deployContractFixture)
```

Testing Smart Contracts

Requirements:

- Create a contract deployment fixture => return the contract and signers for the first 2 accounts
- Transfer 10 ETH to the second account and verify the token balance
- Call ***setBalance*** and verify the updated token balance
- Transfer to a zero address and verify if the call reverts with the message: ERC20: transfer to the zero address => ***to.be.revertedWith("...")***
- Verify if the "transfer" event is emitted after a token transfer - verify also the event arguments => ***to.emit(...).withArgs(...)***
- Verify if the token balance changes after a token transfer => ***changeTokenBalance***

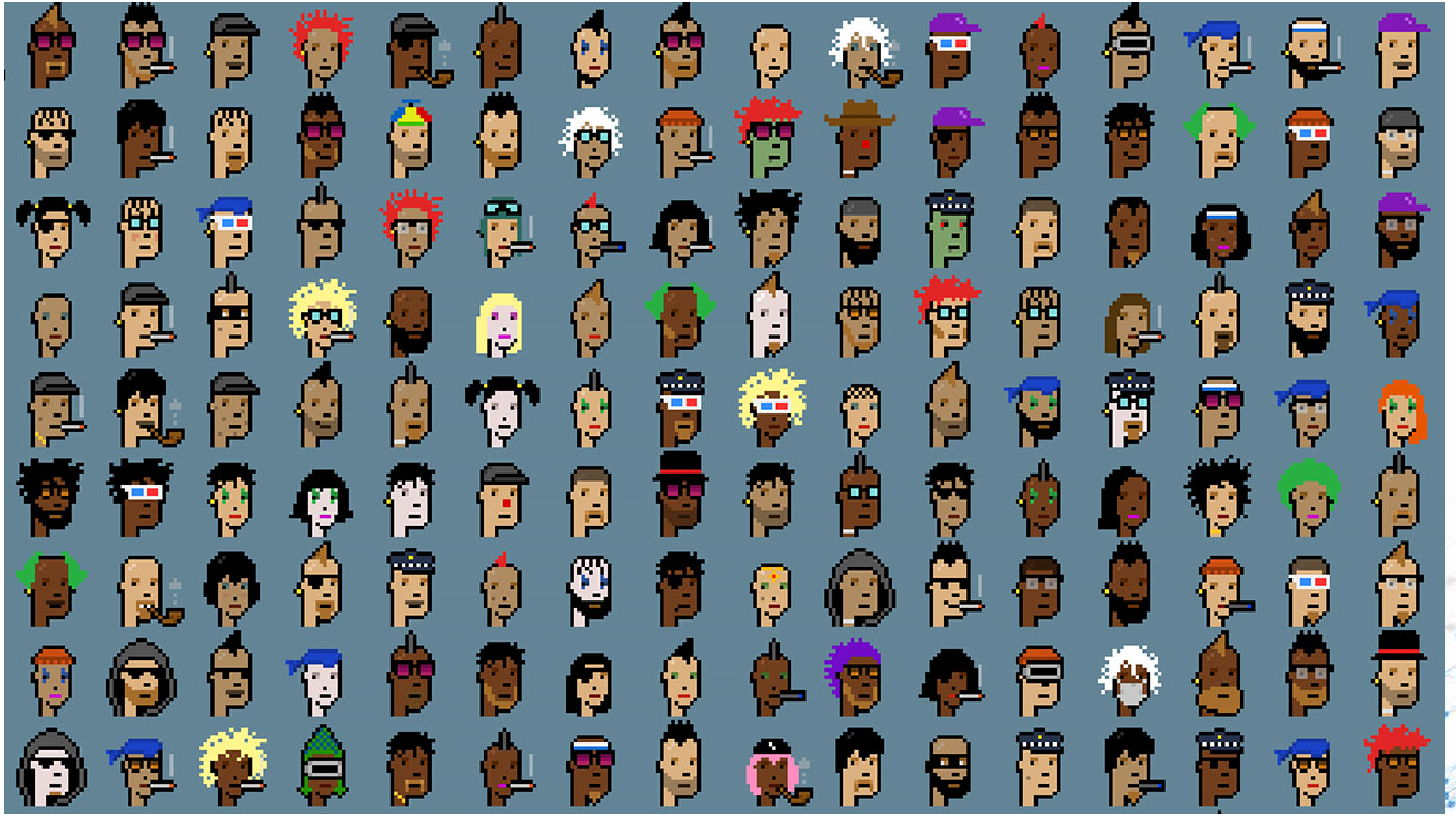


NFT’s & ERC721 Tokens

What are NFT’s - Non-Fungible Token?

- Token with unique properties
- Not interchangeable (contrary to ERC20 tokens)
- Each minted token has a unique identifier that is directly linked to one Ethereum address
- Digital asset that can represent all kinds of things: collectibles, game items, art, real estate...
- Creator of an NFT can define the scarcity of the asset by minting a certain number of tokens from the NFT smart contract
- We can create an NFT where only one token is minted as a special rare collectible
- Or, we can mint 1000 “identical” items - may be used as admission tickets to an event => each NFT still has a unique identifier with only one owner

NFT – CryptoPunks



ERC721 Token Standard

Docs: https://docs.openzeppelin.com/contracts/4.x/api/token/erc721

Code: https://github.com/OpenZeppelin/openzeppelin-contracts/tree/master/contracts/token/ERC721

Methods:

- balanceOf(owner)
- ownerOf(tokenId)
- transferFrom(from, to, tokenId)
- safeTransferFrom(from, to, tokenId)
- approve(to, tokenId)

ERC721 Token Standard

Methods:

- setApprovalForAll(operator, _approved)
- getApproved(tokenId)
- isApprovedForAll(owner, operator)

Events:

- Transfer(from, to, tokenId)
- Approval(owner, approved, tokenId)
- ApprovalForAll(owner, operator, approved)

ERC721URIStorage & ERC1155

OpenZeppelin provides several specialized ERC721 contracts (extensions) - one of them is the **ERC721URIStorage** contract => allows to provide token properties for each minted token:

- tokenURI(tokenId)
- _setTokenURI(tokenId, _tokenURI)

ERC1155 Token Standard:

- Multi-Token Standard => a single smart contract can represent multiple tokens at once
- Massive gas savings for projects that require multiple tokens. Instead of deploying a new contract for each token type, a single ERC1155 contract can hold all required NFT’s
- This can be useful for example for a smart contract that needs to hold various items with specific properties (NFT's) for a game: Sword, shield, knife...

IPFS & Pinata

IPFS:

- Decentralized, peer-to-peer file-sharing system that allows to store and access files, websites, applications, and other data.

Pinata:

- Docs: https://docs.pinata.cloud/introduction :
- Media management company for web3 developers (upload & manage data for web3 apps)
- API to interact with IPFS => “pin” different types of data to IPFS
- Data on an IPFS node is cached and periodically deleted (if it is not pinned)
- To prevent an IPFS node from deleting specific data, that data needs to be labeled (pinned)
- Advantages: Speed of data retrieval, uptime of IPFS nodes, almost unlimited space

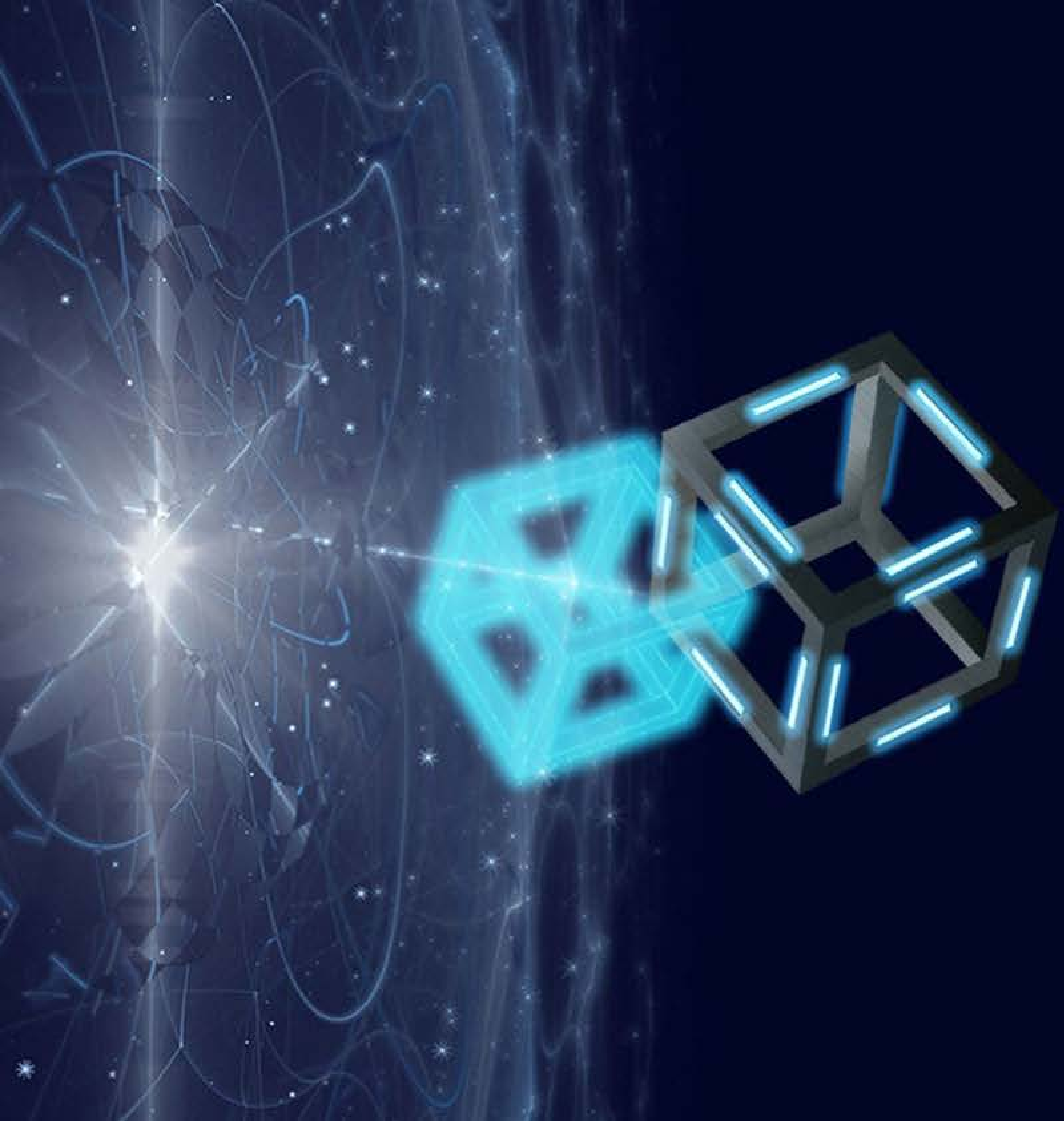
Pinata – API Key & File Upload

Pinata API Key:

- Create a Pinata account: https://app.pinata.cloud/register
- Click on "**API Keys**" => "**New Key**" => select the "**Admin**" option => click "**Create Key**":
- Copy/paste the API Key and the API Secret into your .env file

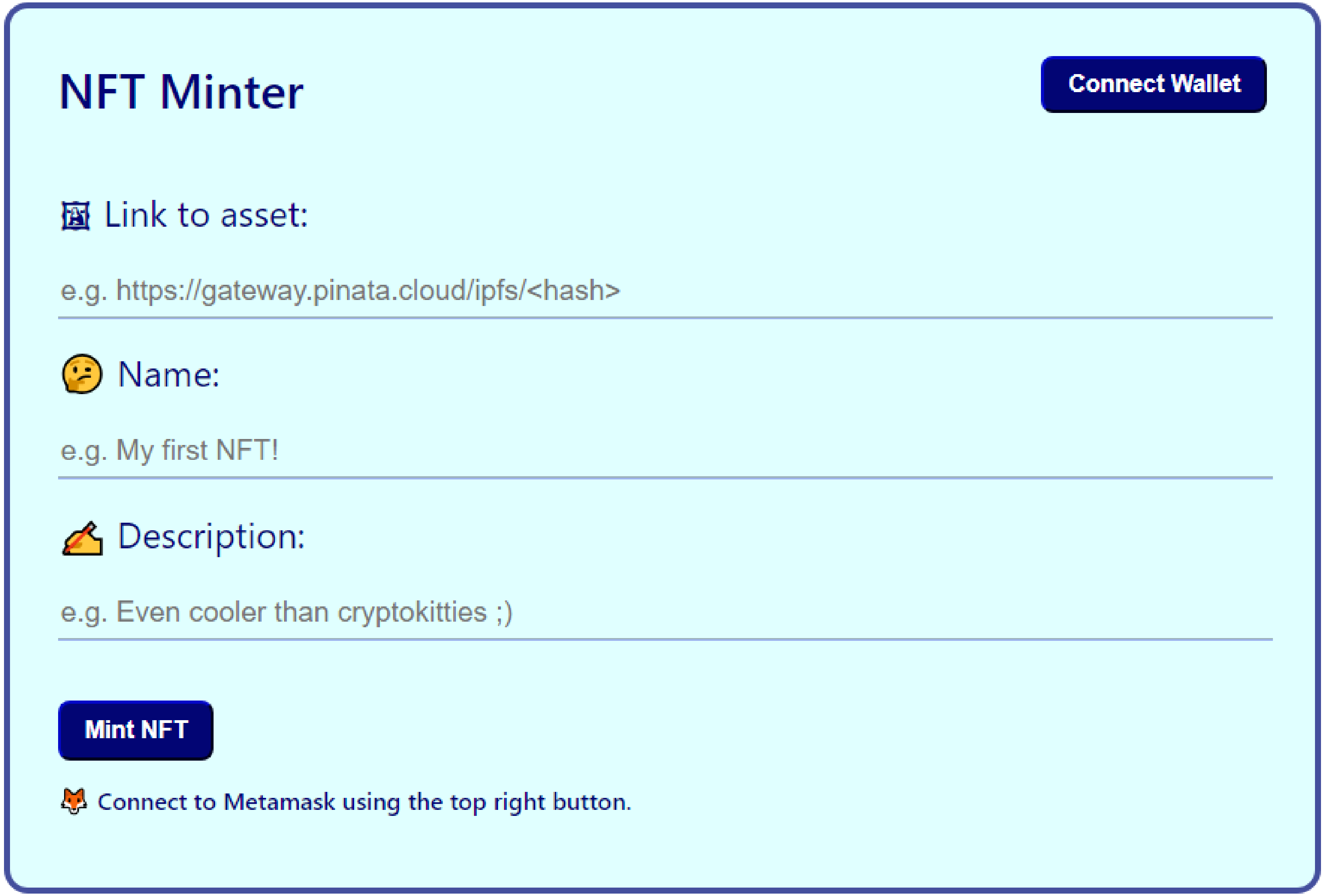
Upload files to Pinata:

- In your Pinata account, click the "**Upload**" button, select "**File**" and upload the cat.jpg file
- Make a copy of the **CID** (the value that starts with Qmc...)
- Open the "nft-metadata.json" file, replace the CID part of the image URL with your own CID and upload the modified .json using Pinata



NFT Minter Project

NFT Minter Project - UI



NFT Minter

🖼 Link to asset:

e.g. https://gateway.pinata.cloud/ipfs/<hash>

🤔 Name:

e.g. My first NFT!

✍ Description:

e.g. Even cooler than cryptokitties ;)

🦊 Connect to Metamask using the top right button.

NFT Minter Project - Requirements

ERC721 Token:

- Create an ERC721 token with the name: ***MyNFT*** and the symbol: ***MNFT***

- The token should inherit from the ***ERC721URIStorage*** contract and only the contract owner should be able to mint NFT's => inherit from the ***ownable*** contract

- Implement a public ***mintNFT*** function that allows to associate a metadata file with the NFT and that manages the token Id => increment the Id each time a new NFT is minted and associate the Id with the provided ***tokenURI***

- The token must provide the following properties, functions and events:
  - balanceOf(account)
  - ownerOf(tokenId)
  - safeTransferFrom(from, to, tokenId)
  - transferFrom(from, to, tokenId)
  - approve(to, tokenId)
  - Transfer(from, to, tokenId) => Event
  - Approval(owner, approved, tokenId) => Event

NFT Minter Project - Requirements

ERC721 Token:

- Deploy the contract to the Sepolia test network
- Import the token into Metamask and send some tokens to a different address
- Upload an image file to IPFS via Pinata
- Create a metadata file for the NFT with 2 properties, a name, a description and a link to the previously uploaded image file. Upload the metadata file to IPFS via Pinata

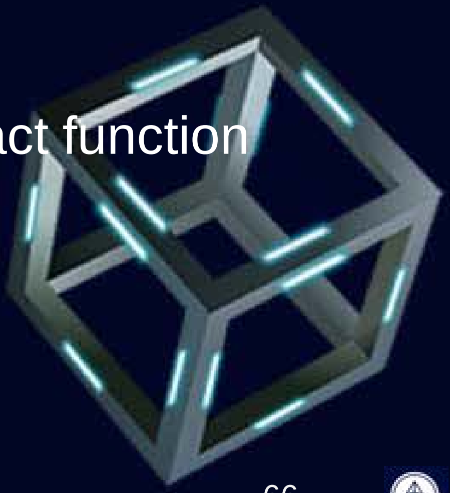
NFT Minter Project - Exercise

ERC721 Token => open scripts/mint-nft.js & provide the following features:

- Mint a NFT for a recipient that is not the token owner and provide a link to a metadata file that is hosted on IPFS
- Display the number of NFT's (of type MNFT) owned by the recipient
- Display the owner of the NFT with the Id of 1
- Transfer the NFT from the recipient to the contract owner

Web Application => open interact.js & provide the following features:

- In the ***mintNFT*** function, encode the function data for the "mintNFT" smart contract function
- Create the txn parameters (from, to and encoded function data)
- Send the transaction using Metamask => ***eth_sendTransaction***



NFT Minter Project - Requirements

Web Application:

- Create a REACT web frontend with the following features:
  - A button to connect the DAPP to Metamask: request({method: "***eth_requestAccounts***"...
  - Provide various NFT metadata: name, description and a URL to an image file that is stored on IPFS
  - A button to mint an NFT with the provided metadata properties
  - Send the transaction data (minting the NFT) to Metamask: request({method: "***eth_sendTransaction***"...
- Use Pinata to pin the provided NFT metadata (.json file) on IPFS => will be used as the **tokenURI** in the ***mintNFT*** smart contract function