Sapphire 101

Developer Office Hours

OASIS NETWORK

Who am I?

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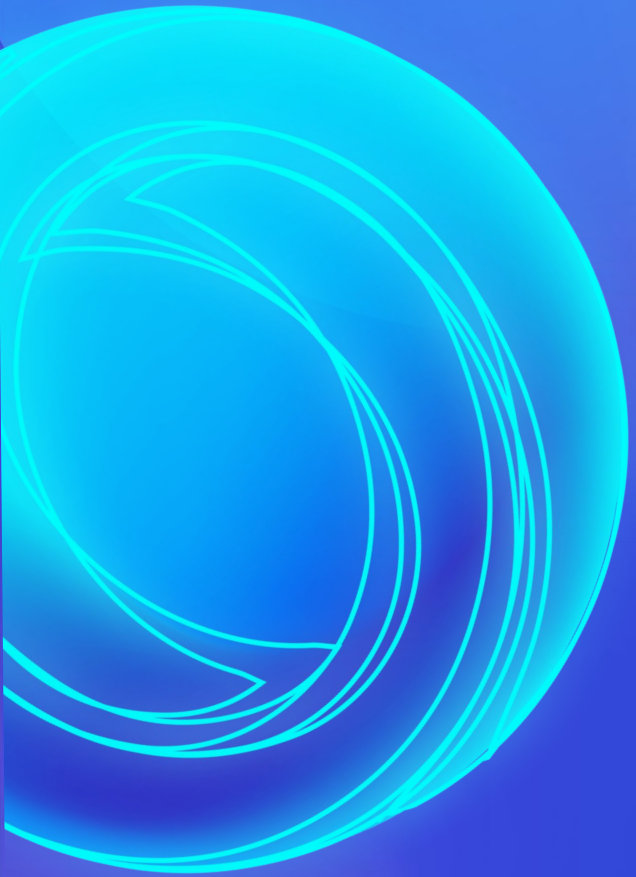
Software Engineer
at Oasis Protocol Foundation

Working (mainly) on docs.oasis.io, Oasis CLI, tooling, Oasis Core and ParaTimes tests, examples and other learning material.

Overview

1. The Oasis Architecture
2. Task 1: Confidential transactions
3. Task 2: Signed view calls
4. Task 3: The Frontend
5. Task 4: Precompiles
6. What to do next



Prerequisites

- Basic programming (e.g. JavaScript will come handy)
- Basic knowledge of the command line
- A working Node.js environment + pnpm

The Oasis Architecture

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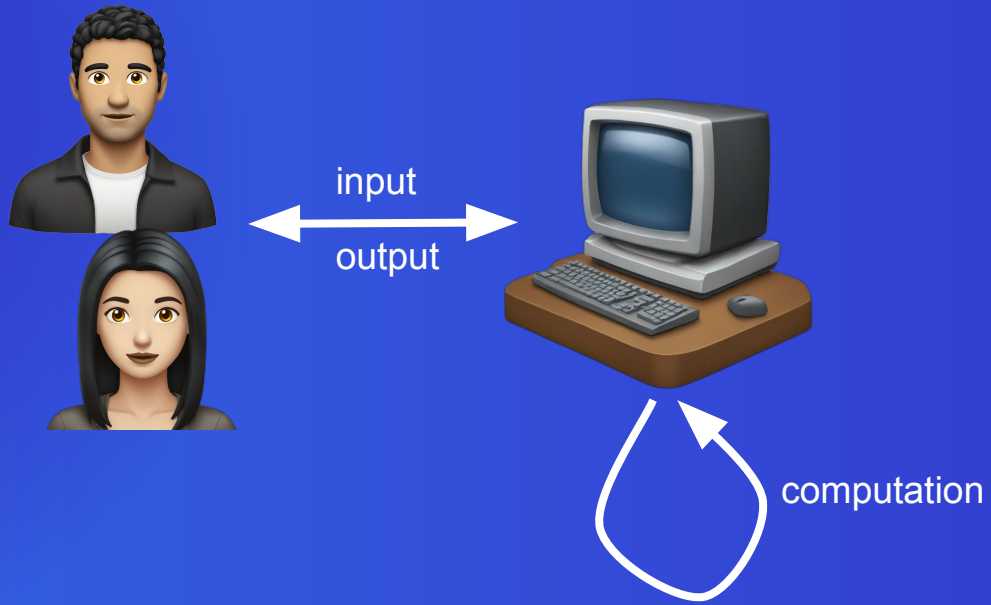
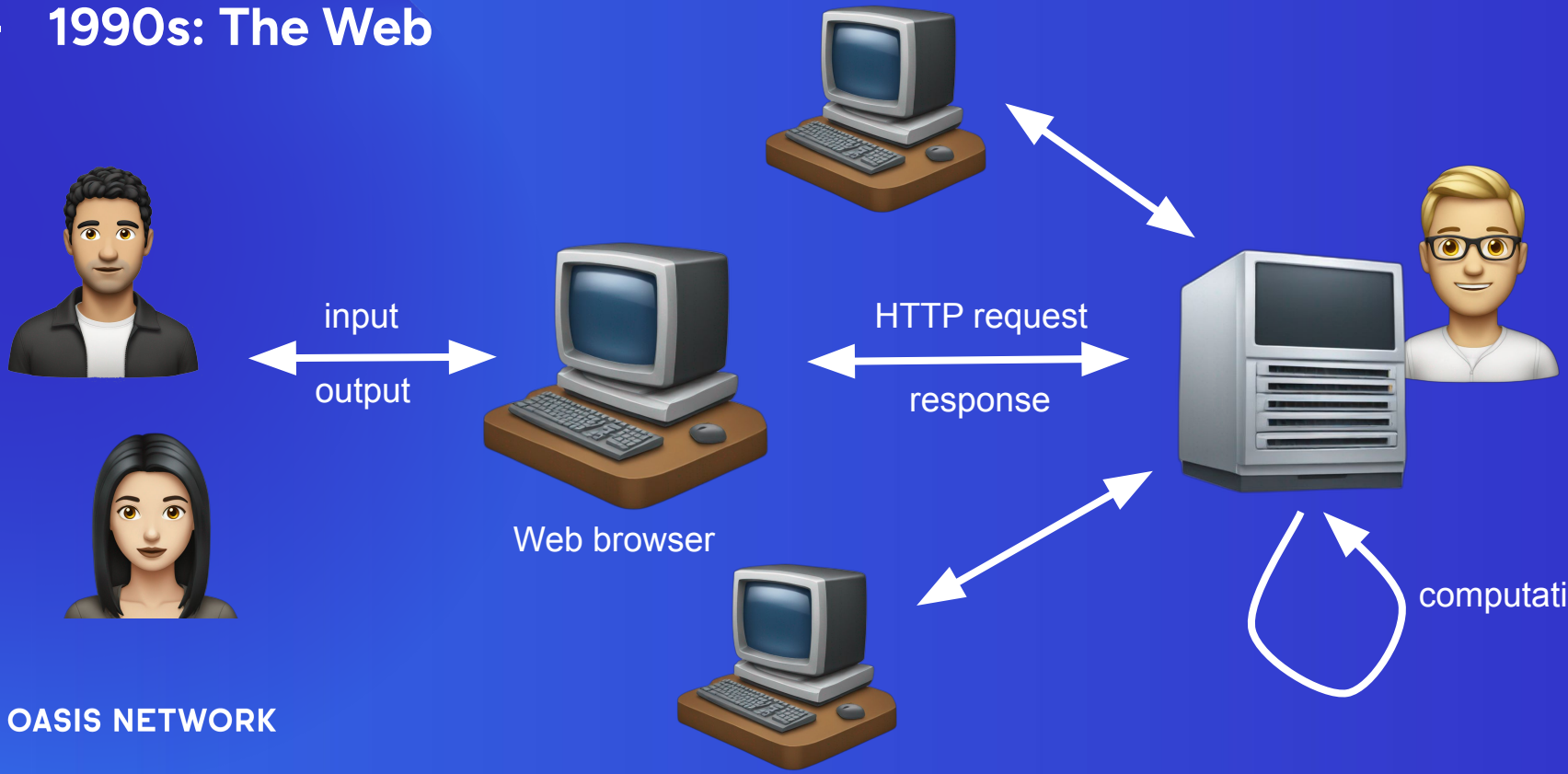
Short evolution of computing for average Alice and Bob

- Before the 90s



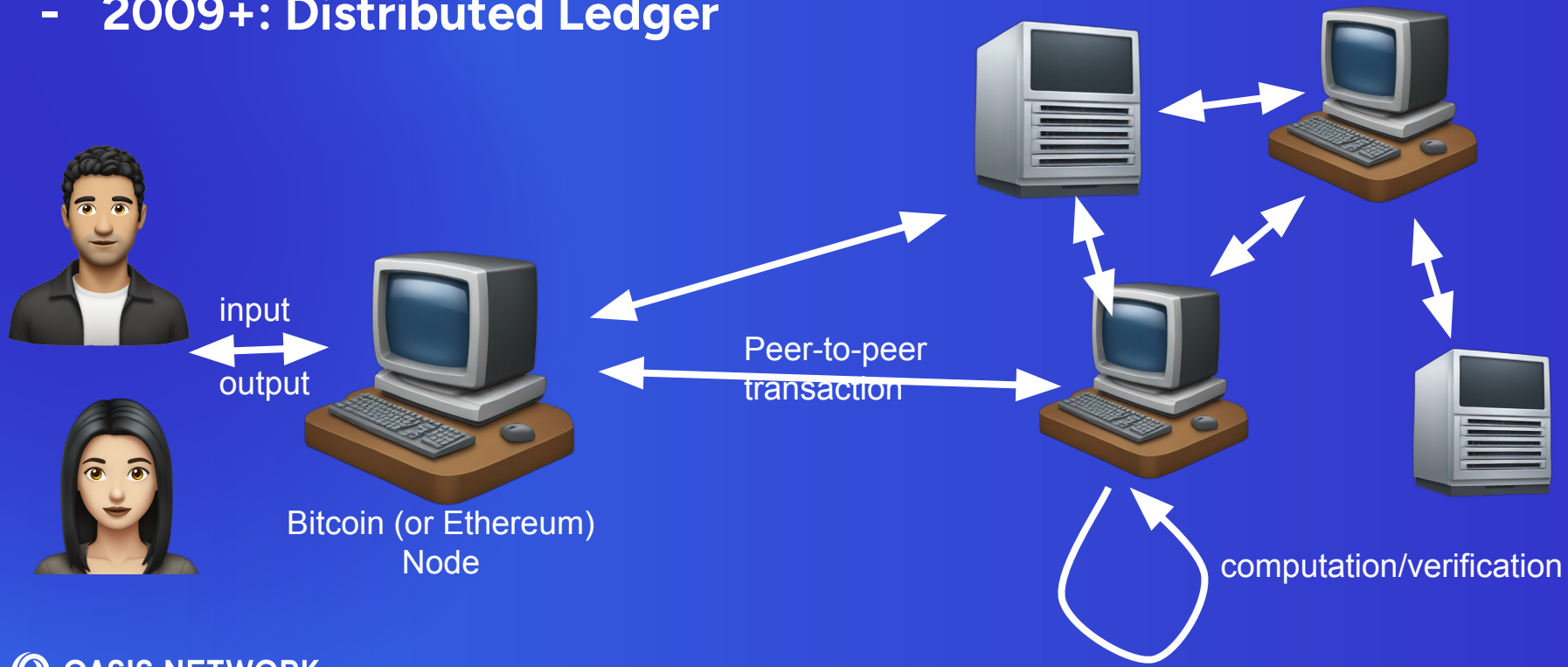
Short evolution of computing for average Alice and Bob

- 1990s: The Web

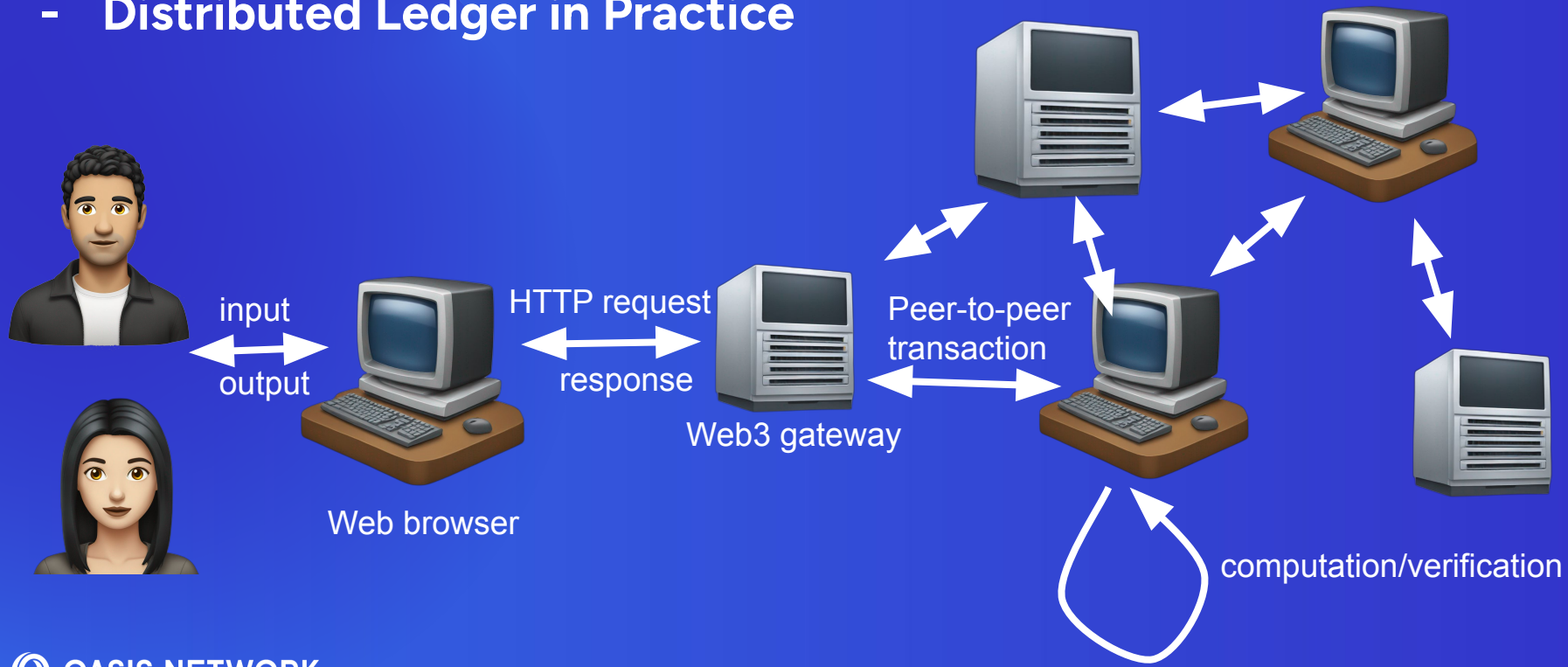


Short evolution of computing for average Alice and Bob

- 2009+: Distributed Ledger



Short evolution of computing for average Alice and Bob - Distributed Ledger in Practice



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Ethereum's Virtual Machine (EVM): Storage and Computation

- How is the contract state stored on Ethereum chain?
  - World state trie
- We can **extract all contract on-chain data**, via `eth_getStorageAt`
- What if we encrypt data?
  - DeFi, MEV, data privacy! ❤️
- But how can nodes *compute* in a *distributed environment*, if the storage is encrypted?
  - Trusted Execution Environment!

What should Confidential EVM Look Like?

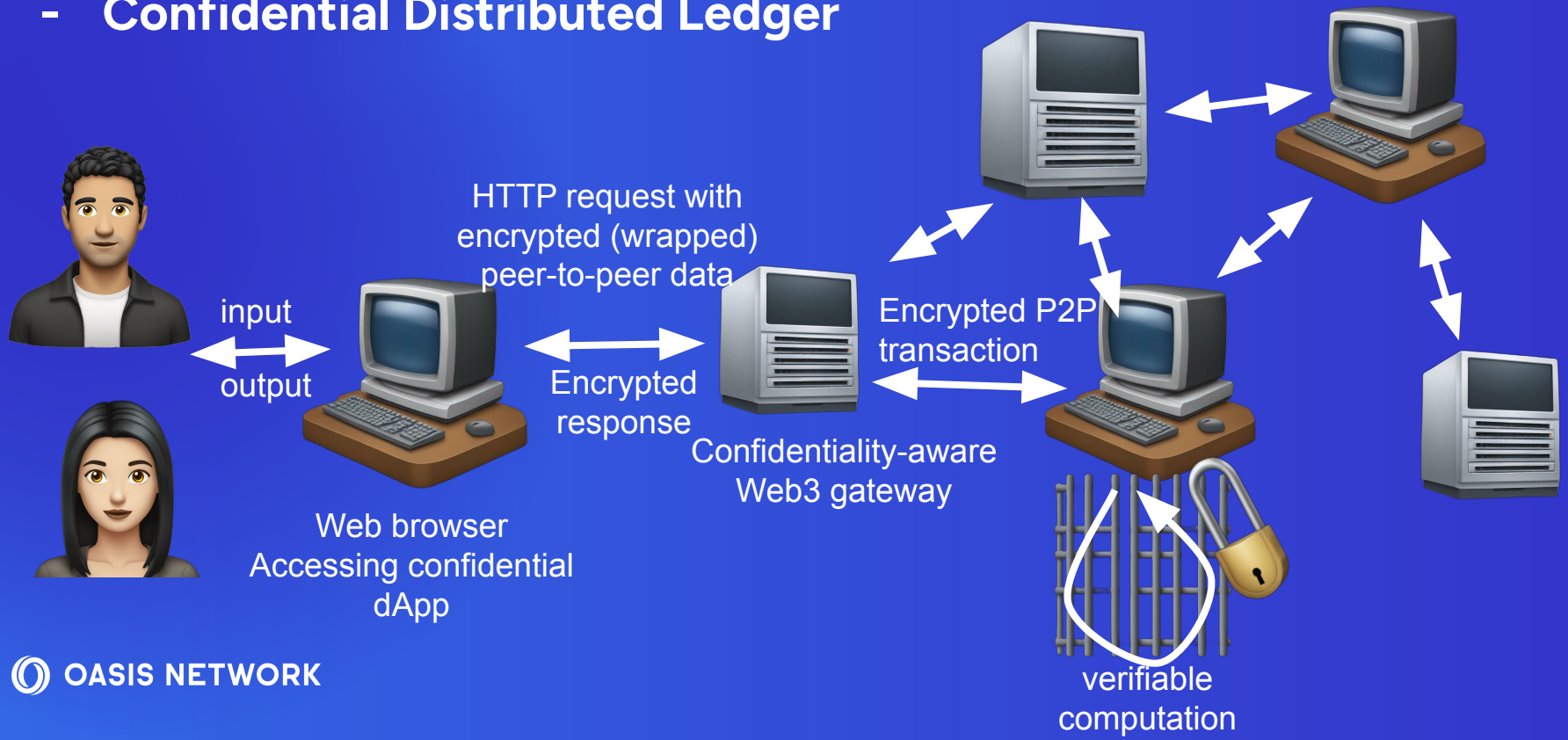
Private Compute

Randomness

Private Storage

End to End Encryption

Short evolution of computing for average Alice and Bob
- Confidential Distributed Ledger



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Sapphire

Confidential EVM

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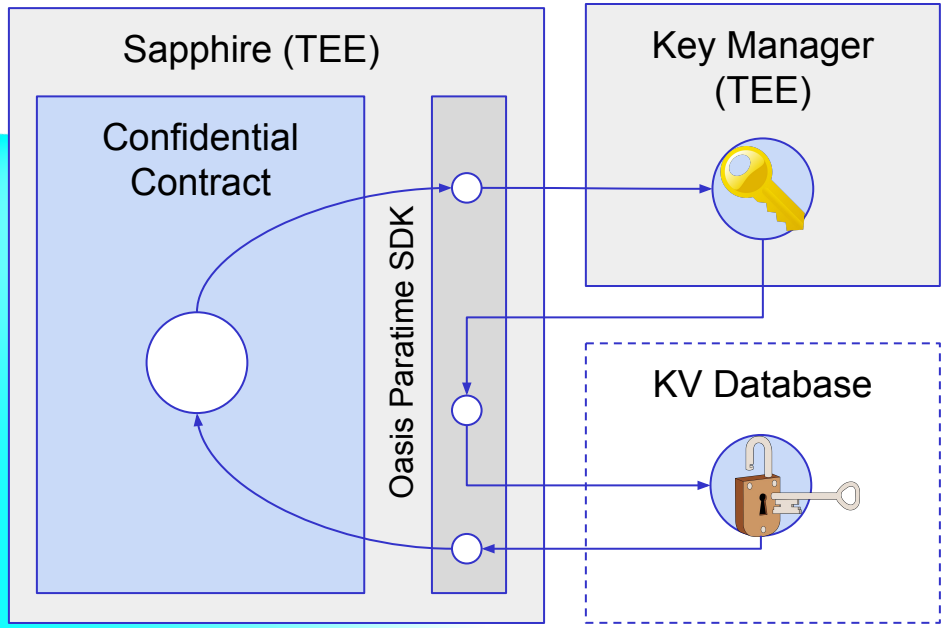
The Oasis Architecture: Sapphire

- Sapphire is a **confidential EVM-compatible** chain running on Oasis network.
- Smart Contracts are executed in **Trusted Execution Environment (TEE)** on a distributed network of compute nodes.
- Smart Contract storage **is encrypted**.
- Sapphire supports **backward-compatible unencrypted and Oasis-wrapped encrypted transactions and calls**.

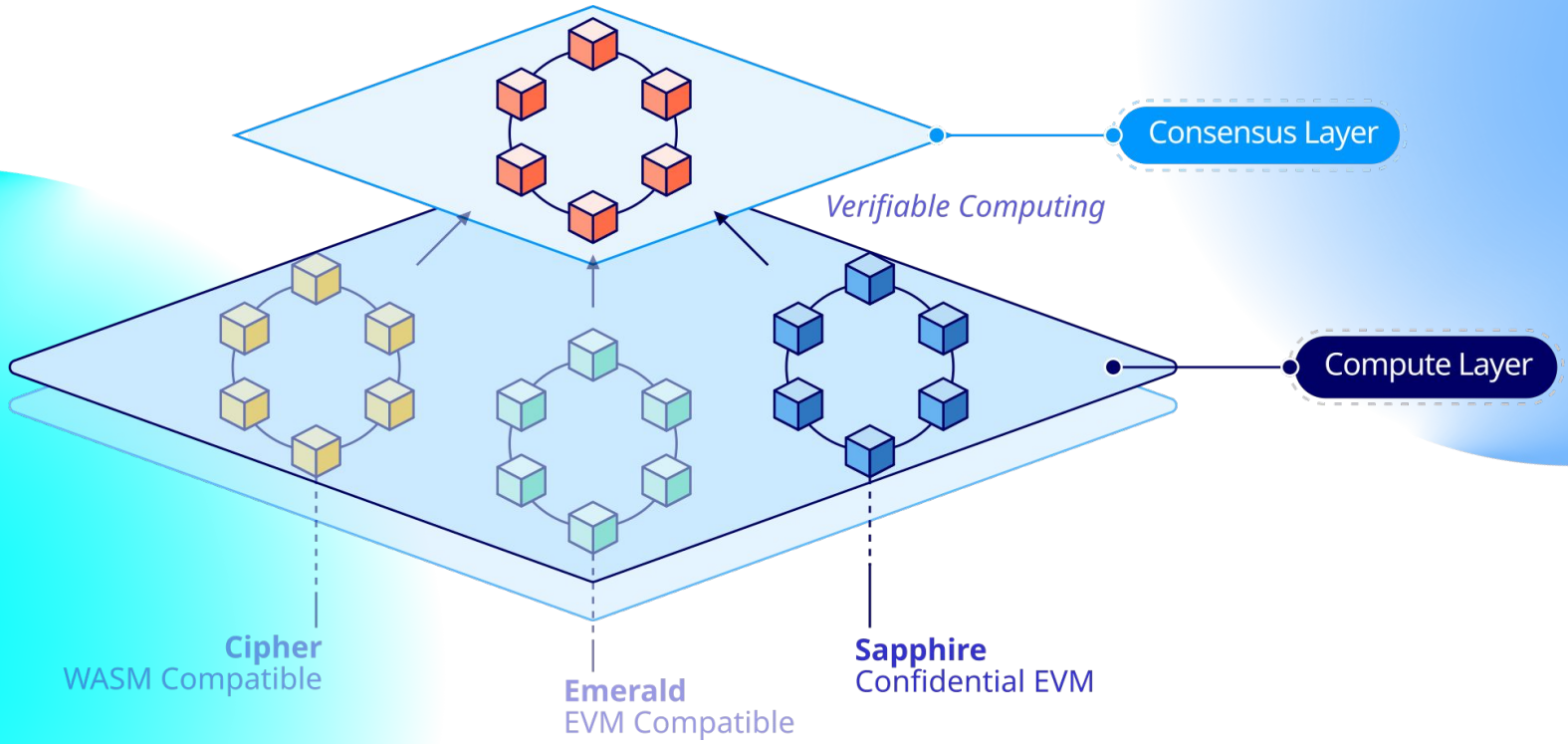
The Oasis Architecture: Sapphire



- Built with **Oasis Paratime SDK**.
- Each contract is **encrypted using a different key**.
- **Isolated Key Manager** improves security by segregating key access.
- The key-value database stores **encrypted data**.

Note: Access patterns are **still visible to node operators**!

The Oasis Architecture: Bigger Picture



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The Oasis Architecture: Sapphire Public Endpoints

Mainnet

- RPC HTTP endpoint: https://sapphire.oasis.io
- RPC WebSockets endpoint: wss://sapphire.oasis.io/ws
- Chain ID:
  - Hex: `0x5afe`
  - Decimal: `23294`
- Block explorer: https://explorer.oasis.io/mainnet/sapphire

Testnet

- RPC HTTP endpoint: https://testnet.sapphire.oasis.dev
- RPC WebSockets endpoint: wss://testnet.sapphire.oasis.dev/ws
- Chain ID:
  - Hex: `0x5aff`
  - Decimal: `23295`
- Block explorer: https://explorer.oasis.io/testnet/sapphire

Let’s get started!

github.com/oasisprotocol/demo-starter

Task 1

Confidential Transactions

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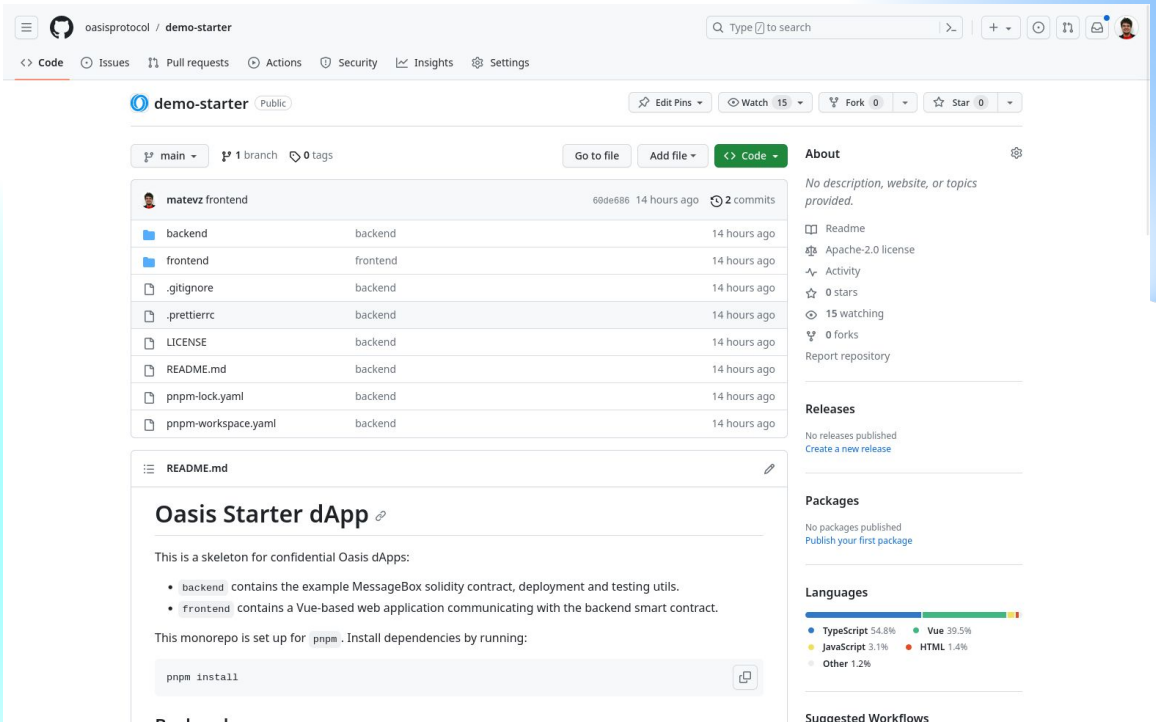
github.com/oasisprotocol/demo-starter

Task 1: Getting Started

1. Clone `github.com/oasisprotocol/demo-starter`



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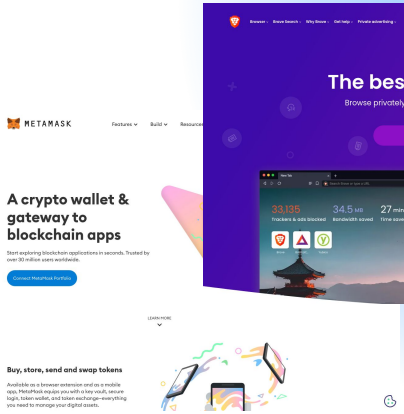
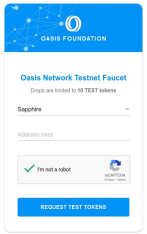
github.com/oasisprotocol/demo-starter

Task 1: Getting Started

2. Generate an Ethereum-compatible wallet (MetaMask, Brave...)



3. Get some Sapphire TEST tokens for your account at faucet.testnet.oasis.dev



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github.com/oasisprotocol/demo-starter

Task 1: Getting Started

4. Deploy contract to Sapphire Testnet.

```
cd backend; pnpm install; pnpm build
PRIVATE_KEY=0x… npx hardhat deploy --network sapphire-testnet
```

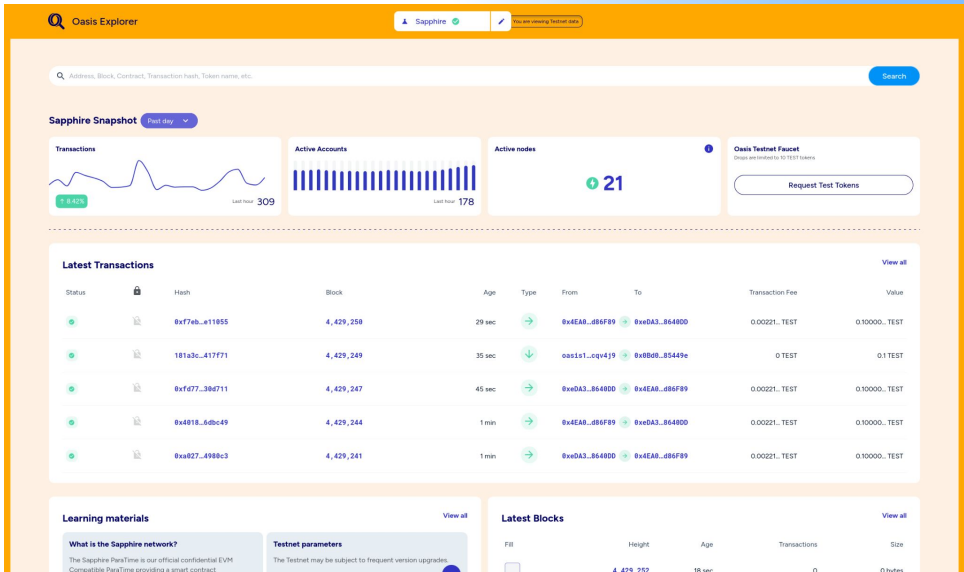
5. Browse Oasis Explorer and try to find your contract:

   explorer.oasis.io

6. Notice:

   Encrypted transactions: 🔒

   Unencrypted transactions: 🔓



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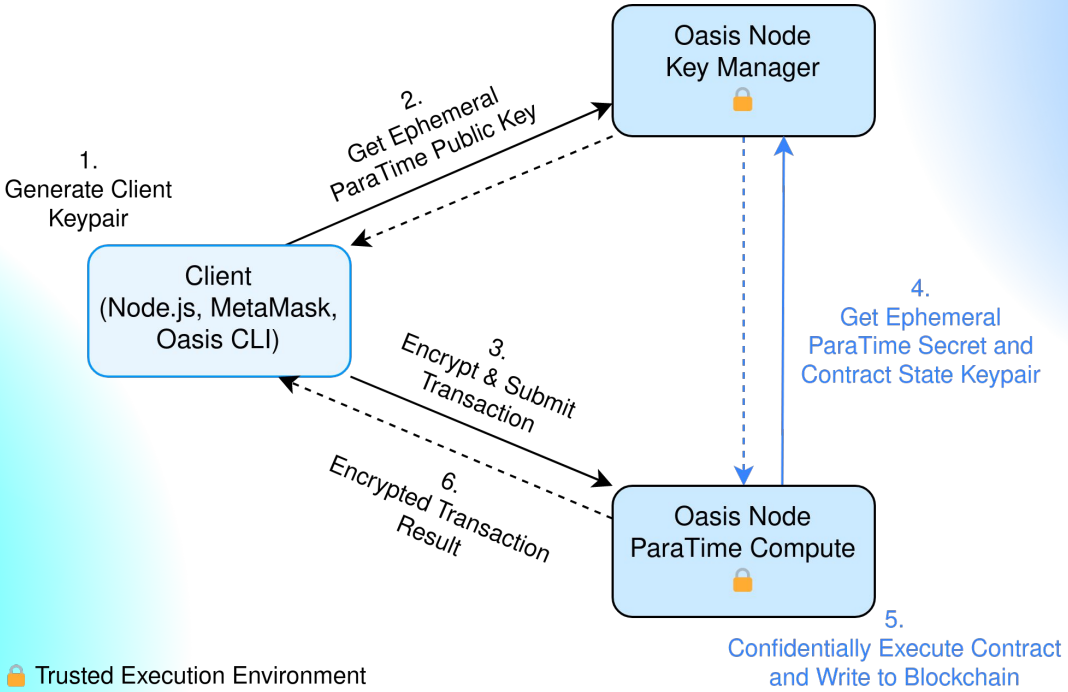
github.com/oasisprotocol/demo-starter

Task 1: Confidential Transactions



Task 1: Confidential Transactions

- To enable encrypted transactions **wrap the `ethers` signer**.
- Hardhat: Add at the top of your `hardhat.config.ts`:

```
import '@oasisprotocol/sapphire-hardhat';
const signer = ethers.provider.getSigner(); // signer is automatically wrapped
```

- In other clients (e.g. browser):

```
import * as sapphire from '@oasisprotocol/sapphire-paratime';
const signer = sapphire.wrap(ethers.provider.getSigner());
```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Task 1: Confidential Transactions

7. Demo starter project already imports the wrapper. Check out how the `setMessage` and `message` Hardhat tasks store and retrieve the message with **encrypted transaction** and **encrypted call**.

```
PRIVATE_KEY=0x… npx hardhat setMessage <CONTRACT_ADDRESS> <YOUR_MESSAGE> --network sapphire-testnet
PRIVATE_KEY=0x… npx hardhat message <CONTRACT_ADDRESS> --network sapphire-testnet
```


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Task 1: Confidential Transactions

But, is it private? Kinda...

The public parameters for both plain and encrypted transactions are:

- From & To
- Gas Price, Gas Used
- Encrypted Calldata size

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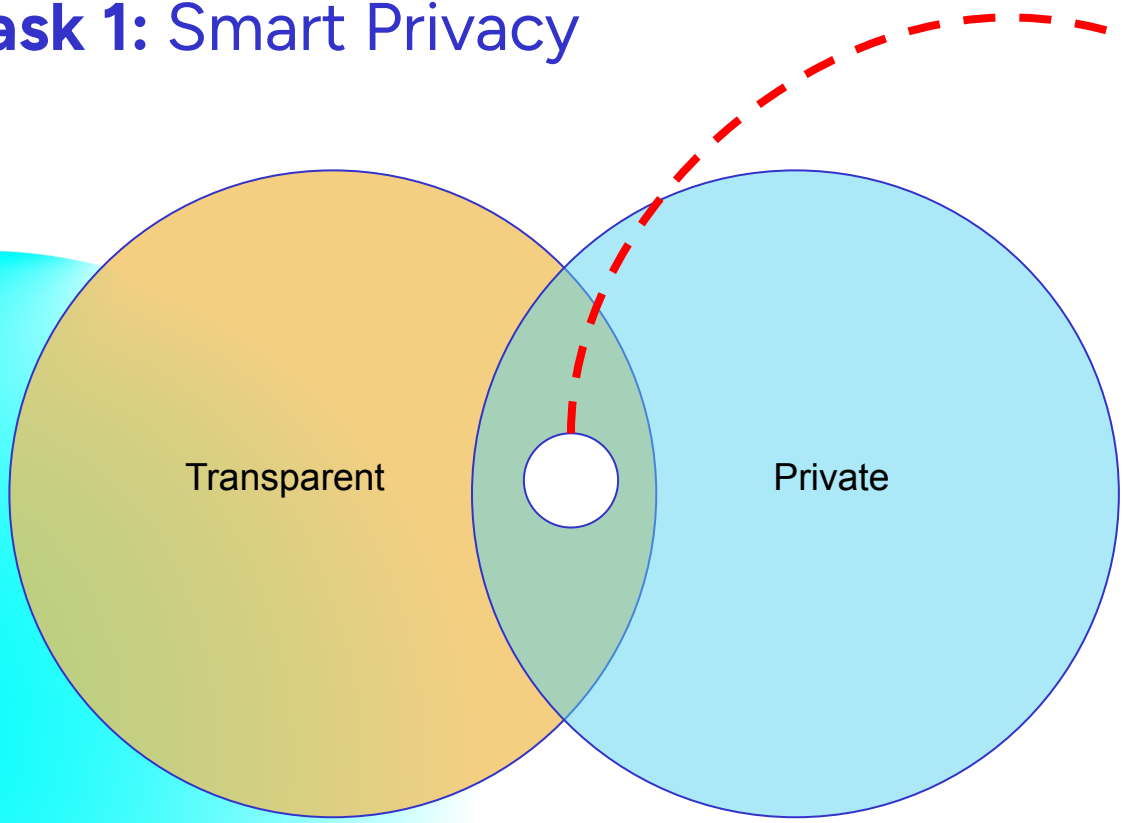
github.com/oasisprotocol/demo-starter

Task 1: Smart Privacy



99% of the world

Business
Regulations
etc.

Task 1: Smart Privacy

8. Try to extend `setMessage` to support **unencrypted transactions** as well. Use Explorer to check the transmitted transaction.

   HINT: Check how `deploy` task was implemented.

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Task 2

Signed View Calls

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Task 2: Impersonation

- When executing a transaction, `msg.sender` contains the address of the caller—the **one who signed the transaction** or the **contract address** of the caller function.
- For **view calls**, Ethereum supports **impersonation**. This means you can set the value of `msg.sender` field to arbitrary value (e.g. some third-party address) and perform read-only queries on behalf of someone else.
- This is perfectly fine in Ethereum, because the contract state is public anyway and anyone can simulate any execution path.

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Task 2: Impersonation

- Sapphire contract storage is **confidential**, it **forbids impersonation**:
  - Anonymous view call:

    `msg.sender` equals `address(0x0)`
  - Signed view call (aka. *signed query*):

    `msg.sender` equals `address(signer)`
- Developers should mitigate **memory access pattern attacks** by requiring specific `msg.sender`.

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Task 2: View calls & Impersonation

1. Make the `message` field in the `MessageBox` contract private and only allow the author of the message to retrieve it.
2. Try out **unwrapped** signer to check whether the `msg.sender` is really zeroed, if view call is unsigned.

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Task 3

The Frontend

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Task 3: Frontend

- The `frontend` folder contains a simple Vue-based app which imports the MessageBox contract from backend.
- Don’t forget to build the backend first!

```
cd backend; pnpm build
```

- In Demo starter, we use Vite to reflect any changes on-the-fly and for deployment. Preview the frontend with:

```
cd frontend; pnpm dev
```

Task 3: Signing in the Frontend

- In Demo starter, we store the *MetaMask instance* into local store so that it's not reloaded each time you open a subpage.
- `useEthereumStore()` returns `{signer, unwrappedSigner, provider, unwrappedProvider}` to access all flavors of the signer or the provider respectively.
- Contract address, expected chain ID etc. is read from `frontend/.env*` files

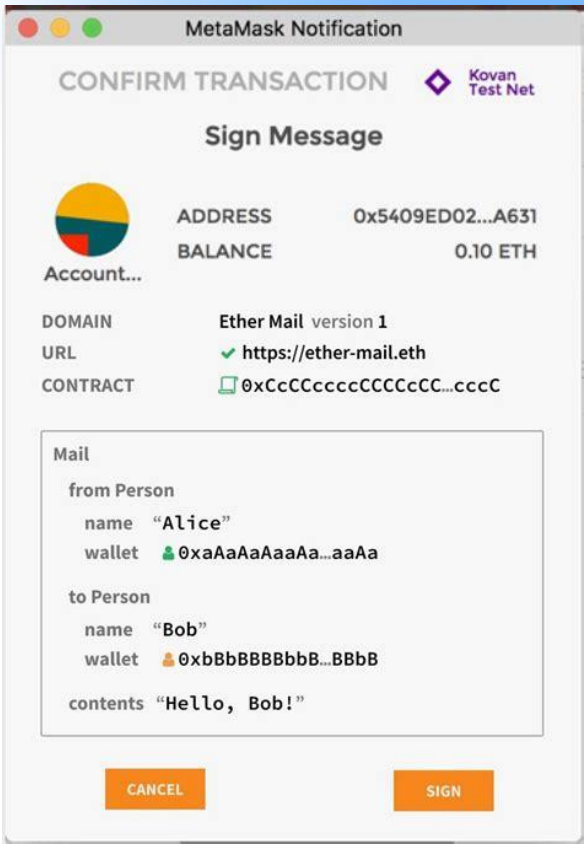
github.com/oasisprotocol/demo-starter

Task 3: Signing in the Frontend

- In `contracts.ts` the wrappers for the contracts are prepared for you:

```
const messageBox = useMessageBox();
const uwMessageBox = useUnwrappedMessageBox();
```

- Calling `uwMessageBox.message()` will execute **Anonymous Unencrypted View Call in background**.
- Calling `messageBox.message()` will activate MetaMask for **Signed and Encrypted View Call**.



Task 3: Signing in the Frontend

- Signing the same query **is cached**. (This helps to reduce annoying popups.)

TASK: Try out **setting the message in the browser** with MetaMask.

Task 4

Precompiles

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Task 4: Precompiles

Precompiles for Solidity are built-in functions that **extend the EVM**.

These are complex operations which are difficult to implement efficiently.

Examples of these on *Ethereum* are:

- SHA256
- Elliptic Curve & Pairing (`ECADD`, `ECMUL`, `ECPAIRING`) for ZK / BN128 curve
- EcDSA Signature Verification (`ecrecover`)

Task 4: Precompiles in Sapphire

```
pnpm install -D @oasisprotocol/sapphire-contracts
```

```
import "@oasisprotocol/sapphire-contracts/contracts/Sapphire.sol";
```

- (Incomplete) list of precompiles:
  - Gas padding
  - Random Number Generation (VRF / CSPRNG)
  - Encryption & decryption (X25519), key generation (Ed25519, SEC P256 k1), signing & verification (EdDSA, EcDSA)
- Learn more: docs.oasis.io/dapp/sapphire/precompiles

Task 4: Sapphire-Localnet

- Sapphire precompiles run on Sapphire only.
- We can use Testnet, but for running the (automated CI) tests each time, this is not viable (slow, gas costs).
- Inspired by `npx hardhat node` and `geth --dev`, the Oasis team provides the `sapphire-localnet` docker image which spins up an isolated Oasis network locally:

```
docker run --rm -it -p8545:8545 -p8546:8546 ghcr.io/oasisprotocol/sapphire-localnet
```

Task 4: Random Number Generator

- Cryptographically secure source of entropy:

```
bytes memory entropy = Sapphire.randomBytes(32, "");
```

- Much easier than using an **external** VRF, it's instant!
- The second parameter seeds the RNG with your own "extra entropy".

TASK: Implement on-chain CAPTCHA (e.g. add two numbers) to prevent spam attacks.

What to do next?

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What to do next? ECDH (Shared Secrets)

- Two people have their own key pairs, say Alice and Bob
- When they have each others public keys they can both derive the point, and nobody else can

  (Unless one of the secrets gets leaked)

$$g^{xa} = A^x = X^a \ : \ A = g^a \ : \ X = g^x$$

What to do next? Encryption & Decryption

1. Our initial example used **end-to-end encryption** between user & smart-contract (and stored on the public ledger in encrypted form).
2. But, we can use X25519 key pairs **inside a smart contract** and derive shared secret on-chain!

Use Cases:

- Encrypted emitted events, stateless view calls.
- Encrypted coupons, proxies, authentication, compliance.

What to do next? Signing & Verification

- Contracts can generate key-pairs (Ed25519, X25519, Bitcoin & NIST)
- Signing with EcDSA and EdDSA

But, what can I do with that?

- Generate Ethereum addresses and sign transactions **on-chain**!
- Verify WebAuthN / TouchID, using Ed25519 & EdDSA
- Broadcast cross-chain without bridges

What to do next? On-chain Single Sign-On

- Viewing Keys: Submit an access token to view your data.
- Permits: Provide access to specific functions (read/write).
- Do we really need so many writes?
- Daily Login with EIP-712:
  - Similar to permits, but application specific.
  - Lets you sign a transaction once per day/week.

Learn more: docs.oasis.io/dapp/sapphire/authentication

Step forward—WebAuthN integration: playground.oasis.io/authzn

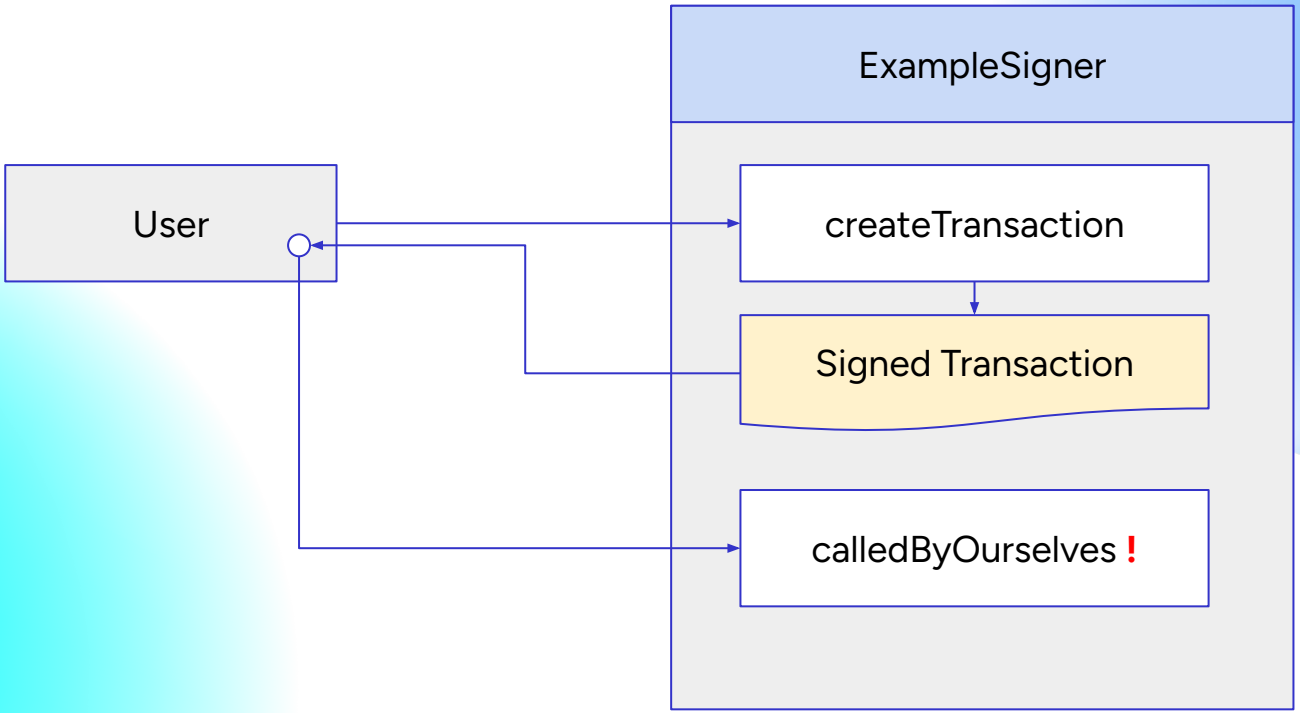
What to do next? Autonomous Contracts

- Using the key generation pre-compiles:

  Sapphire can generate **Ethereum compatible accounts** to **pay their own gas**—either on Sapphire or on other EVM compatible chains.
- Check out the Gasless chapter in the docs:

  docs.oasis.io/dapp/sapphire/gasless

What to do next? Autonomous Contracts

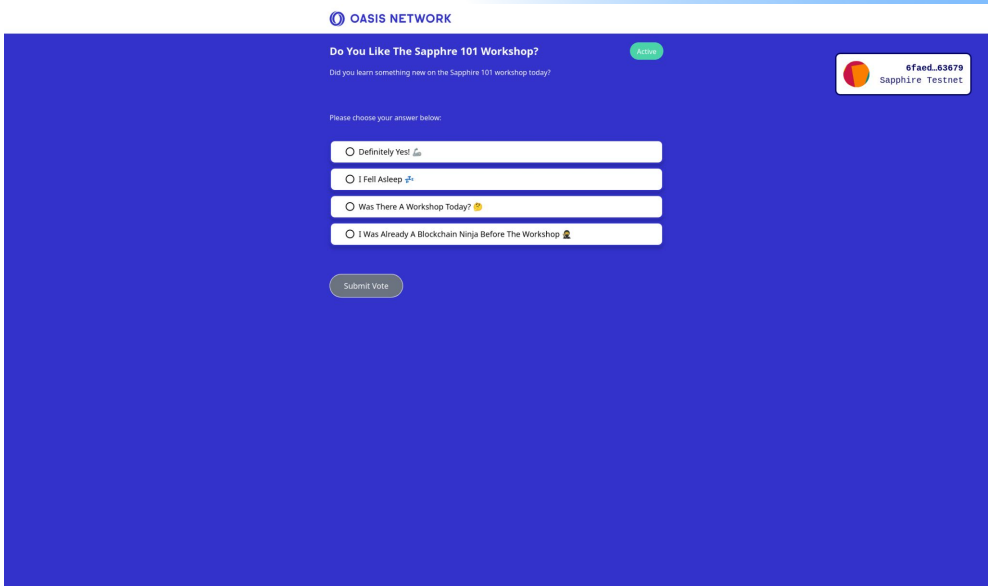


What to do next? Autonomous Contracts

Demo:

playground.oasis.io/demo-voting

- Submit your votes privately.
- Use MetaMask to sign (EIP-712).
- No need for gas token.
- Only to be connected to Sapphire Testnet.



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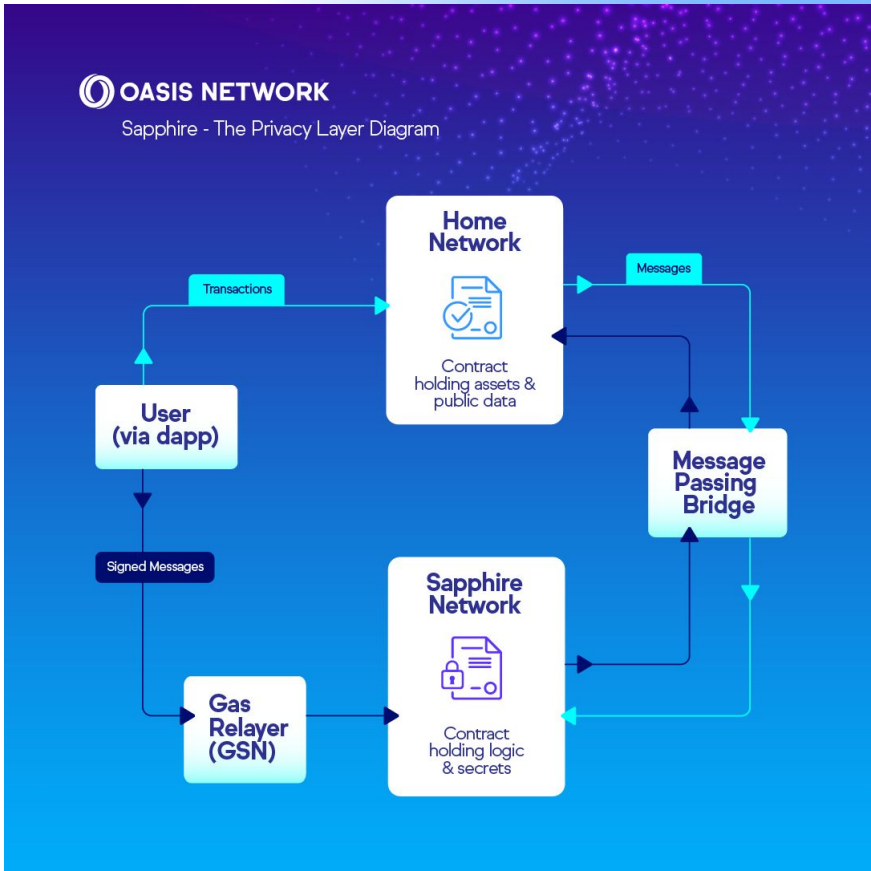
What to do next? Oasis Privacy Layer (OPL)

- Connect Sapphire with the most popular EVM networks (Ethereum, BNB Chain, Polygon…) and add encrypted transactions and confidential state.
- Learn more: docs.oasis.io/dapp/opl



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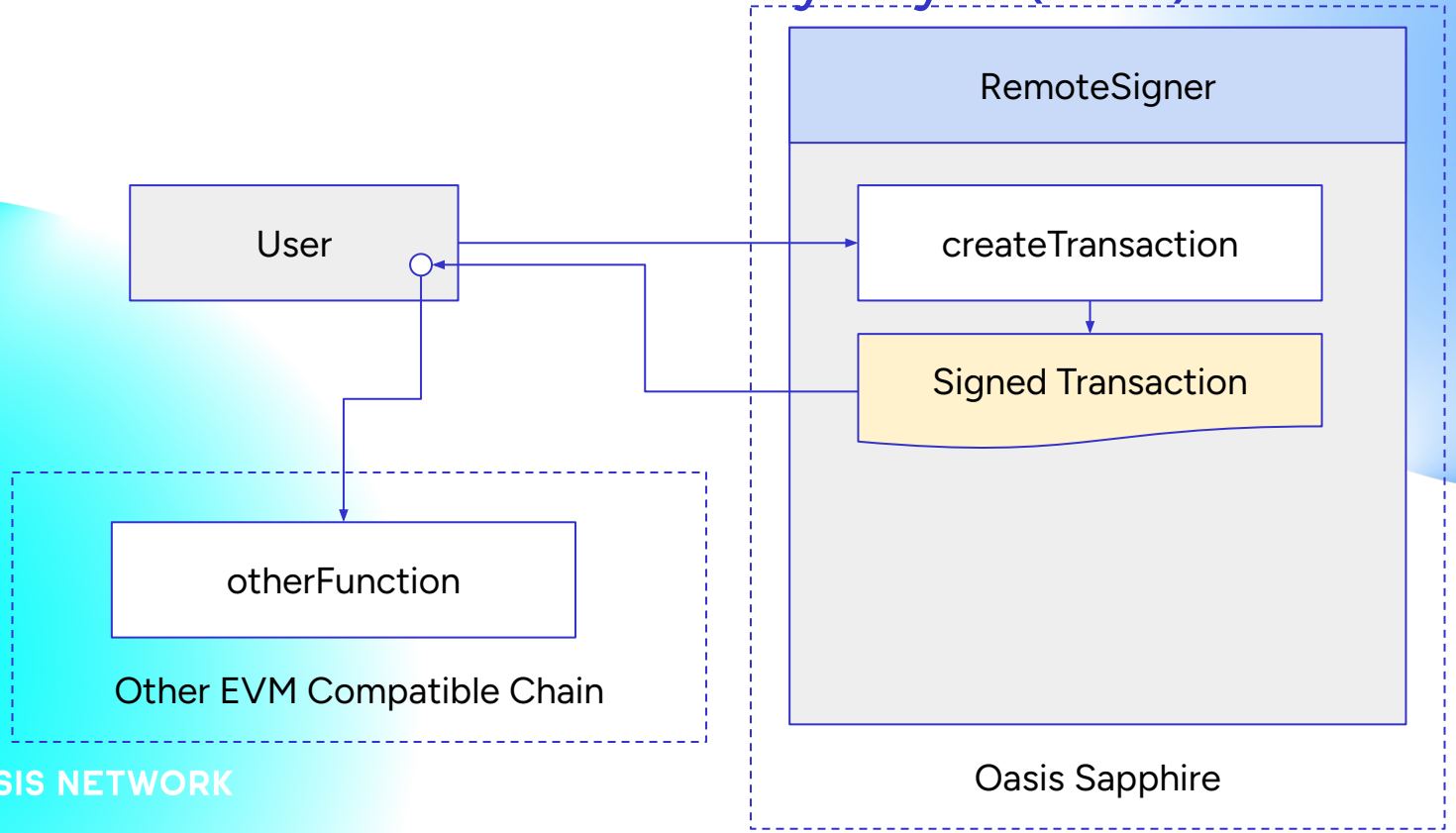
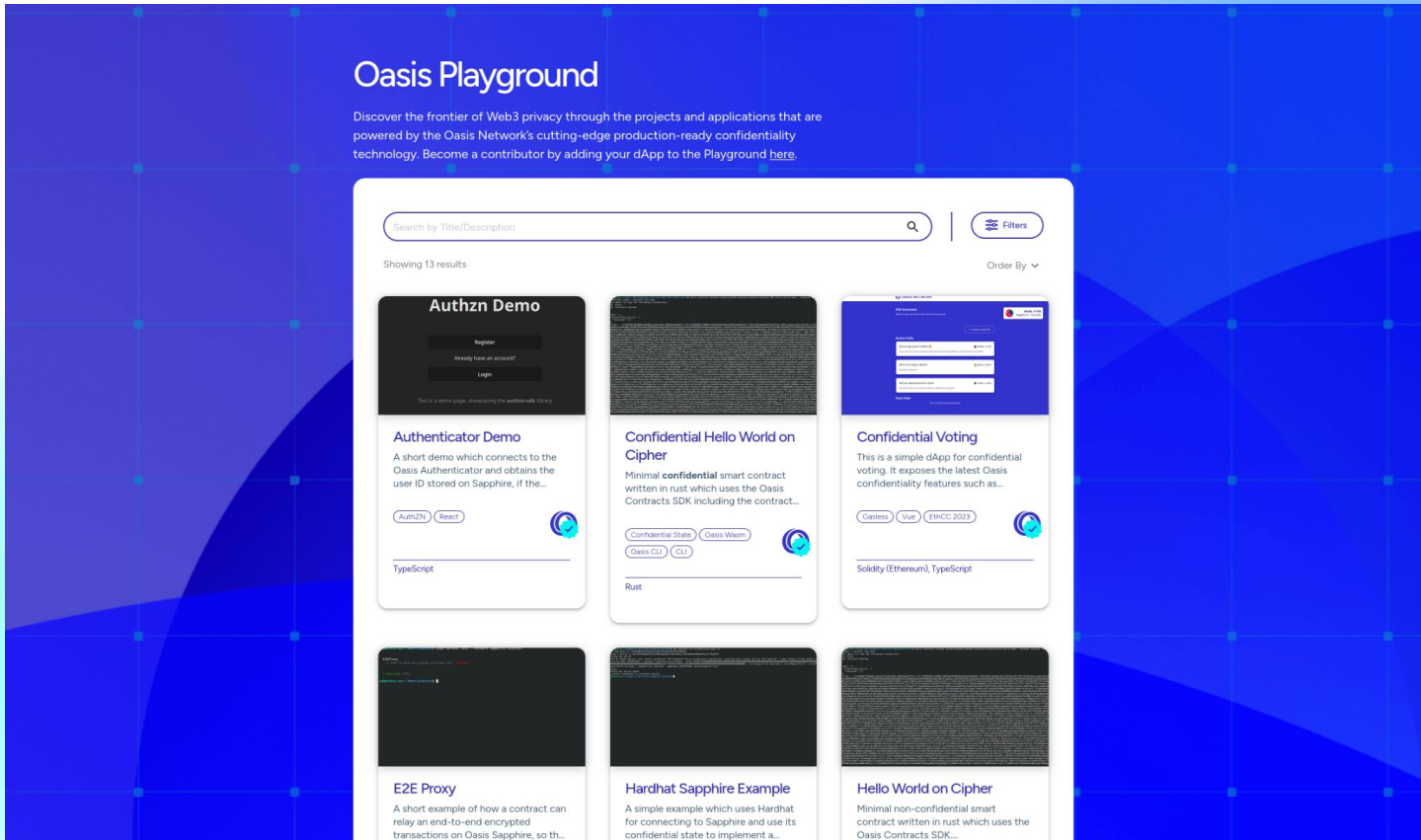
What to do next? Oasis Privacy Layer (OPL)



What to do next? Oasis Playground at playground.oasis.io



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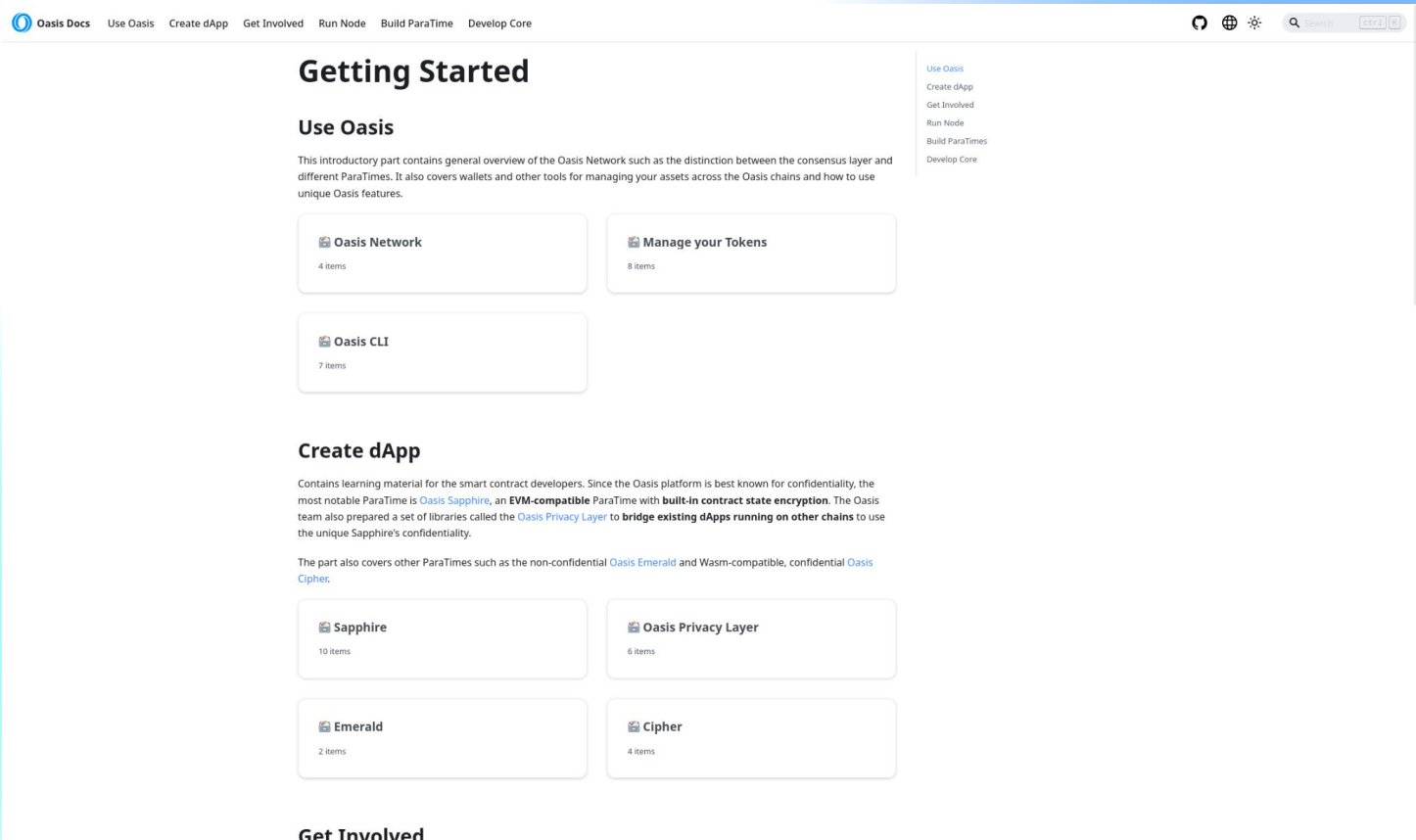
What to do next? Run your node

- Oasis network is a **decentralized network**
- You can help with the decentralization by **becoming a validator** and/or **running a ParaTime compute node** (Emerald, Sapphire, Cipher)
- Or, you can simply run a consensus and/or ParaTime **client node** along with the **web3 gateway** to avoid public (and malicious?) endpoints
- Learn more: docs.oasis.io/get-involved/run-node

What to do next? Oasis Documentation docs.oasis.io



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Question, Answers & Proposals

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THANK YOU

SEE YOU NEXT TIME!

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Task 5: Encryption (TypeScript)

```
import * as sapphire from '@oasisprotocol/sapphire-paratime'

const e2ePubKey = await e2e.getPublicKey();
const box = sapphire.cipher.X25519DeoxysII.ephemeral(e2ePubKey);

let {nonce, cipherText} = await box.encrypt(plaintextBytes);

const nonceBytes32Hex = ethers.utils.hexlify(nonce) +
"0000000000000000000000000000000000000000";
```


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Task 5: Decryption (Solidity)

```
import "@oasisprotocol/sapphire-contracts/contracts/Sapphire.sol";

contract E2EProxy {
  Sapphire.Curve25519PublicKey internal immutable publicKey;
  Sapphire.Curve25519SecretKey internal immutable privateKey;

  constructor (bytes memory extraEntropy) {
    (publicKey, privateKey) = Sapphire.generateCurve25519KeyPair(extraEntropy);
  }

  function getPublicKey() external view returns (bytes32) {
    return Sapphire.Curve25519PublicKey.unwrap(publicKey);
  }
}
```


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Task 5: Decryption (Solidity)

```
import "@oasisprotocol/sapphire-contracts/contracts/Sapphire.sol";

contract E2EProxy {
  function decrypt(bytes32 peerPublicKey, bytes32 nonce, bytes memory data)
    external
  {
    bytes32 sk = Sapphire.deriveSymmetricKey(
          Sapphire.Curve25519PublicKey.wrap(peerPublicKey),
          privateKey);
    bytes memory plaintext = Sapphire.decrypt(sk, nonce, data, "");
  }
}
```


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Task 5: Signing (Solidity)

```
import "@oasisprotocol/sapphire-contracts/contracts/Sapphire.sol";

contract SigningExample {
  function sign(bytes32 hashed_message)
      external returns (bytes)
  {
      Sapphire.SigningAlg alg =
Sapphire.SigningAlg.Secp256k1PrehashedKeccak256;

      bytes memory pk;
      bytes memory sk;
      bytes memory digest = abi.encodePacked(hashed_message);

      Bytes memory entropy = Sapphire.randomBytes(32, "");
      (pk, sk) = Sapphire.generateSigningKeyPair(alg, entropy);

      return Sapphire.sign(alg, sk, digest, "");
  }
}
```


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Task 5: Verification (Solidity)

```
import "@oasisprotocol/sapphire-contracts/contracts/Sapphire.sol";

contract VerifyExample {
  function verify(bytes32 hashed_message, bytes memory signature)
     external returns (bool)
  {
     Sapphire.SigningAlg alg =
Sapphire.SigningAlg.Secp256k1PrehashedKeccak256;

     bytes memory digest = abi.encodePacked(hashed_message);

     return Sapphire.verify(alg, pk, digest, "", signature);
  }
}
```


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Task 5: Autonomous Contracts

Ethereum compatible key-generation & signing is included in the `@oasisprotocol/sapphire-contracts` package:

- EthereumUtils.sol
  - `a, s = EthereumUtils.generateKeypair()`
- EIP155Signer.sol
  - `struct EIP155Signer.EthTx`
  - `EIP155Signer.sign(address,secret,tx)`

Task 5: Ethereum Keypair Generation and Signing (Solidity)

```
import '@oasisprotocol/sapphire-contracts/contracts/EthereumUtils.sol';

contract KeypairExample {
  address pubkey;
  bytes32 secret;

  constructor () {
    (pubkey, secret) = EthereumUtils.generateKeypair();
  }

  function sign(bytes memory data)
    external view returns (SignatureRSV memory rsv)
  {
    bytes32 digest = keccak256(data);
    rsv = EthereumUtils.sign(pubkey, secret, digest);
  }
}
```


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Task 5: Transaction Signing (Solidity)

```
function signTx(uint64 nonce, uint256 gasPrice, uint256 value)
  external view returns (bytes memory txdata)
{
  return EIP155Signer.sign(pubkey, secret, EIP155Signer.EthTx({
    nonce: nonce,
    gasPrice: gasPrice,
    gasLimit: 250000,
    to: msg.sender,
    value: value,
    data: "",
    chainId: block.chainid
  }));
}
```


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Task #1
Message Box

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Task #1: **Message Box**

1. Use Remix to import Git project **github.com/oasisprotocol/demo-starter**, branch **split2023-task1**
2. Deploy the contract
3. Post a message
4. Find your **contract create** and **contract call** transactions on explorer.
   Are they encrypted? Why?
5. Connect to my contract **0x6cEE2AF84941381Bc5f8eA7122e0a70e9Dc1eDbE** and submit a message!

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Task #2: **C10l Message Box**

1. Git clone project **github.com/oasisprotocol/demo-starter**, branch **split2023-task2**
2. Deploy the contract
3. Post a confidential message **using hardhat task** to your second Metamask account
4. Find your **contract create** and **contract call** transactions on explorer. Are they encrypted? Why?
5. Connect to my contract **0x682A74921B6f0194509C01490e35Ac0063a6a1b1** and submit a message for my account **0x90adE3B7065fa715c7a150313877dF1d33e777D5**!

OASIS NETWORK

Task #3
Message Box in the browser

OASIS NETWORK

Task #3: **Message Box in the browser**

1. Git clone project **github.com/oasisprotocol/demo-starter**, branch **split2023-task3**

2. Deploy the contract and configure the contract address in the Frontend folder. Spin up the Frontend locally!

3. Post a confidential message **from the browser** and view it by switching to the second account

4. Find your **contract create** and **contract call** transactions on explorer. Are they encrypted? Why?

5. Connect to my contract **0x682A74921B6f0194509C01490e35Ac0063a6a1b1** and submit a message for my account **0x90adE3B7065fa715c7a150313877dF1d33e777D5**!

Getting Started: Localnet (sapphire-dev)

Run a full Sapphire node locally.

```
IMAGE=ghcr.io/oasisprotocol/sapphire-dev:latest

docker pull $IMAGE

docker run --rm -it -p8545:8545 -p8546:8546 $IMAGE
```

Differences vs Ethereum

The big questions:

- Calldata Encryption
- Encrypted Storage
- Can you trust `msg.sender` ?

How?

- Trusted Execution Environment (Intel SGX)
- Key Manager & EVM run inside different TEEs

Content: **Lorem Ipsum Dolor**

- Reputation/Credit-based Lending
- Crypto Gaming (w. game logic on chain to enable full transparency and auditability)
- Private DEX to eliminate MEV issues
- Decentralized Identity, KYC/AML, verifiable credentials
- Decentralized Society
- Confidential NFT, Data backed NFT