

# Lesson 6 - Cairo contracts

The Starknet Context

Transaction

Layer 2

Prover

Send trace,  
return proof

Get Trace

Sequencer

Runner (VM)

Contract

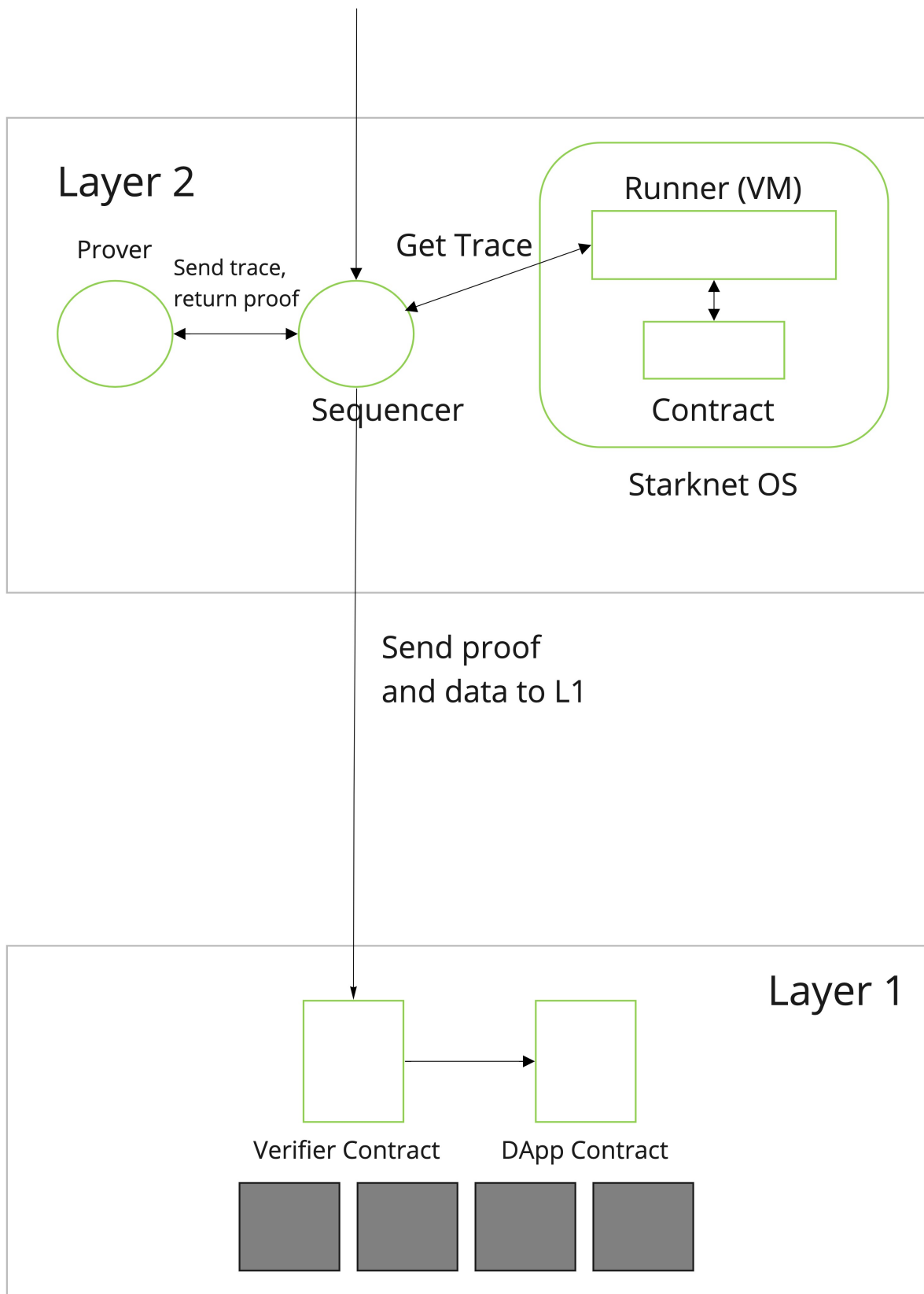
Starknet OS

Send proof  
and data to L1

Layer 1

Verifier Contract

DApp Contract



## Transaction Status

### 1. NOT\_RECEIVED

Transaction is not yet known to the sequencer

### 2. RECEIVED

Transaction was received by the sequencer. Transaction will now either execute successfully or be rejected.

### 3. PENDING

Transaction executed successfully and entered the [pending block](#).

### 4. REJECTED

Transaction executed unsuccessfully and thus was skipped (applies both to a pending and an actual created block). Possible reasons for transaction rejection:

- An assertion failed during the execution of the transaction (in StarkNet, unlike in Ethereum, transaction executions do not always succeed).
- The block may be rejected on L1, thus changing the transaction status to **REJECTED**

### 5. ACCEPTED\_ON\_L2

Transaction passed validation and entered an actual created block on L2.

### 6. ACCEPTED\_ON\_L1

Transaction was accepted on-chain.

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## Transaction types

1. Deploy
2. Invoke
3. Declare

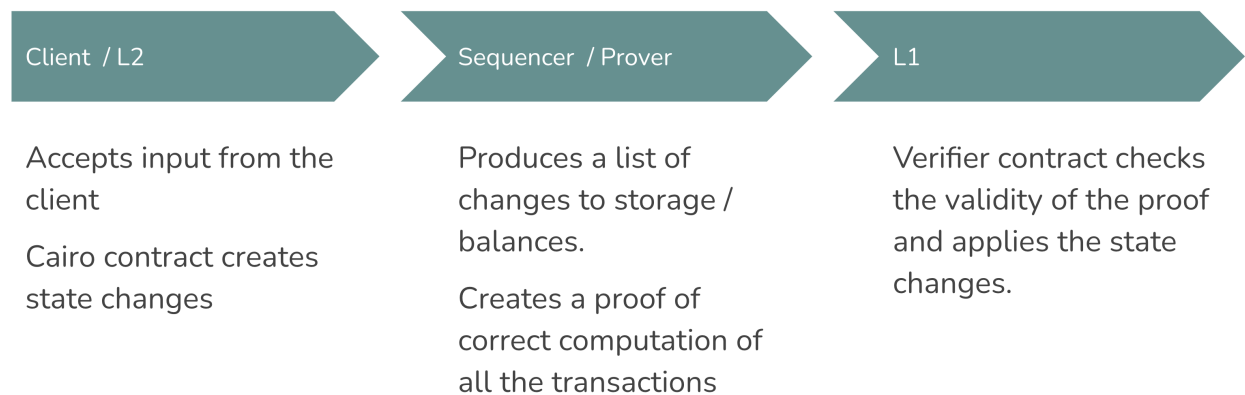
We will see Declare transactions tomorrow when we discuss contract classes.

## Invoke Transaction Structure

Name	Type	Description
contract_address	FieldElement	The address of the contract invoked by this transaction
entry_point_selector	FieldElement	The encoding of the selector for the function invoked (the entry point in the contract)
calldata	List<FieldElement>	The arguments passed to the invoked function
signature	List<FieldElement>	Additional information given by the caller, representing the signature of the transaction
max_fee	FieldElement	The maximum fee that the sender is willing to pay for the transaction
version	FieldElement	The transaction's version <sup>1</sup>

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# Transaction Process



## Data Availability

Currently Starknet is operating in zkrollup mode, this means that upon the acceptance of a state update on-chain, the state diff between the previous and new state is sent as calldata to Ethereum.

This data allows anyone that observes Ethereum to reconstruct the current state of StarkNet.

There are other modes possible :

In ZK-Rollup mode data is published on-chain.

In Validium mode data is stored off-chain.

Volition is a hybrid data availability mode, where the user can choose whether to place data on-chain or off-chain.

## Starknet Fee Mechanism

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See [docs](#)

Users can specify the maximum fee that they are willing to pay for a transaction via the `max_fee` field.

The only limitation on the sequencer (enforced by the StarkNet OS) is that the actual fee charged is bounded by `max_fee`, but for now, StarkWare's sequencer will only charge the fee required to cover the proof cost (potentially less than the max fee).

Presently, the sequencer only takes into account L1 costs involving proof submission. There are two components affecting the L1 footprint of a transaction:

- **computational complexity**: the heavier the transaction, the larger its portion in the proof verification cost.
- **on chain data**: L1 calldata cost originating from [data availability](#) and L2→L1 messages.

The fee is charged atomically with the transaction execution on L2. The StarkNet OS injects a transfer of the fee-related ERC-20, with an amount equal to the fee paid, sender equals to the transaction submitter, and the sequencer as a receiver.

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## Reverting transactions and a problem

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See [documentation](#) for adding error messages

For example

```
with_attr error_message("ERC20: decimals exceed 2^8"):
    assert_lt(decimals, UINT8_MAX)
end
```

But handling reverted transactions is being [debated](#)

Cairo is not natively capable of proving reverted transactions. The reason is that for a transaction to fail, one needs to prove that the transaction resulted in an error.

On the current version of StarkNet Alpha, either a transaction is valid and can be included in a proof or it is unprovable and cannot be included.

The problem this triggers is that an unprovable transaction cannot pay fees and one can imagine sending expensive computation-wise transactions which consume sequencers' resources without compensating for them. This allows DoS attacks on the sequencers.

Suggested solutions

1. Making All Transactions Provable

This can be achieved by using a new programming language (whose syntax can be very similar to Cairo), in which the compiled contract will include the code to handle exceptions.

2. Economic Solution - "Red/Green"

The main idea is that a sequencer can choose to include a transaction without executing it and receive a red fee, thus enabling it to ensure it receives a fee payment for their work. We can design the mechanism in such a way that a Sequencer will always be incentivized to execute a provable transaction and take the green fee instead of the red fee.

3. Transaction level PoW

Users provide a PoW on top of their transactions based on the numbers of reverted txs. In such a way, a user would have to provide a small proof of work or none on the average case, but in the case too many reversions, the PoW will be much larger.

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## Cairo contracts

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Cairo programs are by default stateless, if we want to write contracts to run on Starknet we need additional context provided by the Starknet OS

We need to add the following to our code to declare it as a contract

```
%lang starknet
```

## Adding state

To store state within our contract we use a decorator

```
@storage_var
```

We then specify the variable as a function

```
@storage_var
func balance() -> (res : felt){
}
```

The decorator will create the ability for us to read and write to a variable 'balance'  
For example

```
balance.read();
```

```
balance.write(1234);
```

You would then write getter and setter functions to interact with the variable as usual.  
When the contract is deployed, all the storage is set to 0

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## Function visibility

Unlike a standalone cairo program, we don't have a main function, instead we can interact with any of the functions in the contract depending on their visibility.

The decorators are

`@external`

`@view`

Both external and view functions can be called from other contracts or externally.

If no decorator is specified, then the function is internal.

Although `@view` indicates that we are not changing state, this is not currently enforced.

## Function implicit arguments

```
@view
func get_score{
    syscall_ptr : felt*,
    pedersen_ptr : HashBuiltin*,
    range_check_ptr,
}() -> (score : felt){
    let (score) = score.read();
    return (score);
}
```

We have an additional implicit argument `syscall_ptr` this allows the OS to handle the storage variables correctly.

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## Hints

The situation regarding hints is a little more complex, see [Hints](#)

You generally do not use hints in your contracts due to security concerns (the user and the operator running the code are likely to be different).

You may see hints in libraries however, and there is a whitelisting mechanism to ensure security.

## Constructors

Constructors work in a similar way to Solidity constructors.

- It must be called `constructor`
- It is decorated with `@constructor`
- It is run once, only during deployment.

For example

```
@constructor
func constructor{
    syscall_ptr : felt*,
    pedersen_ptr : HashBuiltin*,
    range_check_ptr,
}(owner_address : felt){
    owner.write(value=owner_address);
    return ();
}
```

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## More complex storage variables

We can create the equivalent of a Solidity mapping as follows

```
@storage_var
func balance(user : felt) -> (res : felt){
}
```

The corresponding read and write functions have the following signatures

```
func read{
    syscall_ptr : felt*, range_check_ptr,
    pedersen_ptr : HashBuiltin*}(
    user : felt) -> (res : felt)

func write{
    syscall_ptr : felt*, range_check_ptr,
    pedersen_ptr : HashBuiltin*}(
    user : felt, value : felt)
```

## Getting the user address

The common.syscalls library allows us to get the address of the user calling a function

```
from starkware.starknet.common.syscalls import get_caller_address

# ...

let (caller_address) = get_caller_address();
```

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For reference this is the default contract created by protostar

```
%lang starknet

from starkware.cairo.common.math import assert_nn
from starkware.cairo.common.cairo_builtins import HashBuiltin

@storage_var
func balance() -> (res : felt){
}

@external

func increase_balance{syscall_ptr : felt*,
pedersen_ptr : HashBuiltin*, range_check_ptr}(
    amount : felt){
    with_attr error_message("Amount must be positive. Got: {amount}."){
        assert_nn(amount);
    }

    let (res) = balance.read();
    balance.write(res + amount);
    return ();
}

@view
func get_balance{syscall_ptr : felt*,
pedersen_ptr : HashBuiltin*, range_check_ptr}() -> (
    res : felt){

    let (res) = balance.read();
    return (res);
}

@constructor
func constructor{syscall_ptr : felt*,
```

```
pedersen_ptr : HashBuiltin*, range_check_ptr){}{
    balance.write(0);
    return ();
}
```

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## Events in Starknet Contracts

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See [docs](#)

The mechanism is similar to that on Ethereum.

A contract may emit events throughout its execution. Each event contains the following fields:

- `from_address` : address of the contract emitting the events
- `keys` : a list of field elements
- `data` : a list of field elements

The keys can be used for indexing the events, while the data may contain any information that we wish to log (note that we are dealing with two separate lists of possibly varying size, rather than a list of key-value pairs).

Events can be defined in a contract using the `@event` decorator. Once an event `E` has been defined, the compiler automatically adds the function `E.emit()`. The following example illustrates how an event is defined and emitted:

```
@event
func message_received(a : felt, b: felt){
}
```

...

```
message_received.emit(1, 2);
```

The emit function emits an event with a single key, which is an identifier of the event, given by `sn_keccak(event_name)`

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## Open Zeppelin cairo contracts

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See [Repo](#)

and [guide](#)

In protostar you need to install the contract libraries

```
protostar install https://github.com/OpenZeppelin/cairo-contracts
```

There are some presets that can be used (Presets are pre-written contracts that extend from the library of contracts. They can be deployed as-is or used as templates for customization.)

- [Account](#)
  - [ERC165](#)
  - [ERC20Mintable](#)
  - [ERC20Pausable](#)
  - [ERC20Upgradeable](#)
  - [ERC20](#)
  - [ERC721MintableBurnable](#)
  - [ERC721MintablePausable](#)
  - [ERC721EnumerableMintableBurnable](#)
-

From the cairo common library

[Signature.cairo](#)

This gives us the function

```
func verify_ecdsa_signature{ecdsa_ptr : SignatureBuiltin*}(  
  
    message, public_key, signature_r, signature_s  
  
):
```

Allowing us to verify that the prover knows a signature of the given public\_key on the given message.

An example of its use see [docs](#)

```
@external  
func increase_balance{  
    syscall_ptr : felt*,  
    pedersen_ptr : HashBuiltin*,  
    range_check_ptr,  
    ecdsa_ptr : SignatureBuiltin*,  
}(user : felt, amount : felt, sig : (felt, felt)){  
    # Compute the hash of the message.  
    # The hash of (x, 0) is equivalent to the hash of (x).  
    let (amount_hash) = hash2{hash_ptr=pedersen_ptr}(amount, 0)  
  
    # Verify the user's signature.  
    verify_ecdsa_signature(  
        message=amount_hash,  
        public_key=user,  
        signature_r=sig[0],  
        signature_s=sig[1],  
    )
```

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## Developing contracts - tools

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### Starknet Playground

An equivalent to the Cairo playground is the [Starknet Playground](#)

### Protostar

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#### Installation

See [documentation](#) and this useful medium [article](#)

#### Linux / Mac

1. ``curl -L https://raw.githubusercontent.com/software-mansion/protostar/master/install.sh | bash``
2. Restart the terminal.
3. Run `protostar -v` to check Protostar and [cairo-lang](#) version.  
It adds to your PATH in `.bashrc`, you may need to move that line to `.bash_profile` If it doesn't find protostar.  
You may also need to update your version of git

#### Testing in protostar

See previous notes, in addition the following flags may be useful

```
protostar test test/test_erc20.cairo --disable-hint-validation
protostar test test/test_ex1.cairo --stdout-on-success
```

#### Cheatcodes

See [documentation](#)

There are a number of keywords to add functionality to your tests, such as mocking, deploying contracts. We will cover these in more detail later.

#### Deploying contracts

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If you are using the starknet CLI you can use

```
starknet deploy --contract compiled_contract.json --address SELECTED_ADDRESS
```

If you are using protostar, see [docs](#)

```
protostar deploy ./build/main.json --network alpha-goerli
```