COP for Smart Contracts
Activity Contexts

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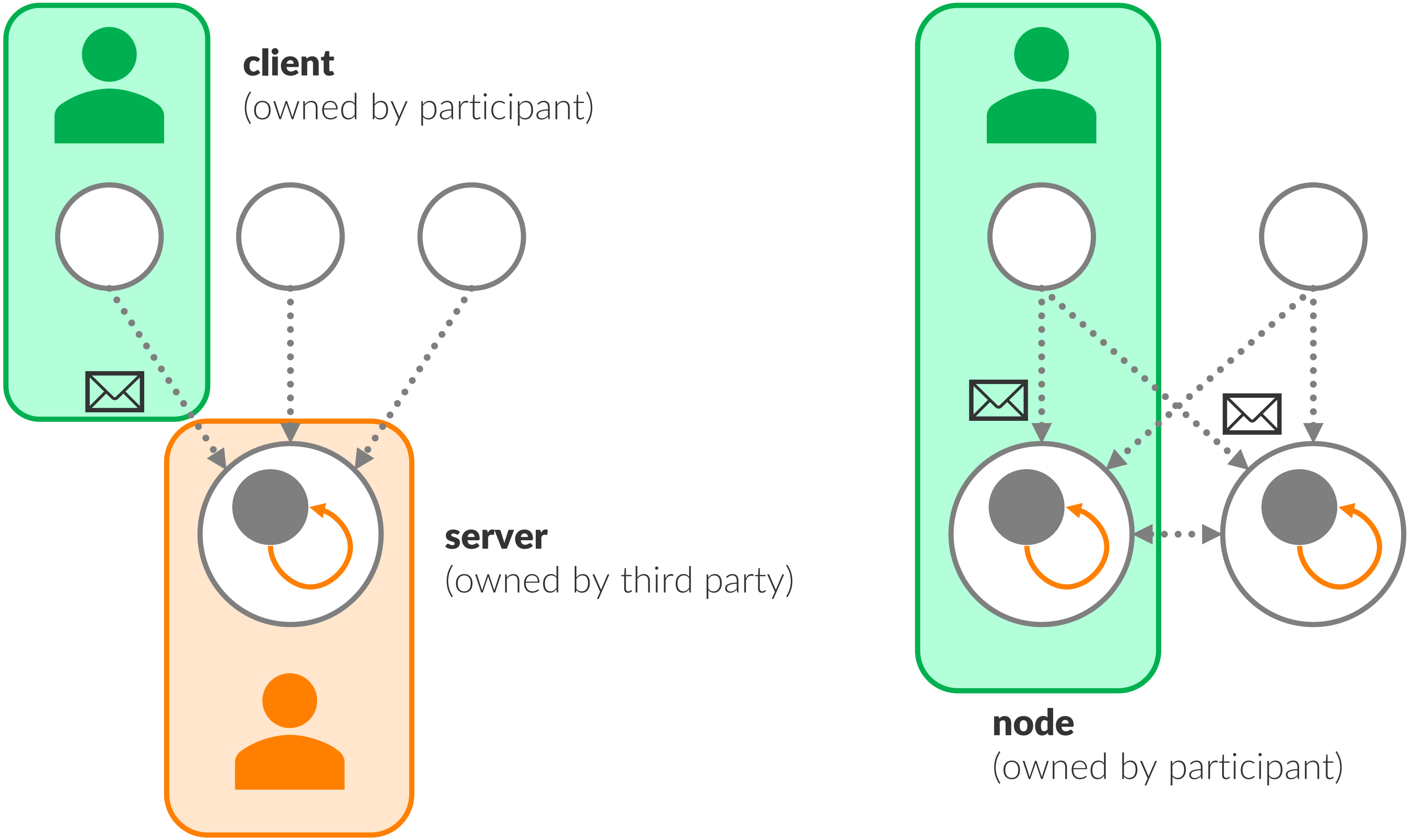
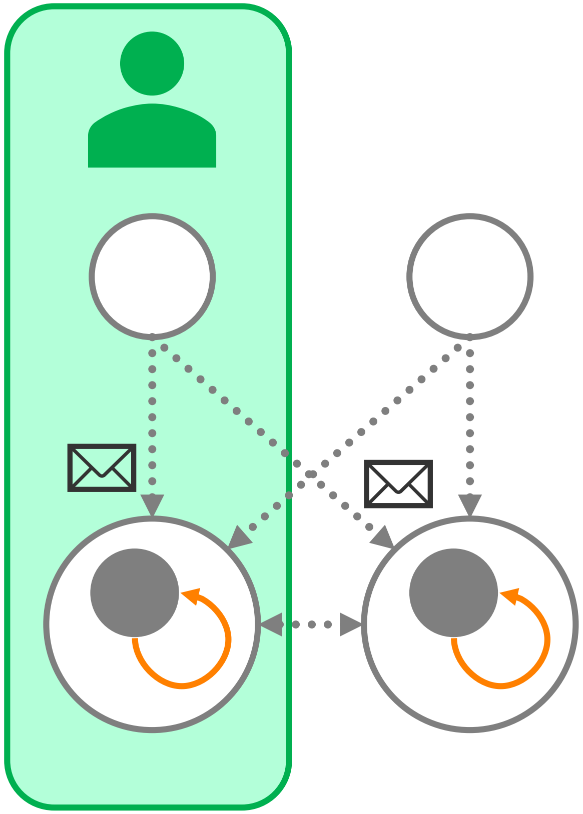
COP '18 17 July 2018, Amsterdam, Netherlands

Centralized vs. Decentralized Services



Smart Contracts as Decentralized Service

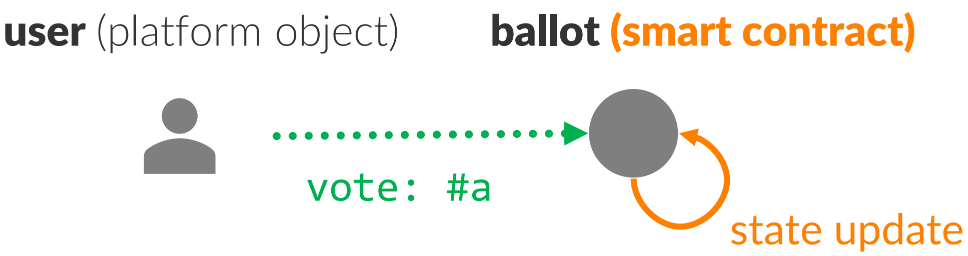
- Set of executable rules according to which real-world actors can interact
  - "Game" (state, moves, players)
  - "Object" (identity, state, behavior)
- Automated enforcement
  - Transfer digitally manageable goods (money, rights, ...)
  - Can take external events as input (deadlines, stock prices, ...)
- No central authority
  - Consensus by quorum
  - Lower transaction costs
  - Trustless



node
(owned by participant)

Decentralized Execution Model

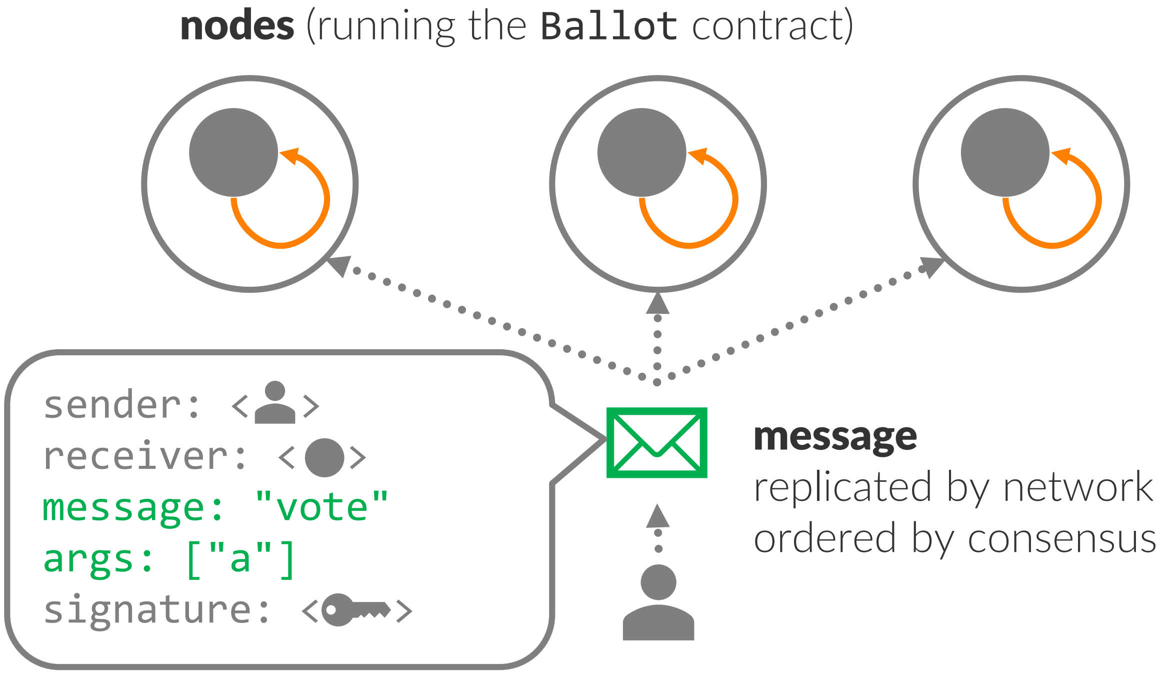
logical perspective
objects and messages



user (platform object)

ballot **(smart contract)**

distribution perspective
replicated copies and messages



nodes (running the `Ballot` contract)

```
sender: <👤>
receiver: <●>
message: "vote"
args: ["a"]
signature: <🔑>
```

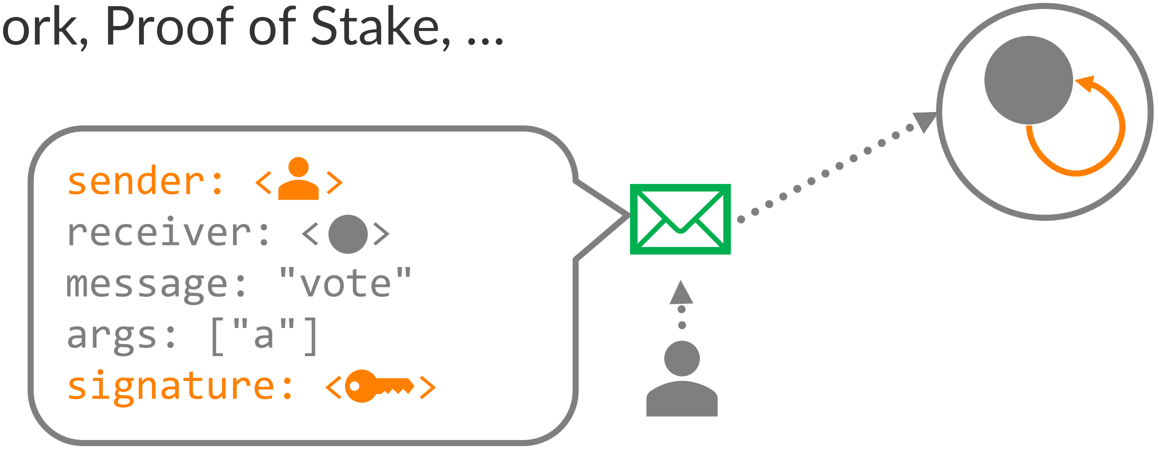
message
replicated by network
ordered by consensus

Security and Consensus

- User identity linked to public key
  - Same public keys = same user
  - User signs all messages using corresponding private key

- Consensus protocol establishes a unique global order of messages
  - Paxos, Byzantine Fault Tolerance (BFT)
  - Proof of Work, Proof of Stake, …

Blockchain



```
sender: <👤>
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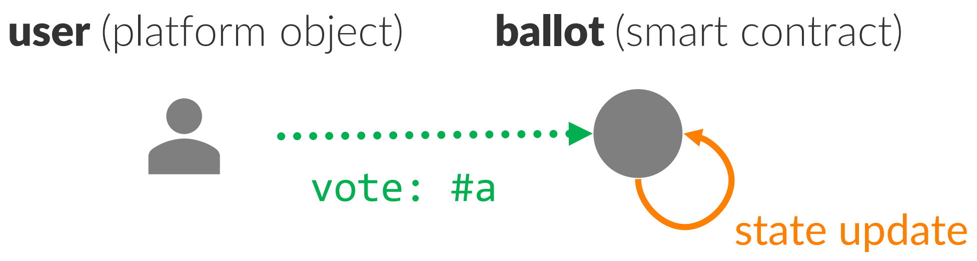
message: "vote"
args: ["a"]
signature: <🔑>
```

Decentralized Execution Model

logical perspective
objects and messages

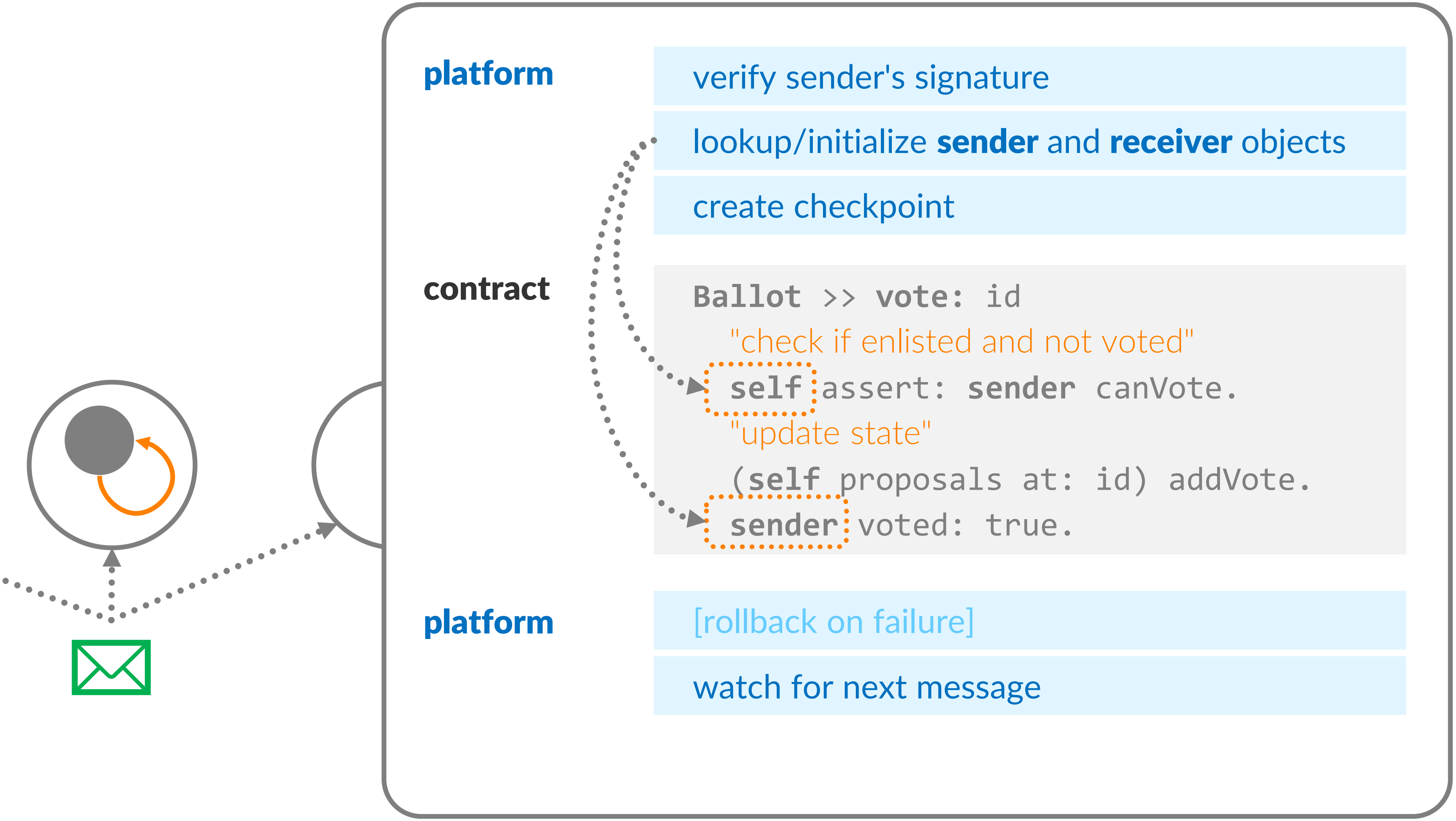


```
Ballot >> vote: id
    "check if enlisted and not voted"
    self assert: ~~sender canVote.~~
    "update state"
    (self proposals at: id) addVote.
    ~~sender voted: true.~~
```

instance of class **User**
provided by platform, not modifiable

How can we add state & behavior?

Decentralized Execution Model



platform

- verify sender's signature
- lookup/initialize **sender** and **receiver** objects
- create checkpoint

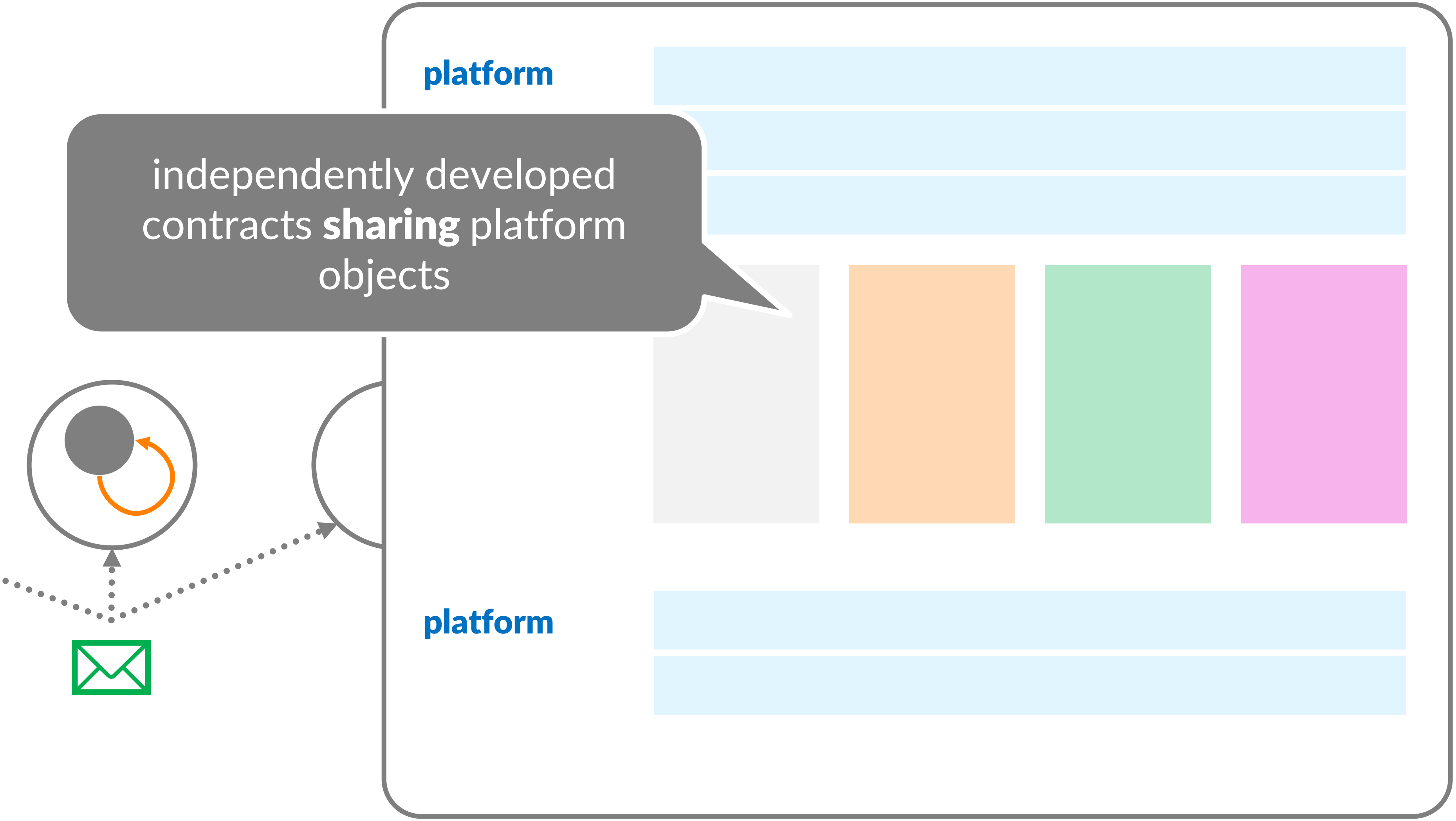
contract

```
Ballot >> vote: id
   "check if enlisted and not voted"
   self assert: sender canVote.
   "update state"
   (self proposals at: id) addVote.
   sender voted: true.
```

platform

- [rollback on failure]
- watch for next message

Decentralized Execution Model



independently developed contracts **sharing** platform objects

Current Workaround: Mediator

Dictionary (voters) with user information

```
Ballot >> vote: id
  | user |
  user := self voters at: sender address.
  "check if enlisted and not voted"
  self assert: user canVote.
  "update state"
  (self proposals at: id) addVote.
  user voted: true.
```

- Lack of encapsulation
- Tendency to drift towards data classes and god-class like mediator

Example in Practice (Solidity)

```
 /// @title Voting with delegation.
contract Ballot {
    // This declares a new complex type which will
    // be used for variables later.
    // It will represent a single voter.
    struct Voter {
        uint weight; // weight is accumulated by delegation
        bool voted;  // if true, that person already voted
        address delegate; // person delegated to
        uint vote;   // index of the voted proposal
    }

    […]

    // This declares a state variable that
    // stores a `Voter` struct for each possible address.
    mapping(address => Voter) public voters;

    […]
```

https://solidity.readthedocs.io/en/v0.4.21/solidity-by-example.html

Decentralized Execution Model

We want to add **behavior** ...

```
User >> canVote
  ^self eligible and:
   [self voted not]
```

and **state** to a platform object
in the context of the voting **activity**

verify sender's signature

lookup/initialize **sender** and **receiver** objects

create checkpoint

```
Ballot >> vote: id
    "check if enlisted and not voted"
    self assert: sender canVote.
    "update state"
    (self proposals at: id) addVote.
    sender voted: true.
```

[rollback on failure]

watch for next message

Activity Contexts

extend `User` objects in the context of `Ballot`
(= during the voting activity)

```
Ballot >> User >> canVote
  ^self eligible and:
   [self voted not]
```

```
Ballot >> vote: id
   "check if enlisted and not voted"
   self assert: sender canVote.
   "update state"
   (self proposals at: id) addVote.
   sender voted: true.
```

behavior and state visible in control flows
originating from `Ballot`

Activity Contexts

```
Ballot >> User >> canVote
  ^self eligible and:
   [self voted not]
```

```
Ballot >> User >> eligible
  <activityAccessor>
  ^false
```

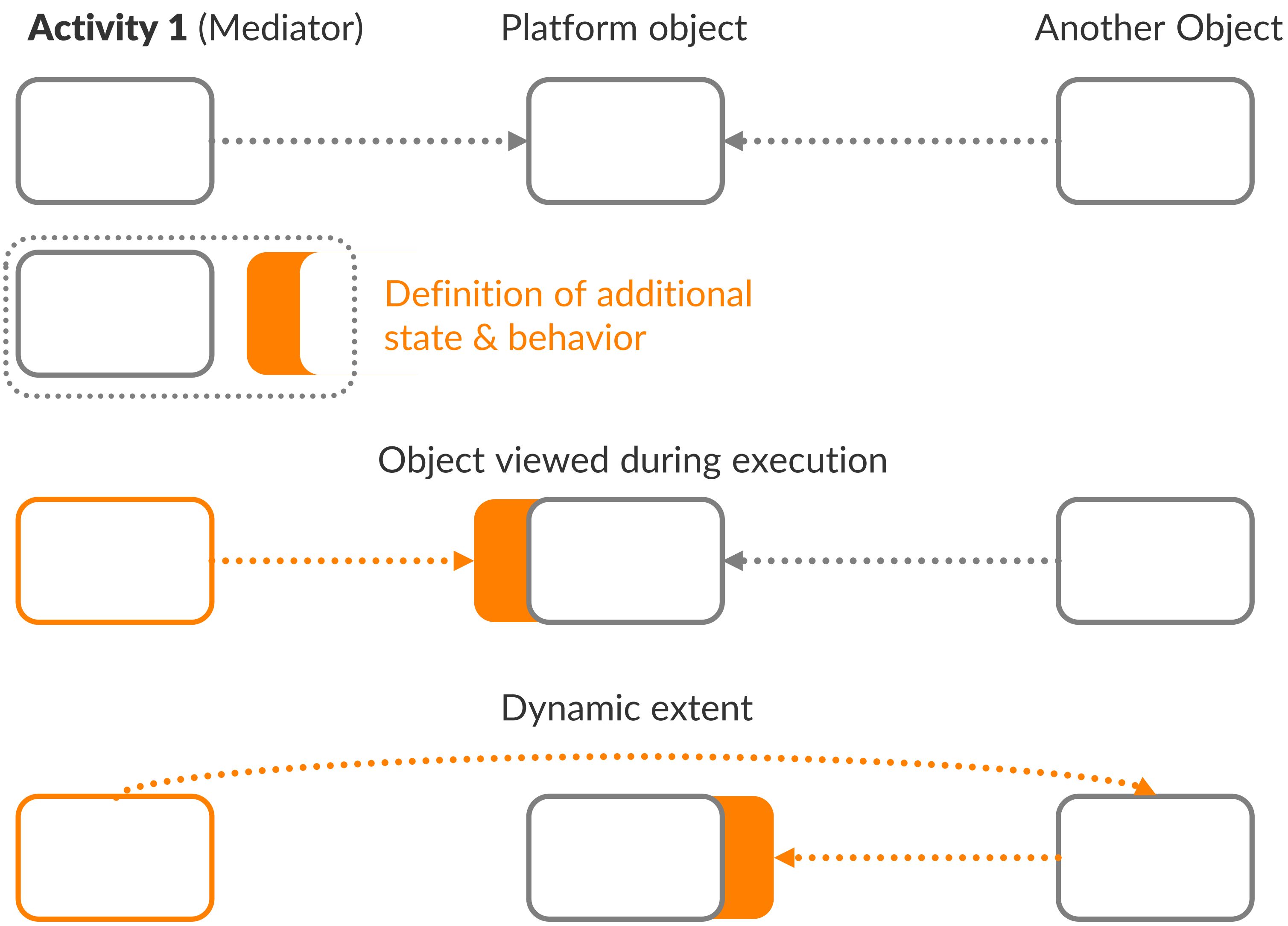
```
Ballot >> User >> voted
  <activityAccessor>
  ^false
```

```
Ballot >> vote: id
  "check if enlisted and not voted"
  self assert: sender canVote.
  "update state"
  (self proposals at: id) addVote.
  sender voted: true.
```

state (accessors)

default value (when the object enters the activity first)

Activity Contexts: Dynamic Extent



Activity 1 (Mediator)

Platform object

Another Object

Definition of additional state & behavior

Object viewed during execution

Dynamic extent

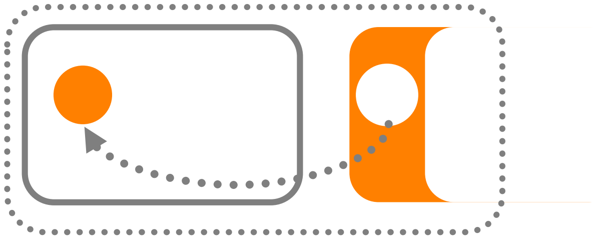
Activity Contexts: State Scoping

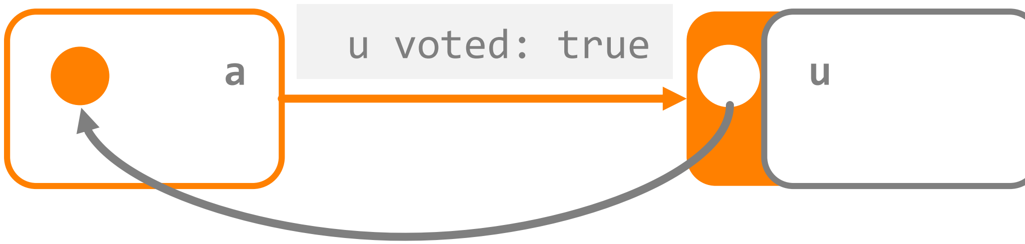
Platform objects may be immutable, where do we store state?

```
Ballot >> User >> eligible
  <activityAccessor>
  ^false
```

```
Ballot >> User >> voted
  <activityAccessor>
  ^false
```

State remains (lexically) scoped to the activity





```
u voted: true
```

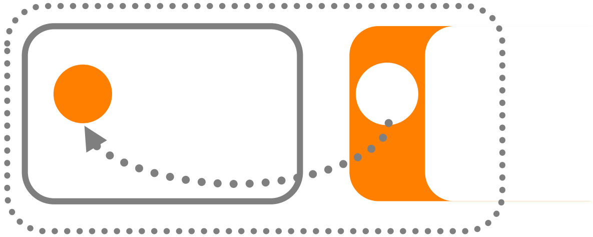
```
a set: #voted to: true for: u
```

(effective behavior of `activityAccessor`)

Activity Contexts: State Scoping

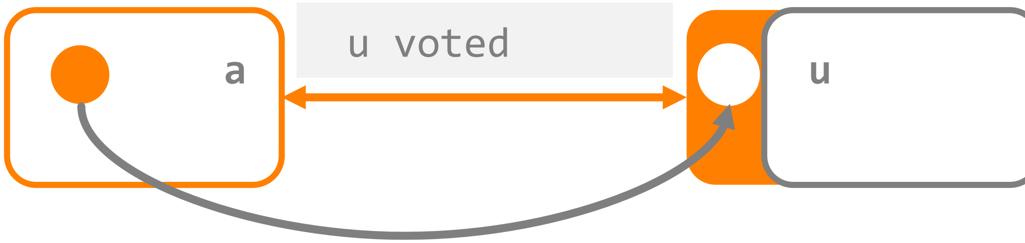
Platform objects may be immutable, where do we store state?

State remains (lexically) scoped to the activity



```
Ballot >> User >> eligible
  <activityAccessor>
  ^false
```

```
Ballot >> User >> voted
  <activityAccessor>
  ^false
```



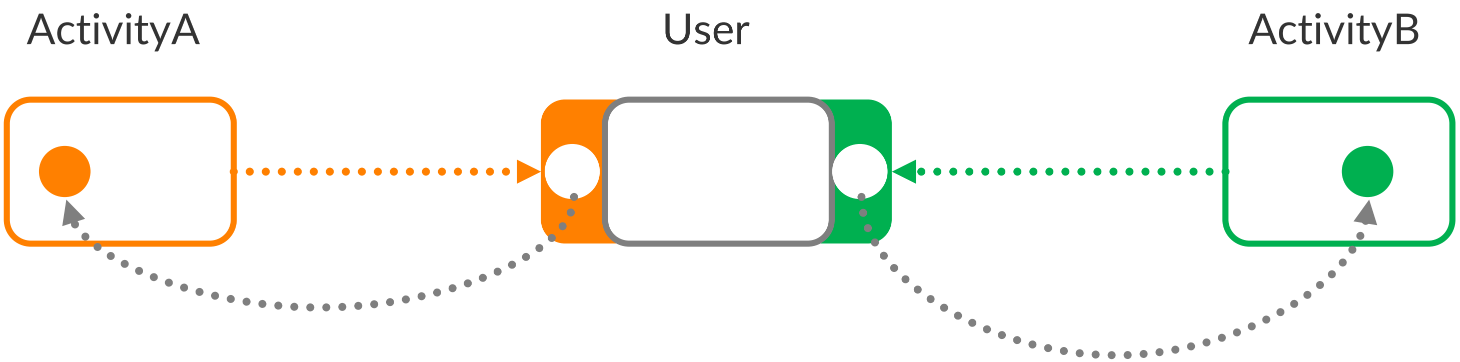
```
a get: #voted for: u
```

(effective behavior of activityAccessor)

Activity Contexts: Names

```
ActivityA >> User >> eligible
  <activityAccessor>
  ^false
```

```
ActivityB >> User >> eligible
  <activityAccessor>
  ^false
```

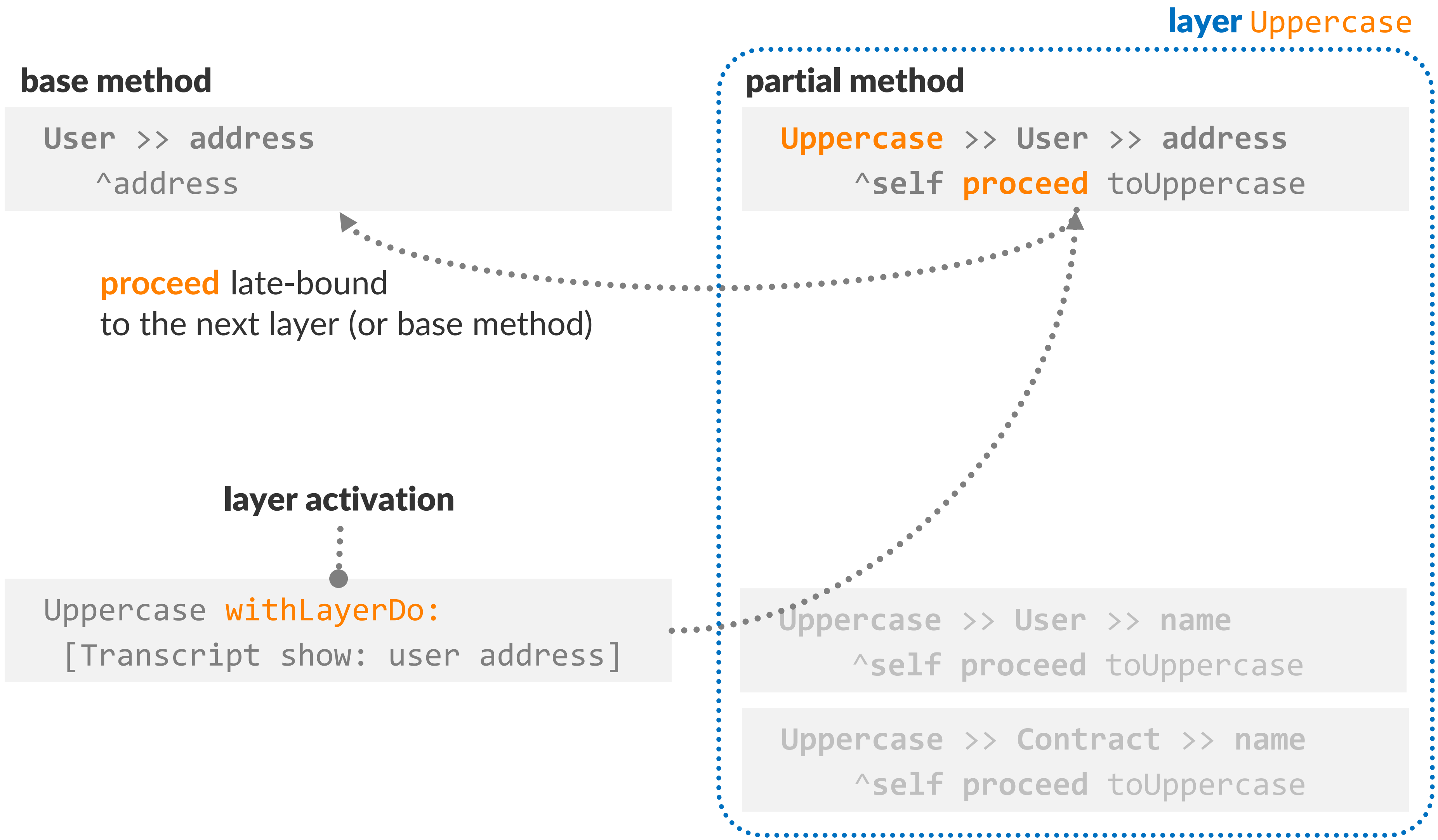


Activities can re-use the same name, but always see their **own** state.

critical, since code is independently developed

`eligible` has no meaning outside an activity.

Recap: Layer-based COP



layer Uppercase

base method

```
User >> address
   ^address
```

partial method

```
Uppercase >> User >> address
     ^self proceed toUppercase
```

proceed late-bound
to the next layer (or base method)

layer activation

```
Uppercase withLayerDo:
 [Transcript show: user address]
```

```
Uppercase >> User >> name
     ^self proceed toUppercase
```

```
Uppercase >> Contract >> name
     ^self proceed toUppercase
```

Activity Contexts vs. Layers

- Activity Contexts are **objects**
  - Identity, state, behavior
  - Communicating via messages

- Activity Contexts are **layers**
  - Partial state/behavior for other objects
  - Cross-cutting (adapts multiple objects/classes at once)
  - Run-time activation and composition

- Subtle differences
  - State per activity (neither layer, nor layered object)
  - Composable with layers, but not other ACs (i.e., no `proceed`/`next` between activities)

Layers within Activities

» Can we exploit composability of layers (and Activity Contexts) to further improve contract code?

Role (of a user)

State (of the activity)

```
Ballot >> initialize
    "contract constructor"
    sender isPollLeader: true.
```

```
Ballot >> startPoll
    self assert: sender isPollLeader.
    self open: true.
```

```
Ballot >> vote: id
    self assert: self open.
    "check if enlisted and not voted"
    self assert: sender canVote.
    "update state"
    (self proposals at: id) addVote.
    sender voted: true.
```

Roles as Layers

- Replace role checks by layer with role-specific behavior

```
Ballot >> initialize
  "contract constructor"
  sender isPollLeader: true.
```

```
Ballot >> startPoll
  self assert: sender isPollLeader.
  self open: true.
```

```
Ballot >> initialize
  "contract constructor"
  sender attach: PollLeader
```

activate Layer at instance

```
PollLeader >> Ballot >> startPoll
  self open: true.
```

Layer definition
(startPoll invisible outside)

State as Layers

- Replace state checks by layer with state-specific behavior

```
Ballot >> startPoll
  self assert: sender isPollLeader.
  self open: true.
```

```
Ballot >> vote: id
  self assert: self open.
  [...] "check if enlisted and not voted"
  [...] "update state"
```

```
Ballot >> startPoll
  self assert: sender isPollLeader.
  self attach: PollOpen.
```

activate Layer at activity

```
PollOpen >> Ballot >> vote: id
  [...] "check if enlisted and not voted"
  [...] "update state"
```

Layer definition
(`vote:` invisible outside)

Layers in Smart Contracts

Traditional contract

```
Ballot >> initialize
   "contract constructor"
   sender isPollLeader: true.
```

```
Ballot >> startPoll
   self assert: sender isPollLeader.
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```

Roles and state as layer

```
Ballot >> initialize
   "contract constructor"
   sender attach: PollLeader
```

```
PollLeader >> Ballot >> startPoll

   self attach: PollOpen.
```

```
PollOpen >> Ballot >> vote: id

   "check if enlisted and not voted"
   self assert: sender canVote.
   "update state"
   (self proposals at: id) addVote.
   sender voted: true.
```

Layer Activation Mechanisms in Use

layer activation scoped to **specific instance** (sender "sees" layer whenever control flow enters its scope)

```
Ballot >> initialize
    "contract constructor"
  sender attach: PollLeader
```

```
PollLeader >> Ballot >> startPoll

  self attach: PollOpen.
```

activation during **control flow**

```
SomeLayer withLayerDo: [...]
```

global activation

```
SomeLayer activate.
```

Limitations and Outlook

- **Tooling:** Arrange code in a useful way

- **Use cases:** Explore additional smart contract types
  - (Blind) Double auctions
  - Decentralized Market places
  - Supply chain ledgers
  - …

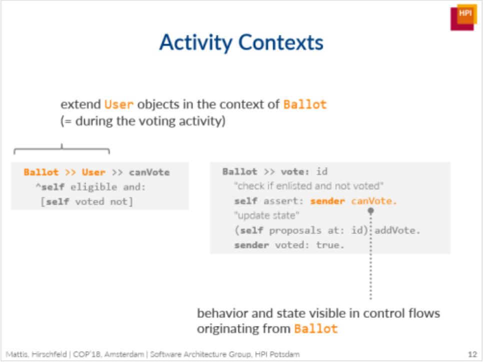
- **Integration:** Explore how to target existing smart contract platforms (e.g. EVM on the Ethereum Blockchain)

Summary

- Activity Contexts have **layer and object** personalities

- ACs are a tool to **decompose large mediators**, such as smart contracts, back into smaller responsibilities
  - Restore encapsulation
  - Scope extensions to activity only

- **Layers** integrate with ACs and can provide further modularity



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behavior and state visible in control flows originating from Ballot

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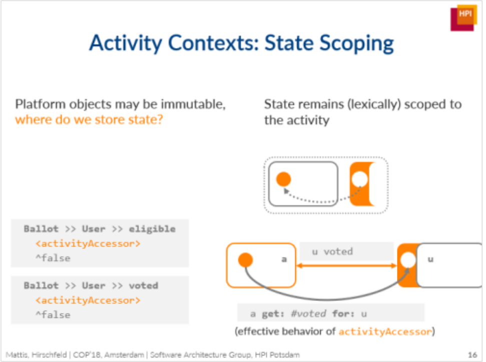

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(effective behavior of activityAccessor)

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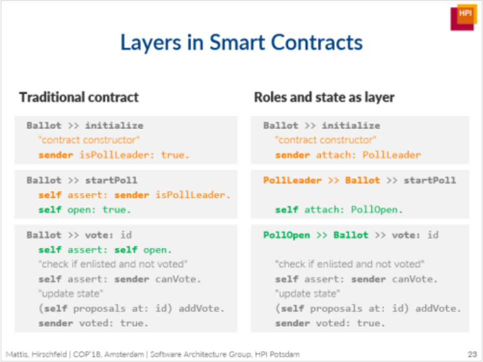

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Roles and state as layer

```
Ballot >> initialize
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  sender attach: PollLeader
```

```
PollLeader >> Ballot >> startPoll

  self attach: PollOpen.
```

```
PollOpen >> Ballot >> vote: id

  "check if enlisted and not voted"
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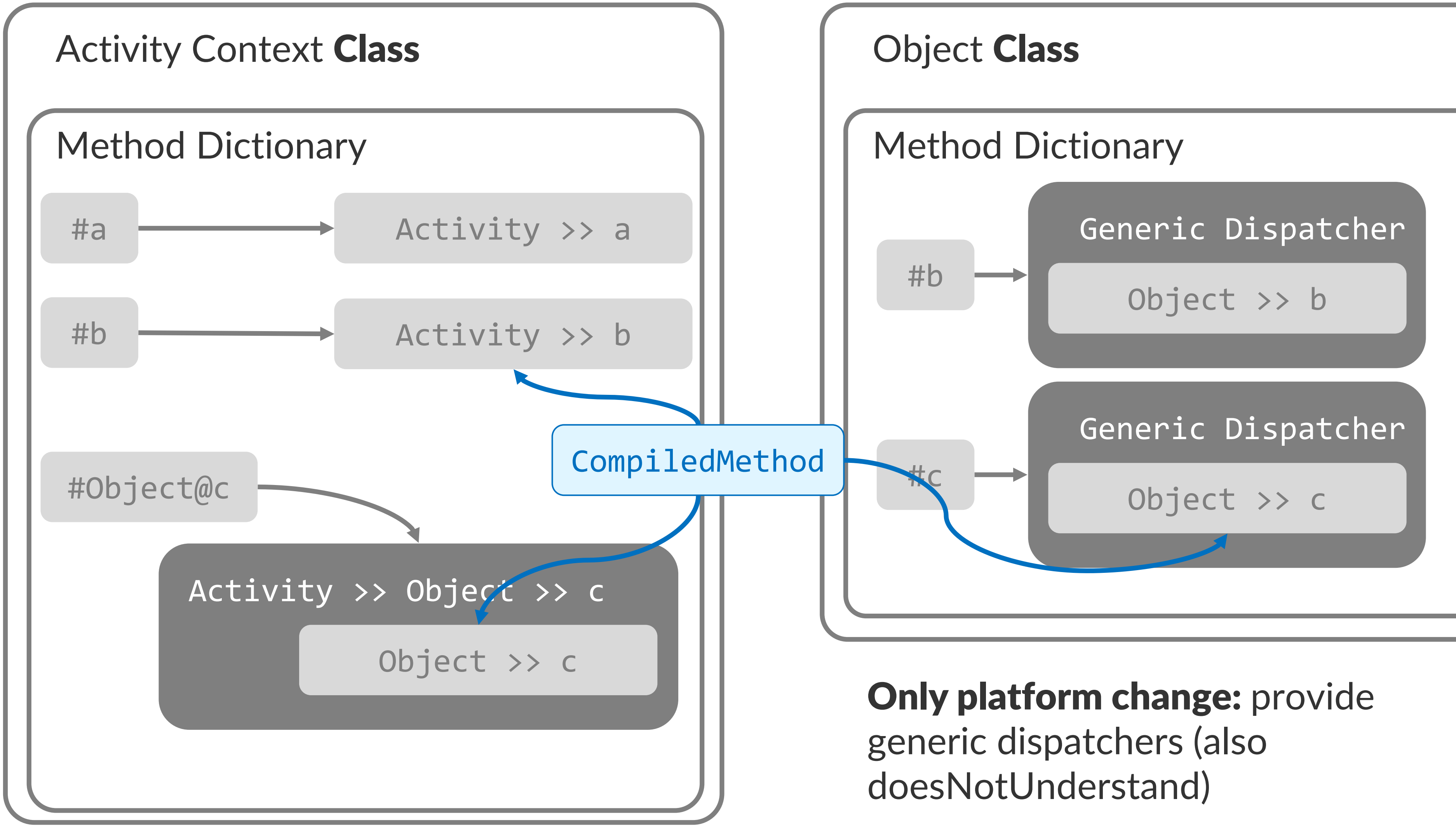
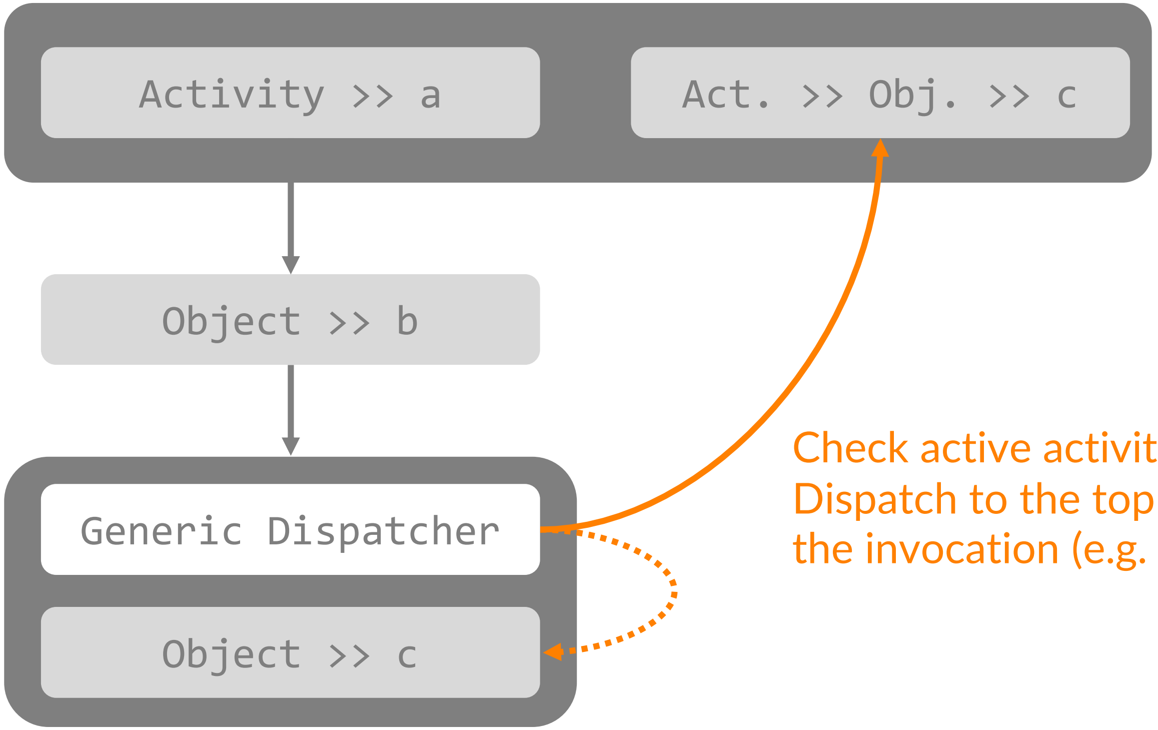
Backup Slides

Implementation



Only platform change: provide generic dispatchers (also doesNotUnderstand)

Implementation



Check active activities on call stack. Dispatch to the top-most that handles the invocation (e.g. `#Object@c`)