Failure Handling in a Network-Transparent Distributed Programming Language

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Abstract

- We present a model for reflecting failures at the level of entities in a distributed programming language.
- The model favors *asynchronous* failure handling, where the failure is notified independently of the entity's usage (sort of failure *listener*).
- We think that this model is more expressive than exception-based failure reflection.

Plan

- Oz and Mozart
- Transparent distribution
- Tuning the distribution with annotations
- Reflecting and handling failures
- Implementation

The programming language Oz

- High-level programming language, with well-integrated declarative, stateful, and concurrent paradigms.
- Implemented by the platform Mozart.
- Provides support for *transparent distribution*.
  - in case of no failure, the semantics does not depend on how the program is distributed
- Now provides enhanced support for *distribution awareness* at the language level.

The platform Mozart

- Implements the language Oz.
  - First released in 1998
  - Provides support for distribution and fault handling
- Will be used for one of the project's implementations.
- The distribution support is reimplemented on top of the library DSS (distributed subsystem, see later).

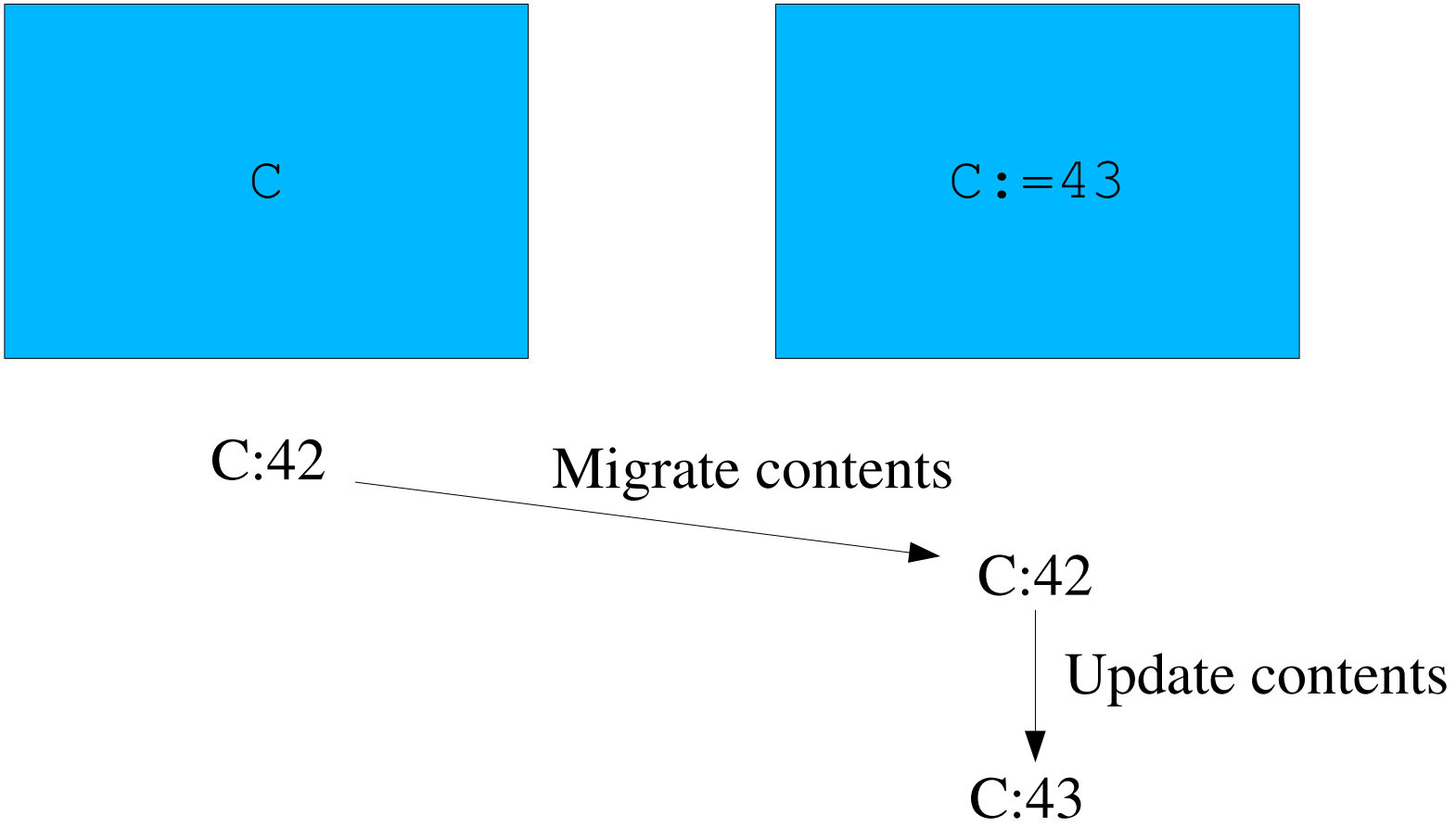
Transparent distribution

- Language entities (logic variable, object, record) can be shared between *sites* (system processes).
- The system hides the distribution to the programmer. Entity operations on distributed entities are implemented by protocols.
- In case of no failure, the semantics of the program is the same as if the whole program was running on a single site.

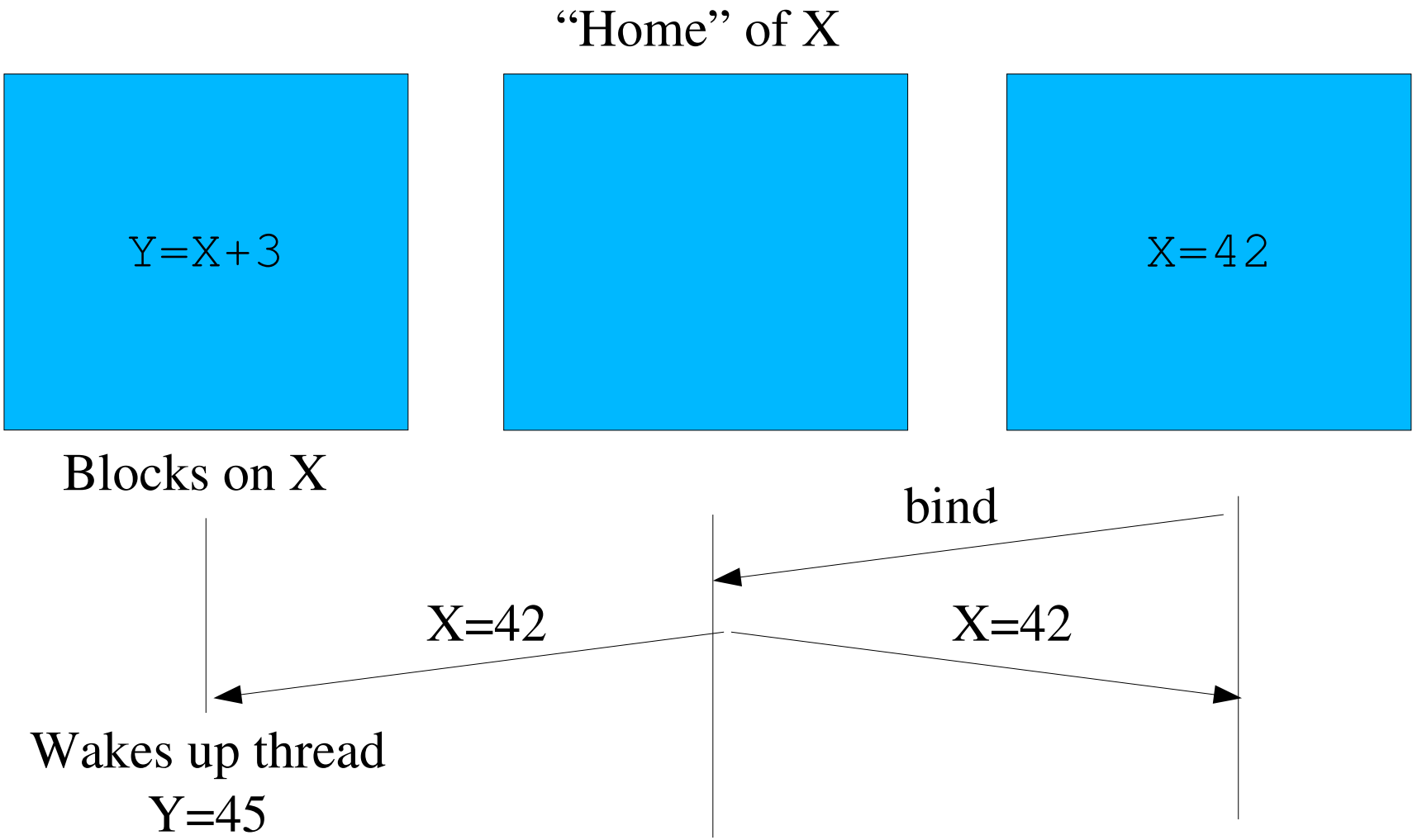
Example : getting connected

- `C={NewCell 42}`
  `T={Connection.offer C}`
  - T is a string that can be transmitted to the other site by any means.
- `D={Connection.take T}`
  `D:=43`
  - C and D refer to the same shared entity. Both sites can use it. Other references are obtained by transitivity.

Example : cell with mobile state



Example : dataflow variables



Tuning by annotation

- Distribution parameters can be defined for an entity before it is distributed. One can choose the most appropriate network behavior without changing the entity's semantics.
- Separation of concerns!
- Examples:

```
{Annotate A stationary}
{Annotate B migratory}
{Annotate C gc(lease 30000)}
```

Fault model

- For every entity, each site maintains a *fault state* that reflects the entity's ability to function.
  - `ok`, `tempFail`, `localFail`, `permFail`
- An operation on a failed entity simply *blocks* until the entity (possibly never) works again.
- You never get unexpected behavior from a distributed program that experiences failures!
  - Exception are difficult to deal with in a highly concurrent programming language.

Fault model

- An entity's fault state can be monitored in the language by reading its *fault stream*, that reifies the history of fault states of the entity.

$fstream_i(x)=fs \wedge fs=s\|fs'$	$fstream_i(x)=fs' \wedge fs=s\|fs' \wedge fs'=s'\|fs''$	The fault state of x on site i goes from s to s'

- `{GetFaultStream E}` returns the current fault stream of entity E (given by fstream()).

Printing an entity's states

- States are observed in a sequential way, and the observer is woken up by dataflow.

```
for S in {GetFaultStream E} do
   case S
   of ok          then {Show 'fine'}
   [] tempFail    then {Show 'check network!'}
   [] localFail   then {Show 'unusable here'}
   [] permFail    then {Show 'unusable'}
   end
end
```

Switching between servers upon failure

```
fun {MakeProxy Servers}
   Ms
   Unsent={NewCell Ms}
in
   thread
      for S in Servers do
         thread
            for M in @Unsent do
               {Send S M} Unsent:=@Unsent.2
            end
         end
         {Wait {Member permFail {GetFaultStream S}}}
      end
   end
   {NewPort Ms}
end
```

Making an entity fail

- The programmer can manually make an entity fail. This is convenient for triggering a recovery mechanism.
- `{KillLocal E}` makes the entity `E` fail on the current site only.
- `{Kill E}` attempts to make the entity `E` fail on a global scale. This operation is asynchronous.

Propagating failure on a set of entities

```
fun {WhenFailed E}
   thread {Member permFail {GetFaultStream E}} end
end

proc {SyncFail Es}
   thread
      Trigger
   in
      for E in Es do Trigger={WhenFailed E} end
      {Wait Trigger}
      for E in Es do {Kill E} end
   end
end
```

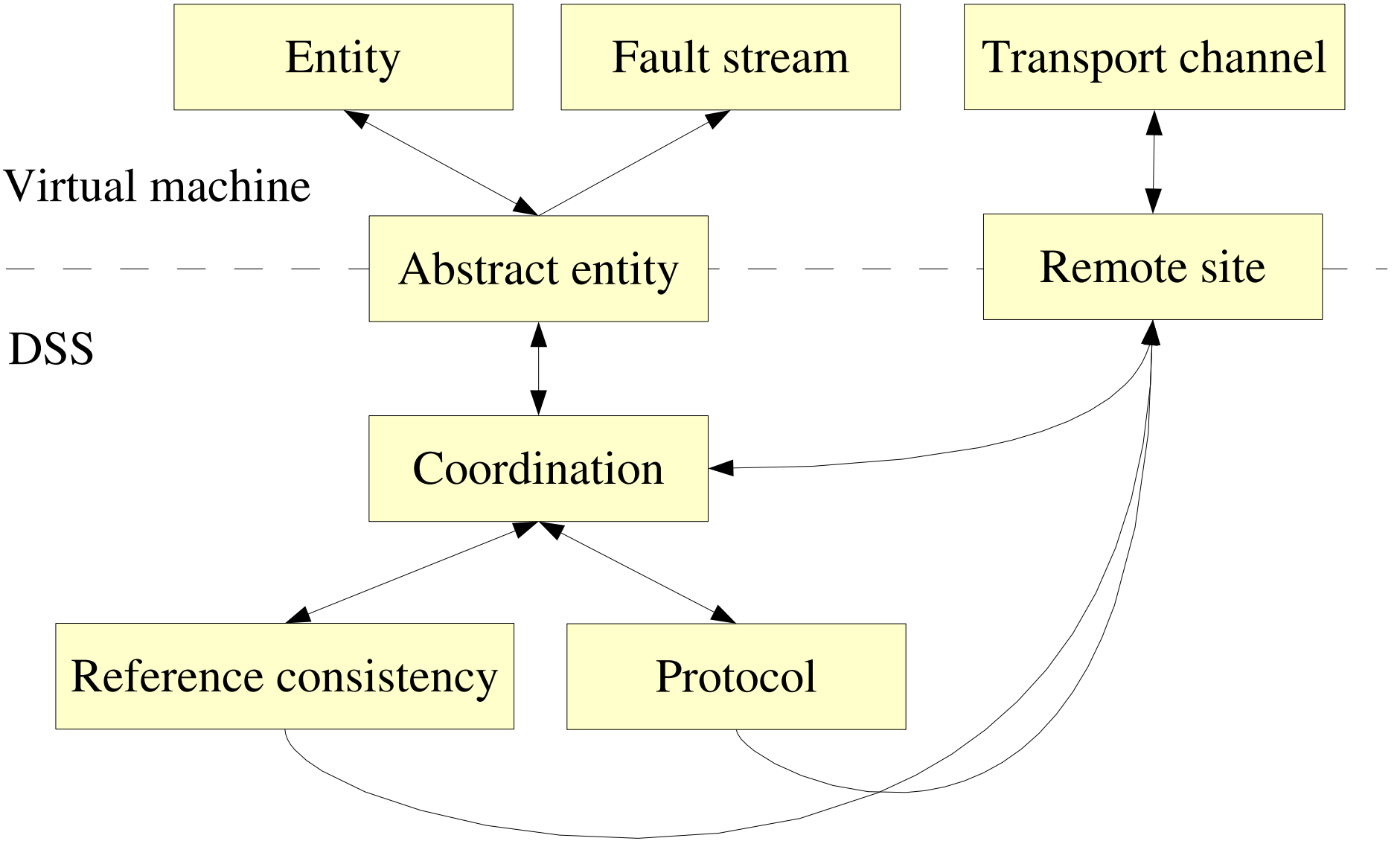
Asynchronous failure handling

- This model improves the *modularity* of failure handling, because one can easily make it orthogonal to the “functional” code.
  - Handling rules “when failure do recover” are coded in a natural way.
  - Improves the separation of concerns.
- We believe this model is good for Selfman's purposes.

Implementation: Mozart/DSS

- The distribution support of the upcoming Mozart release is built on top of the DSS.
- DSS is a C++ library that provides generic distributed entities to support any programming system. Main design and implementation by Erik Klintskog at SICS.
  - Protocols to manage the entities' state
  - Protocols to garbage collect entities

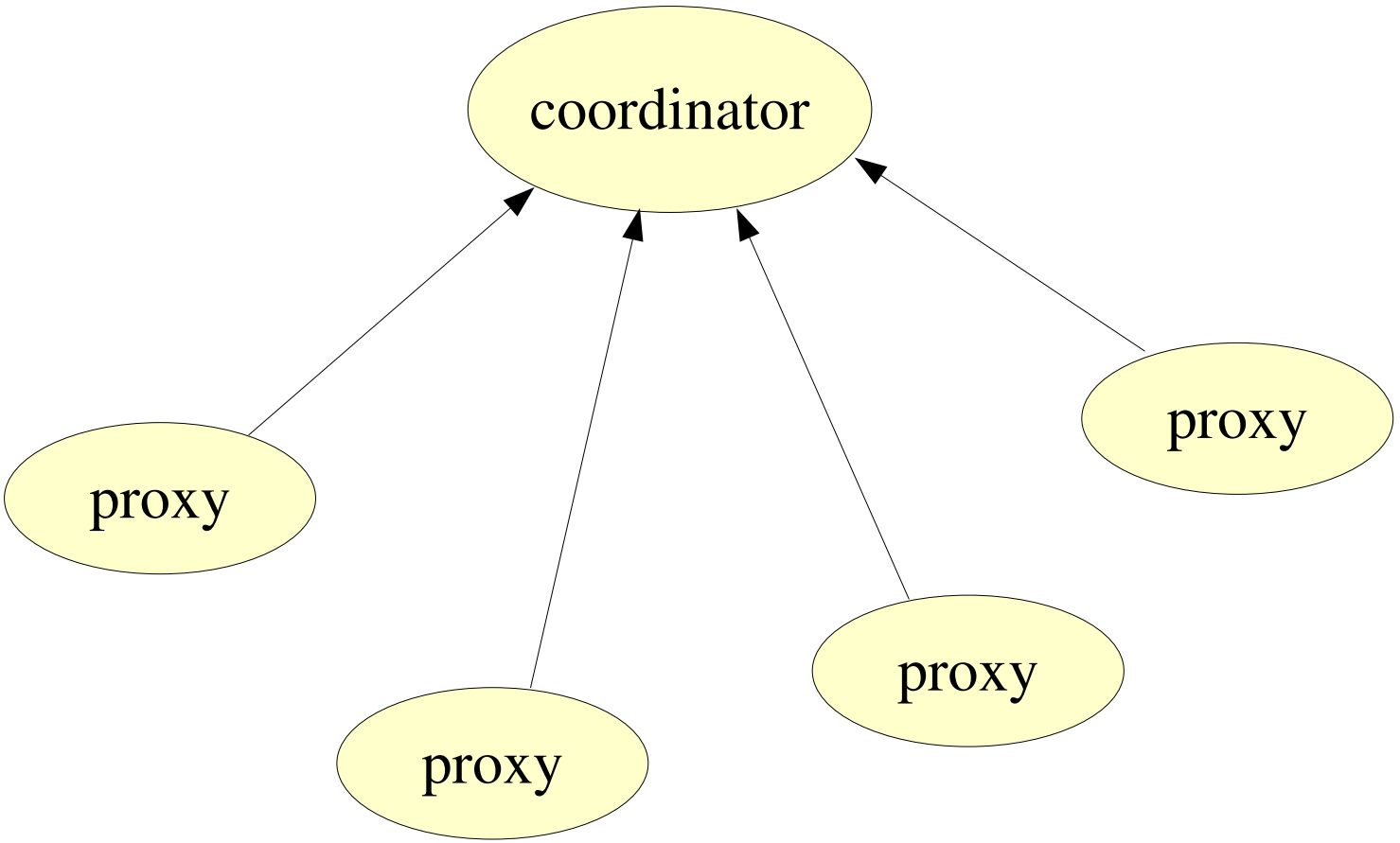
Architecture overview



Abstract entities

- The DSS defines three categories for abstract entities: *immutable*, *monotonic* and *mutable*. Each category defines a small set of abstract operations.
- Each category comes with a set of protocols that implement its abstract operations. The protocols are designed to give the best behavior for each kind of entity.
  - No “one size fits all”.

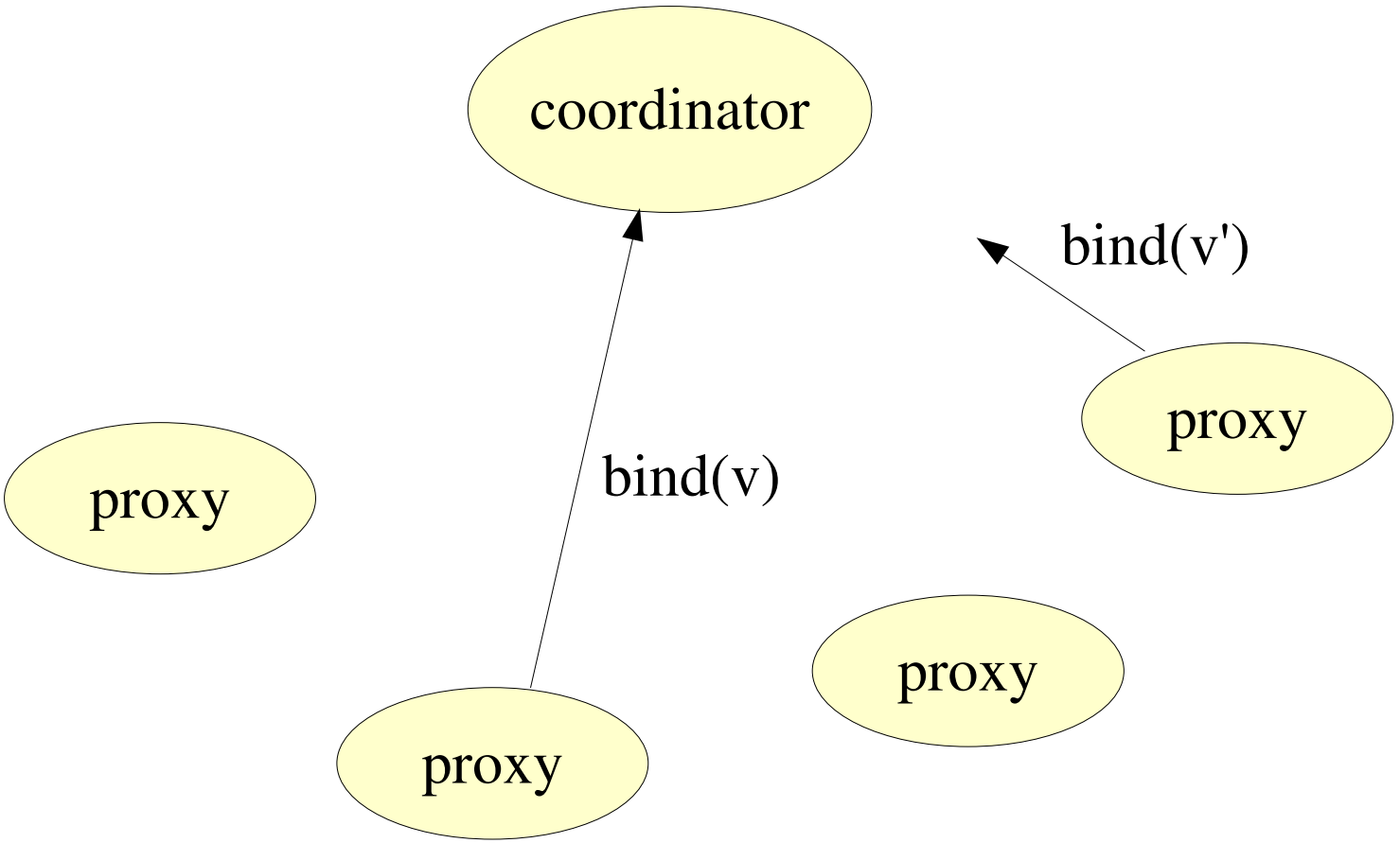
Coordination structure



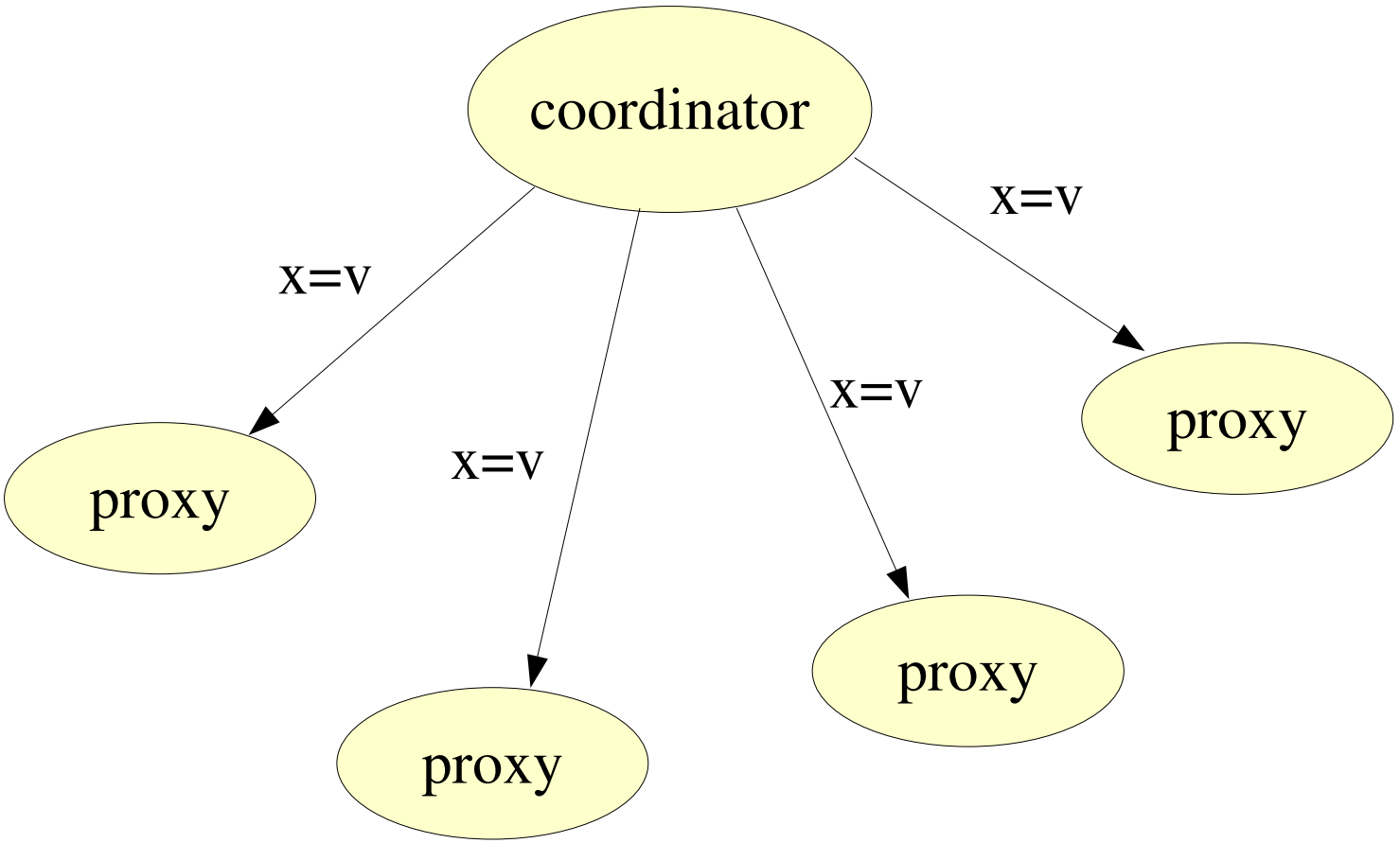
State protocols

- immutable: immediate or lazy copying
- monotonic:
  - single assignment protocol (with by-need sync),
  - stream communication
- mutable:
  - stationary state,
  - migratory state (2 protocols),
  - replicated state (2 invalidation protocols)

Single assignment protocol



Single assignment protocol



Distributed garbage collection

- Simple reference counting: the coordinator counts its proxies.
- Weighted reference counting: a proxy has an amount of credits. When a proxy send its reference to another site, it put some of its credits in the message. The coordinators simply counts how many credits are away.
- Time lease algorithm: proxies must regularly notify the coordinator.

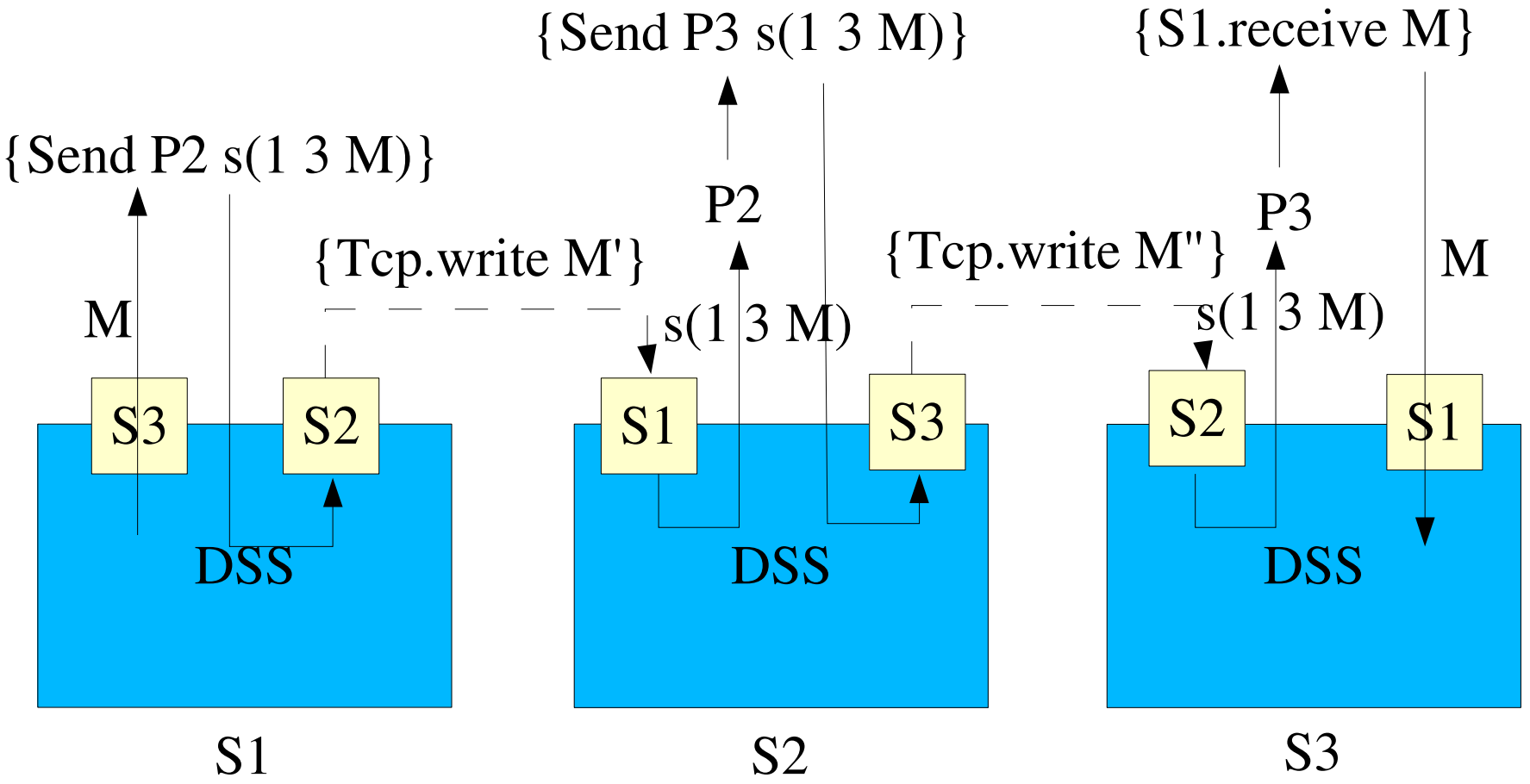
Reflecting failures

- Remote site failures are notified to coordination and protocol objects. The programmer can help diagnosing site failures.
- Coordinators and protocols reflect the site failure in the entity's fault state, and notify the above layers when the fault state changes.
- Site dependencies vary from protocol to protocol. Each one has its own way to diagnose an entity failure.

Route reflector

- The user of the DSS must provide transport channels to the remote sites. Currently TCP connections are used
- The idea behind the "route reflector" is to let the programmer provide its own channels. One can provide connections on top of an overlay network ***programmed in Oz***.
  - TCP connections to neighbors
  - "Overlay channel" to other nodes.

Route reflector



Route reflector

- The overlay network can provide more complex ways to diagnose a site failure (consensus).
- The overlay network is mostly invisible to the application. One can therefore make some self-* properties partly transparent too!

Conclusion

- We define a language model to reflect failures and to handle them. The model chooses asynchronous failure handling as the preferred way to make robust applications.
- Mozart/DSS is an improved implementation of the distribution of Oz.
  - Currently available in Mozart's CVS repository.
  - Release in a few months.