Architectural design: the coordination perspective

José Proença
HASLab - INESC TEC & UM
Arquitectura e Cálculo 2015-16

Software architecture for reactive systems

There is **no general-purpose**, **universally tailored**, approach to architectural design of **complex** and **reactive** systems

In this course:

introduce different models for reactive systems

discuss their architectural design

with (reasonable) tool support for modelling and analysis

Models of Concurrency

Traditional models are action-based

- Petri nets
- Work flow / Data flow
- Process algebra / calculi
- Actor models / Agents
- …

Interaction appears as an implicit side-effect;
Makes coordination of interaction more difficult to

- Specify
- Verify
- Manipulate
- Reuse

Interaction with process algebra

```
act
  g, r, b, d : String    % synchronisation points
  print, genG, genR;

proc
  B = b(t) . print(t) . d̄("done") . B
  G = g(k) . genG(t) . b̄(t) . d(j) . r̄(k) . G
  R = r(k) . genR(t) . b̄(t) . d(j) . ḡ(k) . R

init
  G || R || B || ḡ("token")
```

Model constructed by composing actions into more complex actions

Interaction with Object Oriented Software

- In OO the architecture is **implicit**:
  source code exposes class hierarchies but not the run-time interaction and configuration
- Objects are wired at a very low level and the description of the wiring patterns is distributed among them

The semantics of method invocation is heavy and non-trivial:

- The caller must know the callee and the method.
- The callee must (pretend) to interpret the message.
- The caller suspends while the callee (pretends to) perform the method and resumes when the callee returns a result.

Implicit interaction

Interaction (protocol) is implicit in action-based models of concurrency

Interaction is a by-product of processes executing their actions

Action *a* of process A **collides** with action *b* of process B

Interaction is the specific (timed) sequence of such collisions in a run

Interaction protocol is the (timed) sequence of the ***intended*** collisions in such a sequence.

How can the intended and the coincidental be differentiated?

How can the sequence of intended collisions (the interaction protocol) can be

- Manipulated?
- Verified?
- Debugged?
- Reused ?

Interaction with components

Shift from class inheritance to object composition

Avoid interference between inheritance and encapsulation and pave the way to a development methodology based on third-party assembly of components

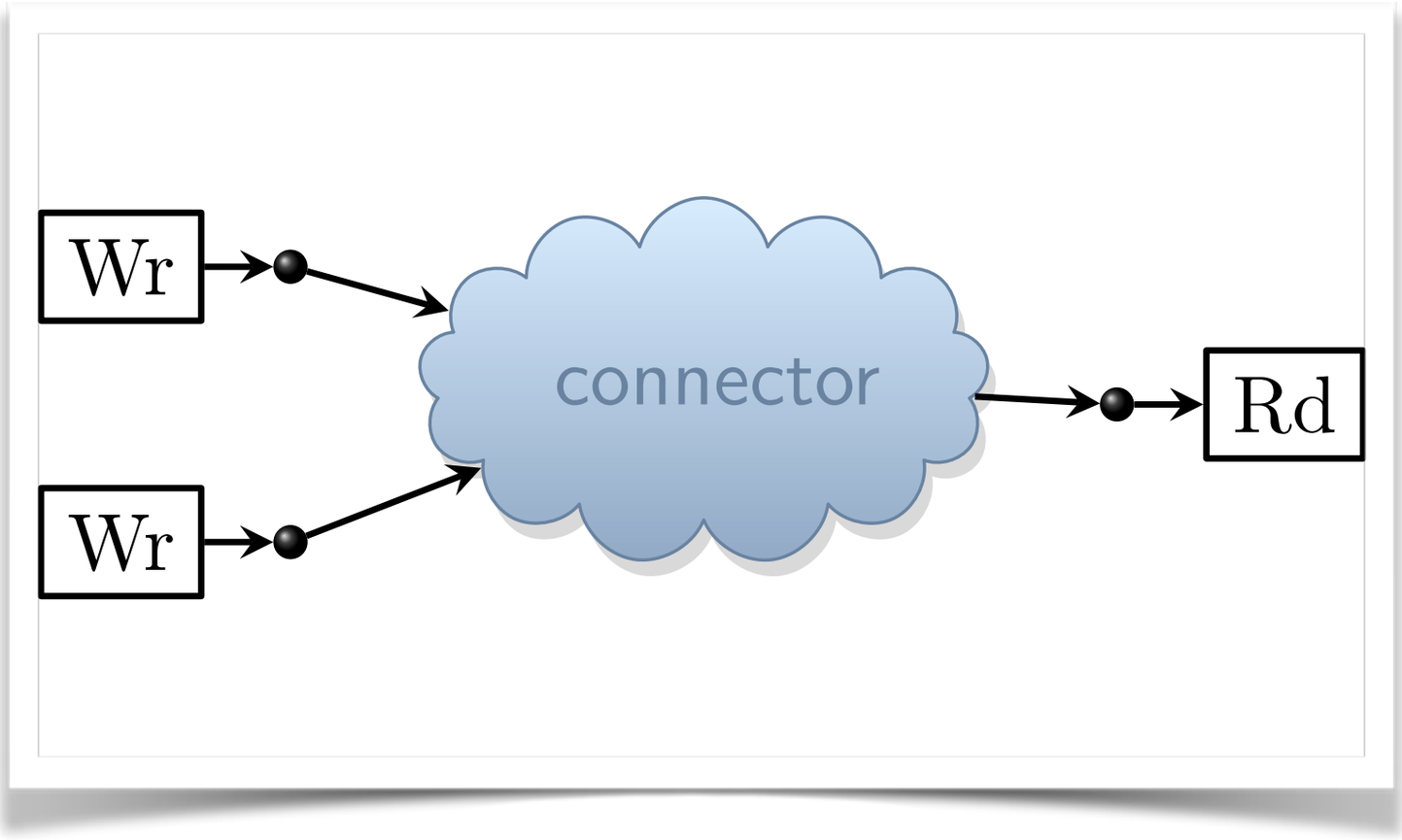
Move from an action-based to an interaction-based model of concurrency

Black box computation units

canvas to drop them

connections via wires

Component coordination in Reo



- Exogenous coordination
- Compositional (channel based)
- Synchronous (atomic)
- Coordination is constrained interaction

[Peter Wegner, 2000]

Component coordination in Reo

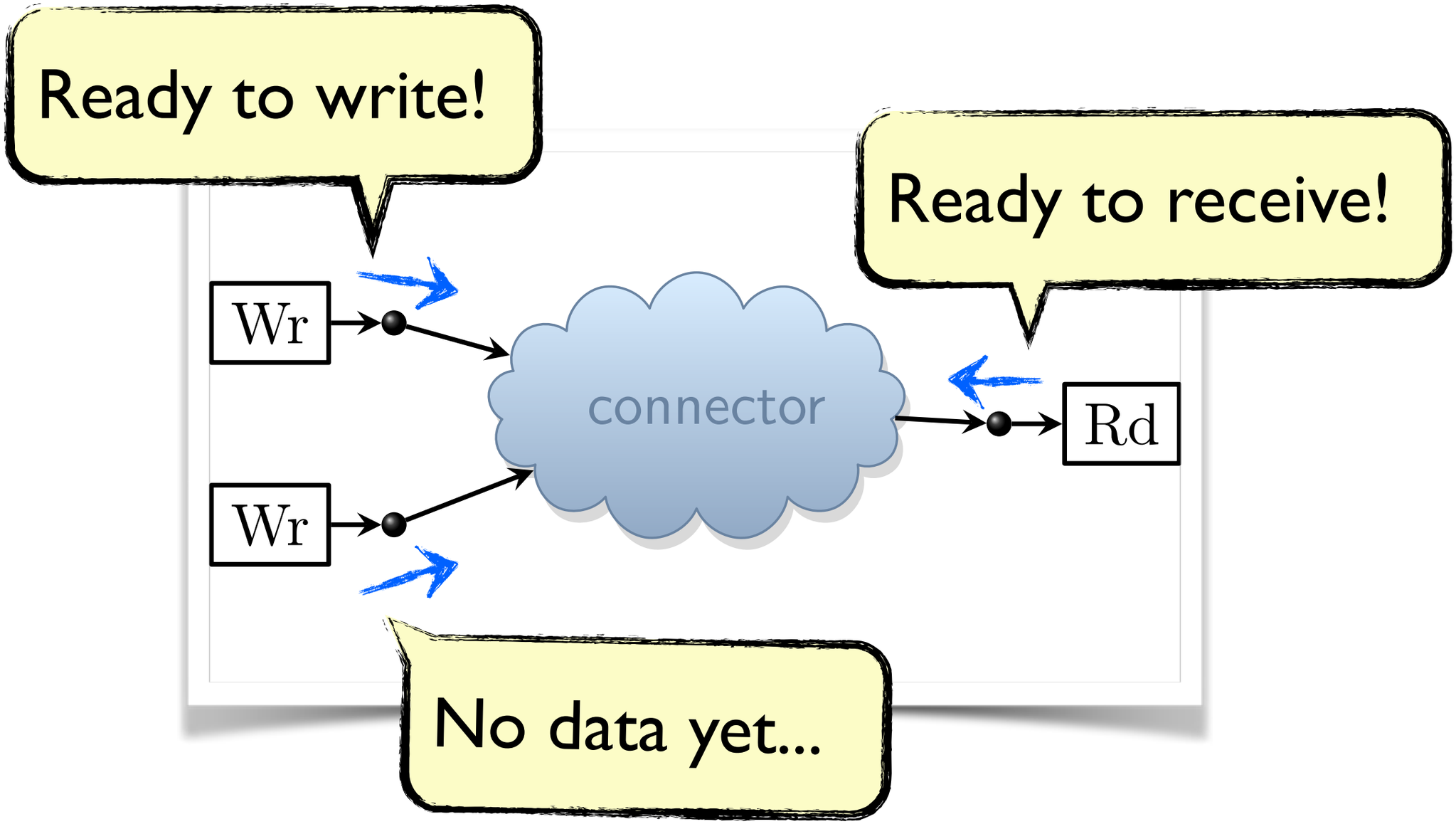
Endogenous: provide primitives that must be incorporated within a computation for its coordination
Exogenous: ensure that the conceptual separation between computation and coordination is suitably respected

- Exogenous coordination
- Compositional (channel based)

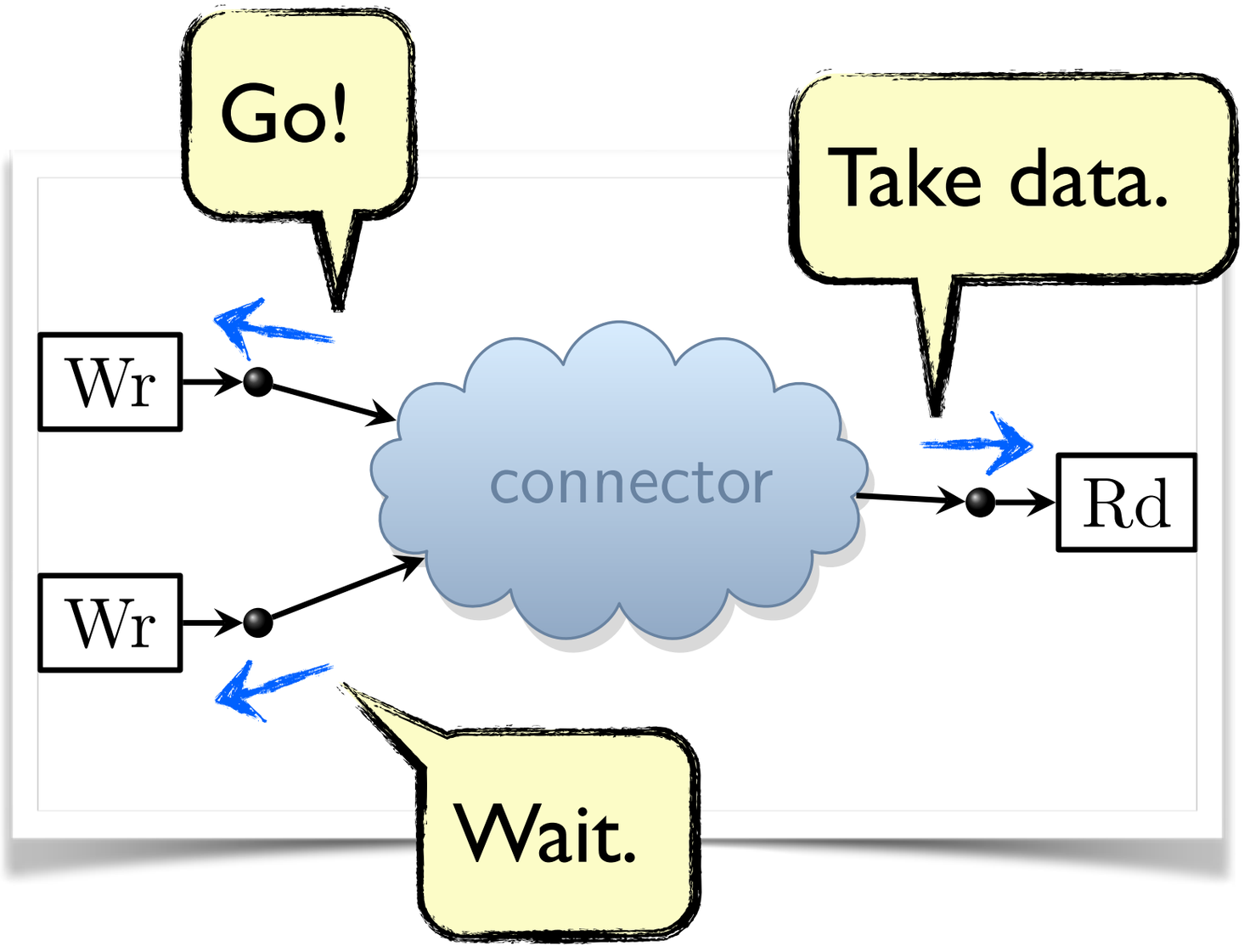
- Synchronous (atomic)
- Coordination is constrained interaction

[Peter Wegner, 2000]

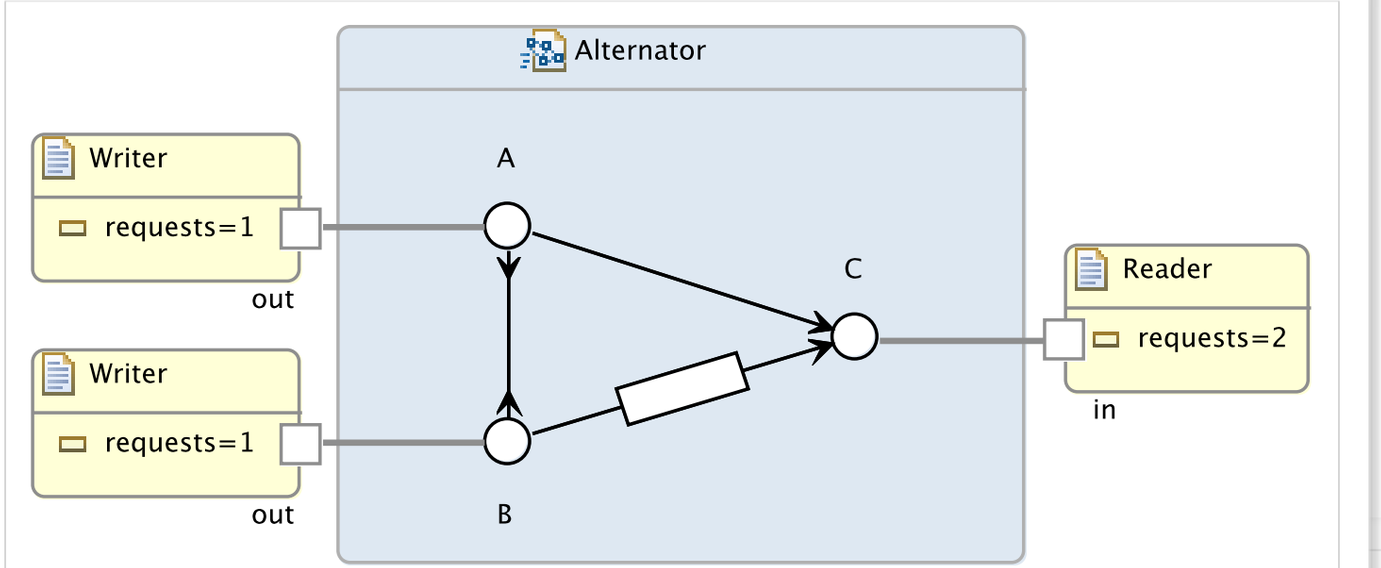
Discrete atomic steps

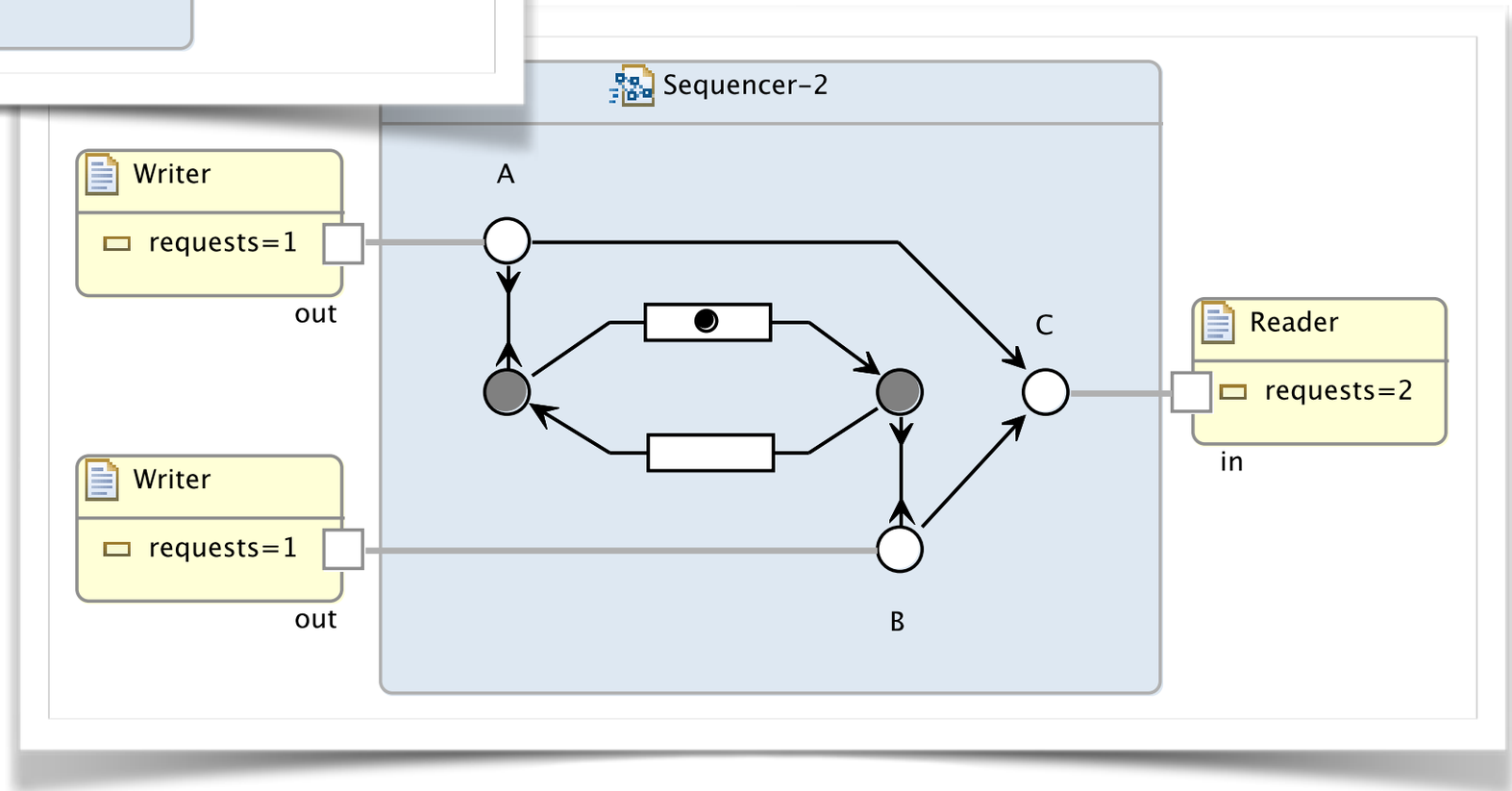


Discrete atomic steps

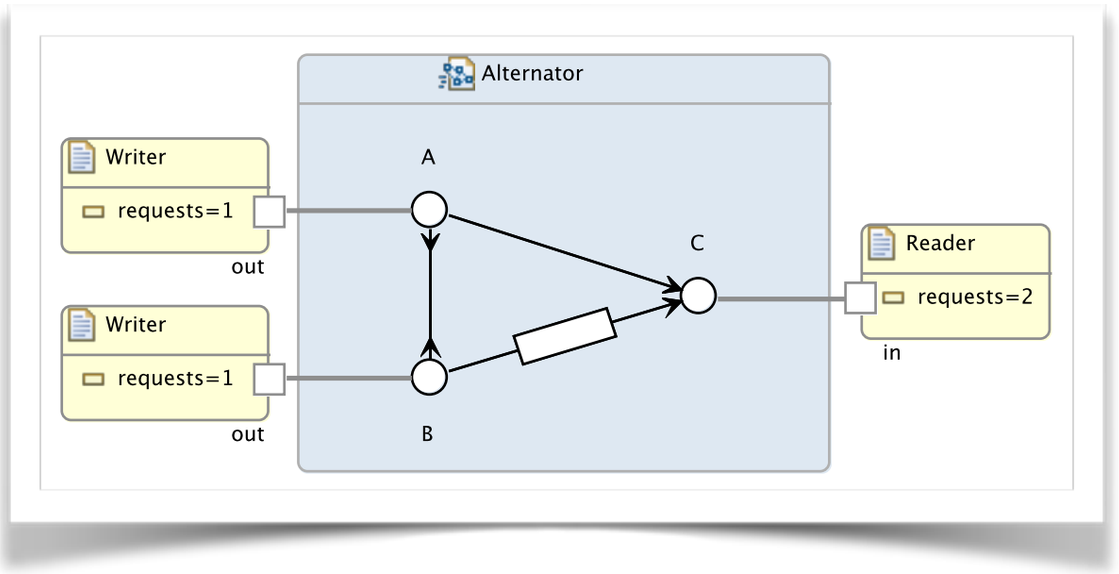


Reo: Channel composition





Reo



- Language for compositional construction of interaction protocols
- Interaction is the only first-class concept in Reo:
  - Explicit constructs representing interaction
  - Composition operators over interaction constructs
- Protocols manifest as a connectors
- In its graphical syntax, connectors are graphs
  - Data items flow through channels represented as edges
  - Boundary nodes permit (components to perform) I/O operations
- Formal semantics (various formalisms - shown later)
- Tool support: draw, animate, verify, compile

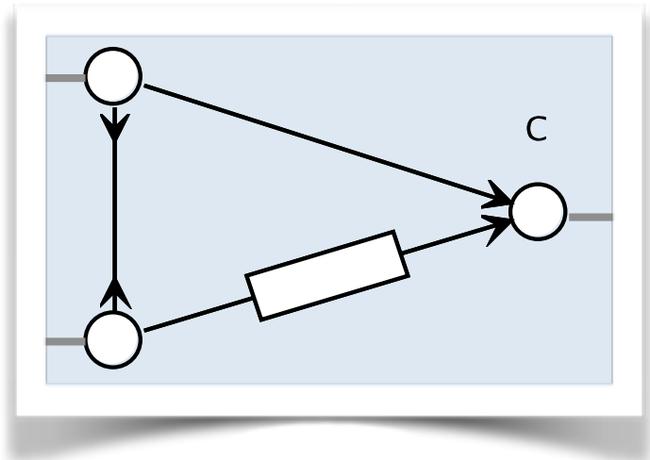
Composition as coordination

- interacting components need not know each other. (cf traditionally communication is targeted, making the sender semantically dependent on (the scheme used to identify) the receiver)
- communication becomes anonymous: components exchange identifiable sequences of passive messages with the environment only
- therefore third parties can coordinate interactions between senders and receivers of their own choice

Components

- loci of computation
- are kept independent of each other and of their environment
- Components communicate with the environment only through read and write operations on the connector ends (or ports), possibly according some behavioural interface description

Connectors

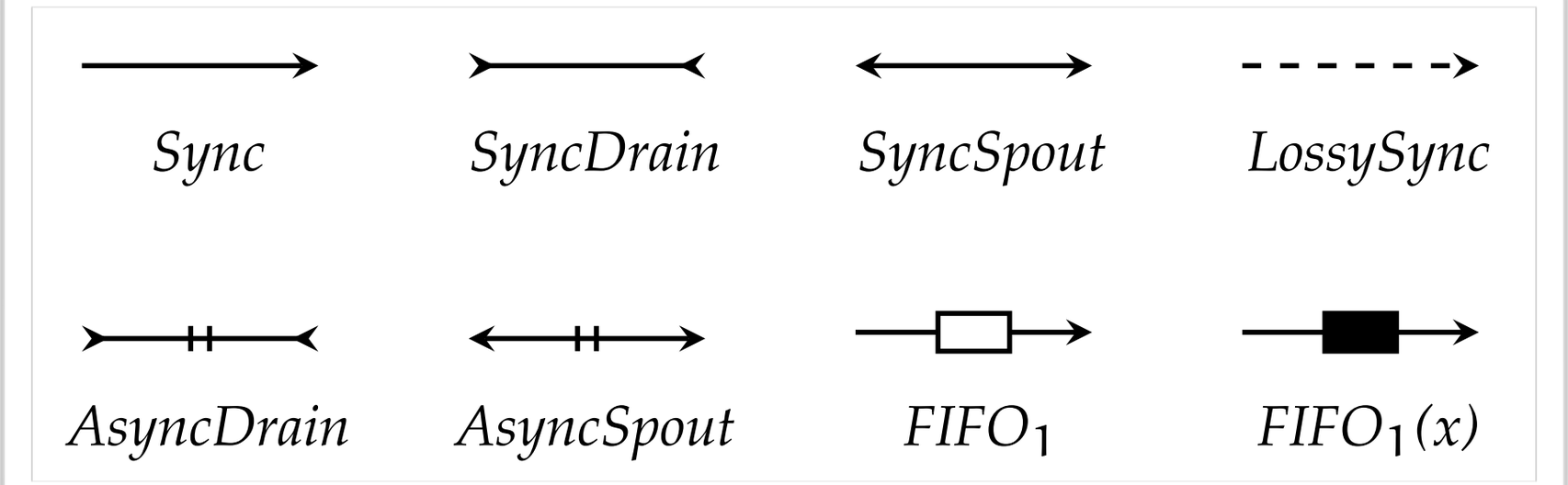


- act as interaction controllers: the glue code that makes components interact
- i.e., they coordinate the activities of individual components to ensure their proper interaction with one another to form a coherent system that behaves according to its requirements
- have no relevant role in the computation carried out by the overall system: they are component-independent and agnostic wrt the underlying computation model
- provide systems-independent interaction protocols (whereas components provide systems-specific functionality)
- … built compositionally.
- but traditionally, glue code is the most rigid, component specific, special purpose software in component based systems!

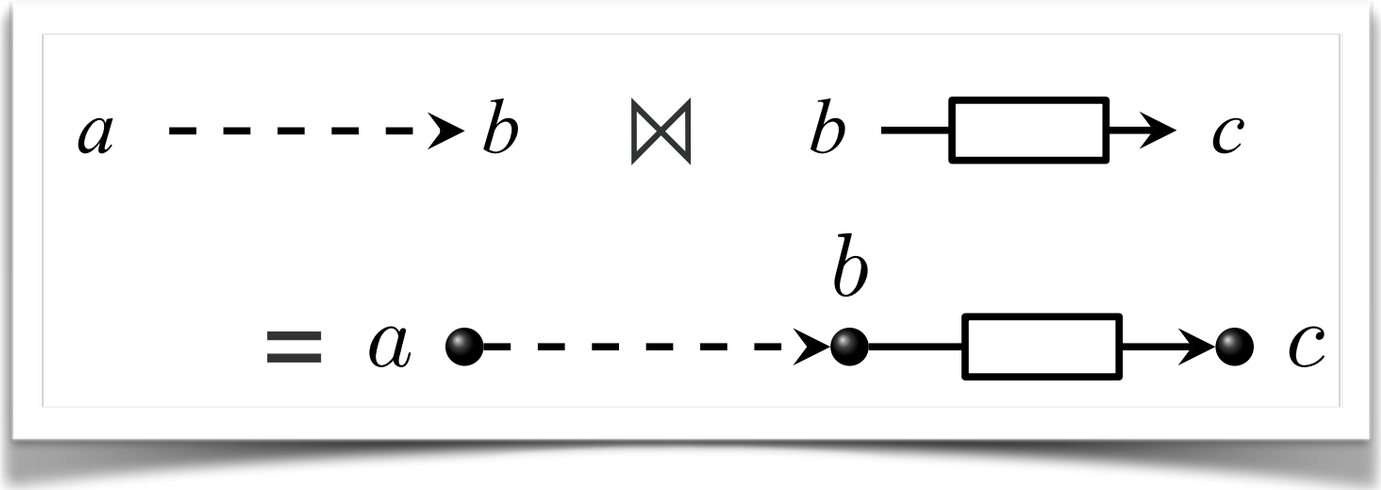
Reo connectors

- Source end: through which data enters the connector
- Sink end: through which data comes out of the connector

Examples:



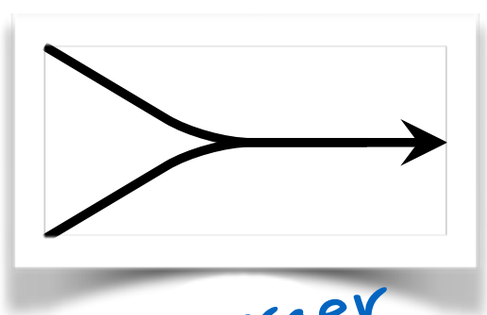
Composing Reo connectors



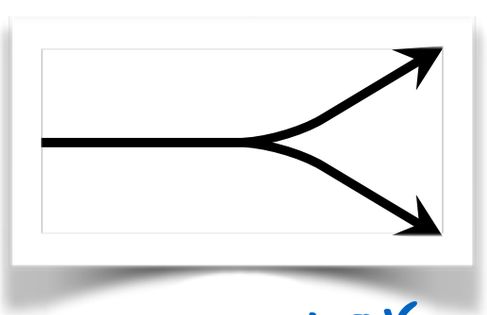
join
source ends
with
sink ends

one to one

Nodes: syntactic sugar for
mergers and replicators

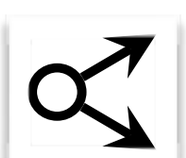


merger

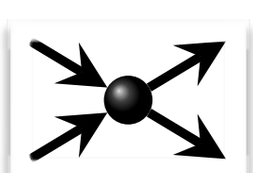


replicator

source nodes

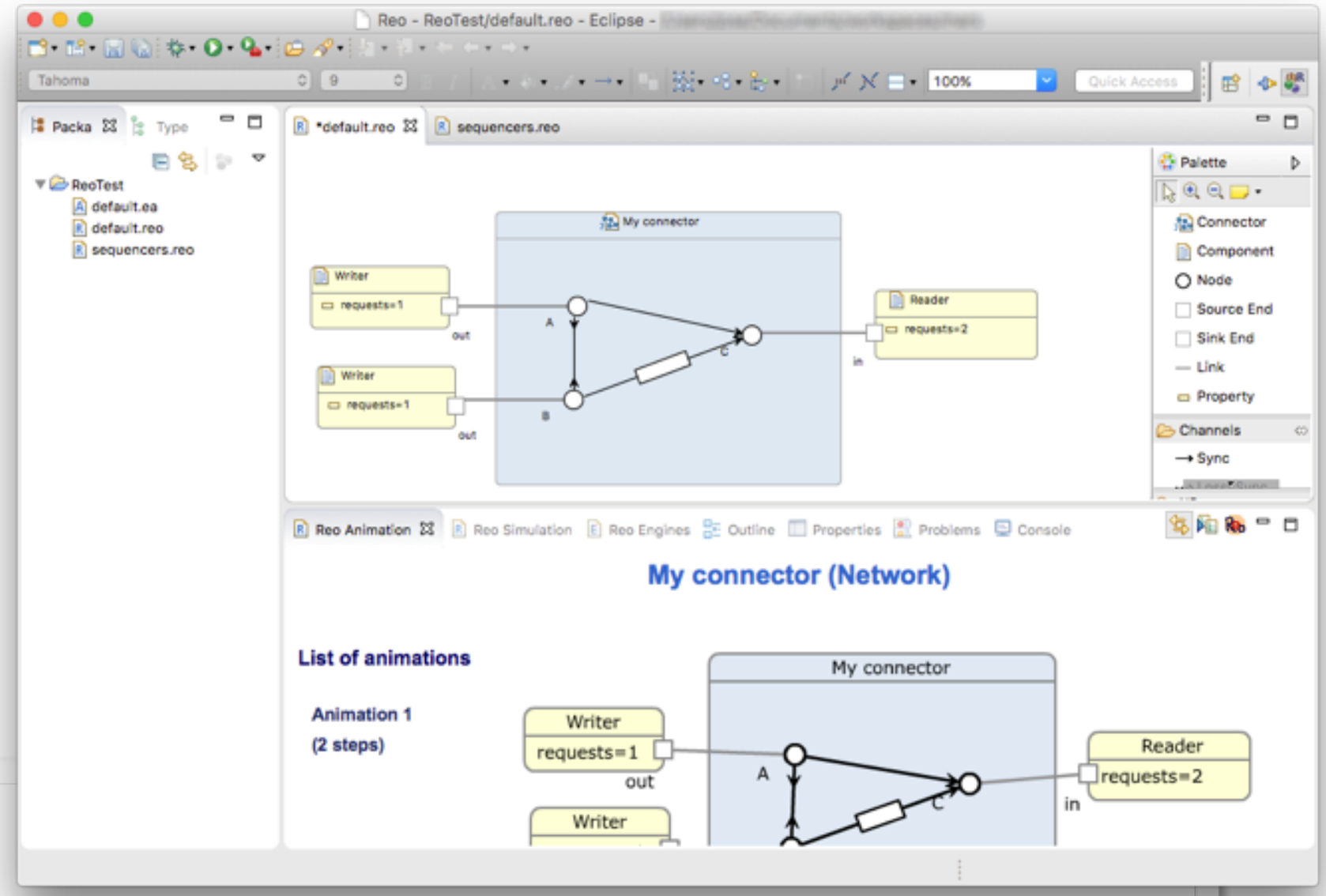


sink nodes



mixed nodes

Reo eclipse toolset



get Eclipse

update site: http://reo.project.cwi.nl/update