IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

Interaction and Verification

A. Beugnard
SIIA – IV – C2
2021

Why do we communicate ?

- Coordination, cooperation, deal, …

What do we exchange ?

- Information (status, results, intentions, …)

How do we communicate ?

- By observation (1 active/1 passive)
- By sharing (canals, memory, conventions) messages (many active actors ; ex. expeditors, receivers)

- Transport protocol (shared)
- Communication language (shared)
- Interaction protocol (shared)

This course focusses on Interaction protocol.

- Whom are we communicating with
- How initiating an exchange
- (Out of scope) Effect of the communication

Classification criteria ?

- Active/passive actors
- How many actors : 2, more than 2
- Actor's roles : symmetric or not
- Who initiate the communication
- Any shared state
- Asynchronous or synchronous
- Blocking or not
- Message order ensured (FIFO) [asynchrone]
- Loss of message [fault management]

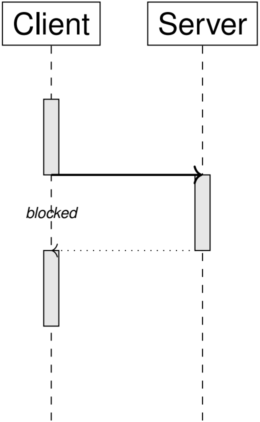
Classification criteria ?

- Let know
- Request for information
- Request for doing
- Answers
- Promisses
- Proposals
- Deals
- Choose, elect, decide
- …

2-interaction

4 models :

- Synchronous
- Asynchronous
- Future
- By necessity [Car93]



Client side

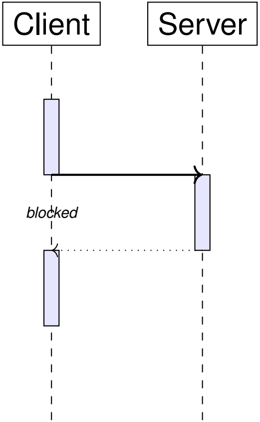
- call
- wait result
- get result
- continue

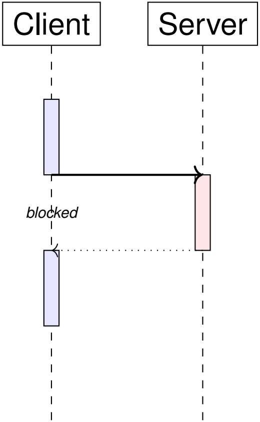
Nit visible (internal)

Serveur side

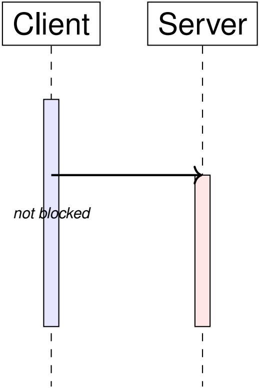
- wait call
- compute
- return result

Visible in interface





Or Rendezvous (ADA)



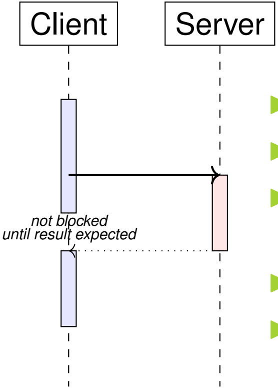
Client side

- send message
- continue

Serveur side

- wait message
- compute

We must have 2 threads . . .(either on the same machine, either on remote ones).



Client side

- call
- continue
- wait result when needed
- get result
- continue

Server side

- wait call
- compute
- return result

We must have 2 threads …(either on the same machine, either on remote ones).

Abstraction and implicit mechanism that behaves as :

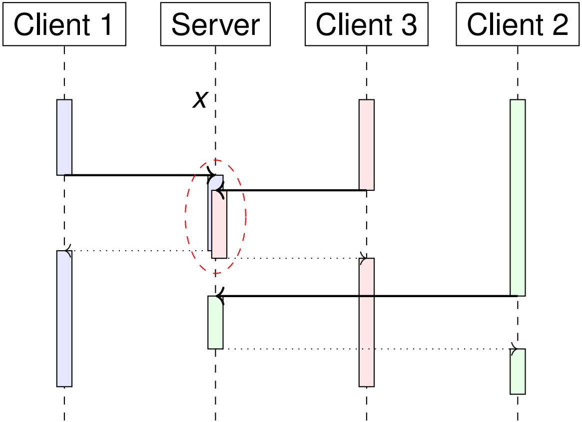
- Asynchronous ; if the result is not required
- Synchrone ; if the result is immediately required
- Future ; if the result is required later

Interactions are interesting only among active entities[1]

Passive entities are only useful for sharing states.

Sharing state is difficult ; it introduces mutual exclusion issues (safety) and deadlocks issues (vivacity).

1. With a single thread, communication can oly be synchronous.



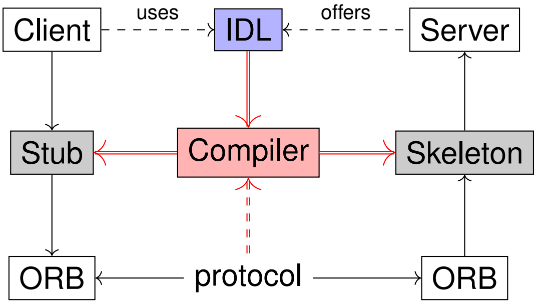
Competition fot accessing the shared state x.

Safety
: properties ensure nothing wrong happens. For instance ; invariant satisfaction or mutex . . .

Vivacity
: properties ensure that something happens. For instance, no deadlocks.

Synchronous	**Asynchronous**	**Future**	**By necessity**
ADA, C, Caml, functional, object	dart, erlang, elixir, via libraries	via libraries	ProActive [OW217], via libraries

Previous properties apply to remote (or heterogeneous) interactions.



This is the principle of RPC, CORBA, Java RMI, .NET, etc. connectors

2+-interaction

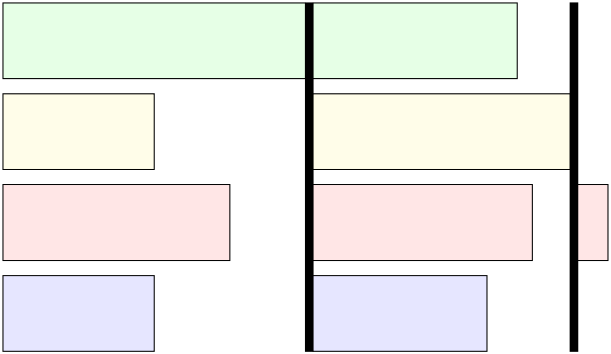
Interactions with more than 2 actors :

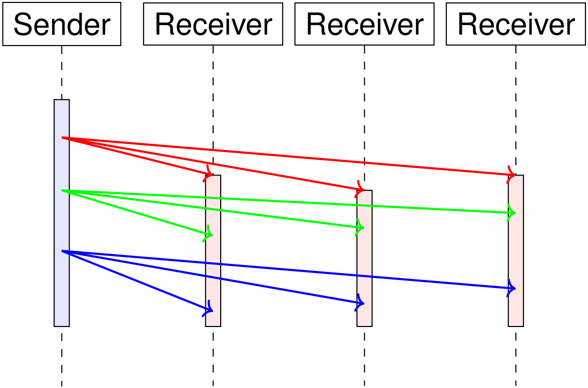
- Synchronization barrier
- Broadcast
  - Asynchronous (ex ; UDP)
  - With quaranties
- Consensus
- Group membership
- Tuple space
- Conversational language

More abstract interactions :

- Publish/subscribe [EFGK03]
- Negotiation
- Vote
- Auction
- …
- Communication abstractions

A basic coordination mechanism that ensures that entities have reached a specific point (the barrier) to continue their activity.





Properties

- No message loss
- Non message replication
- Fairness : all receive
- Atomicity : all or none
- Keep messages sequence

UDP : loss, non guaranty
reliable broadcast algorithms.
Ensure message order (red, green, blue)

Ensures that a message sent to a group is received by all or none.

Distributed systems study the interactions between processes (machine, actors, agents) by taking into account :

- The transmission delays
- The potential errors of the actors
- The potential errors of the communication channels

Distributed algorithms propose solutions to control the properties when theoretical solutions exist.

Messages are not transmitted instantly ; they can be lost.
It is impossible to distinguish between a lost message and a very long transmission time.
The notion of global time is meaningless - each actor has his own time. It is impossible to date an event in an absolute manner. event.
The notion of *causality* must be reconstructed ; lamport clock, vector clock, etc.

m_1 causally precedes m_2 ($m_1 \rightsquigarrow m_2$) iff :

- p sent m_1 before sending m_2
- p received m_1 then sent m_2
- There exists m_3 so that $m_1 \rightsquigarrow m_3 \wedge m_3 \rightsquigarrow m_2$

It must be taken into account that an actor (process, program, machine, channel, network, human, etc.) can make mistakes.

- By omission ; forgets to send a message, to reply, . . .
- Arbitrary ; sending the wrong message (voluntarily[2] or not)

For omissions, the simplest model consists of considering that an actor breaks down (crash-stop model) ; when he fails to send a message, it fails to send all the following

2. the actor is said to be malicious or Byzantine.

Perfect (or Reliable) links (PL)

- (Validity) If p_i and p_j are correct, then any messagesent by p_i to p_j is eventually delivered to p_j
- (No duplication) No message iis delivered more than once
- (No creation) No message is delivered without being sent

Reliable FIFO links (FIFO)

- Perfect links
- (FIFO) Messages are delivered in the same order as they are sent.

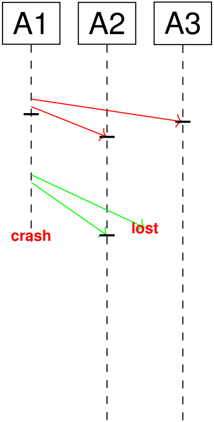
In this course, we assume channels are Perfect Links.

Best-effort Validity, No duplication, No creation (as PL)

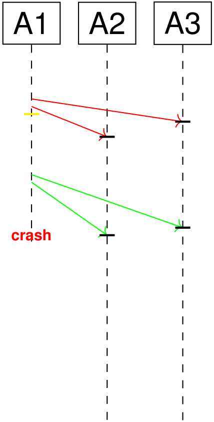
Reliable BE + Agreement : If a message *m* is delivered to a correct receiver, then all correct receivers will receive the message.

Uniform BE + Uniform agreement : For all message *m*, if a receiver get *m* then all correct receivers get it.

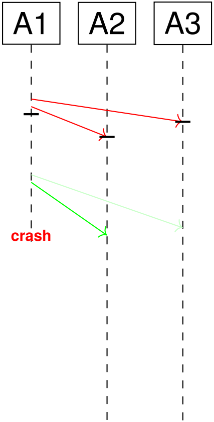
See R. Guerraoui courses for algorithms descriptions.



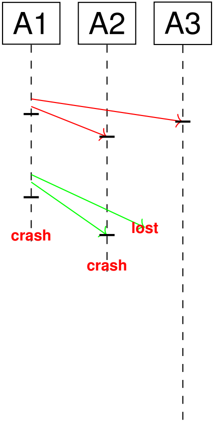
A1 do its best, but while correct A3 does not receive a message A2 received.



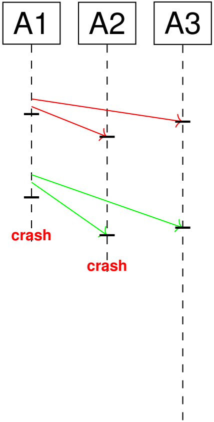
All correct processes receive the message.



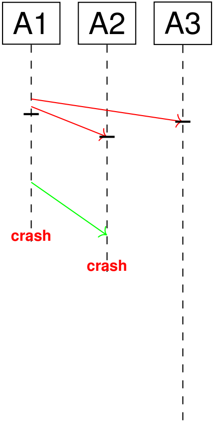
Or none.



Reliable broadcast, since A2 being not correct, *m* can be lost.

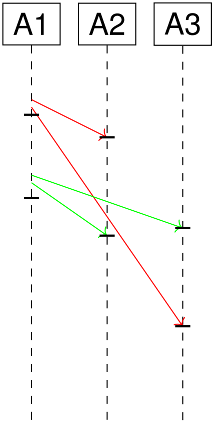


Evn if a receiver crashes, all receive…

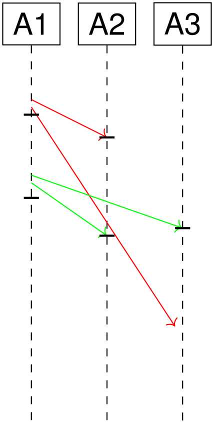


…or none.

Ensure order of messages.
If p reveives m_2 then p received all m such that $m \rightsquigarrow m_2$



No.



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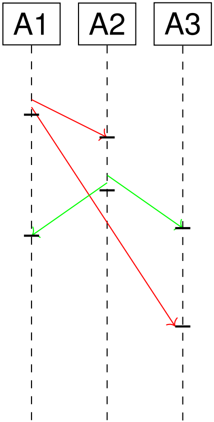
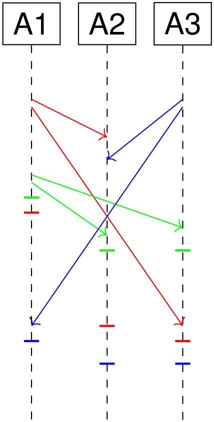
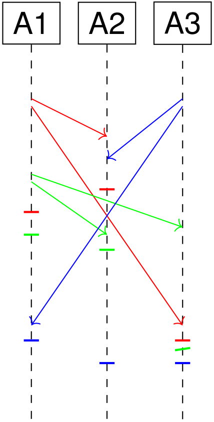


No.

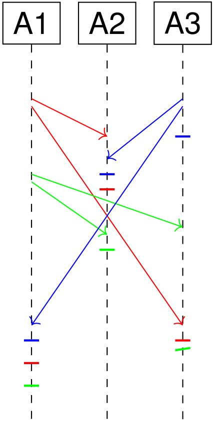
Ensure all processes see the same message order.
If the order ensure causality, it's a total causal order.



Total, not causal



Total and causal



Total and causal

Blue messages are causally independent from red and green ones.

Reliable broadcast abstractions

Best-effort broadcast

- Guarantees reliability *only if sender is correct*

Reliable broadcast

- Guarantees reliability *independent of whether sender is correct*

Uniform reliable broadcast

- Also *considers behavior of failed nodes*

Total reliable broadcast

- Reliable broadcast *with same delivery order for all correct nodes*

Causal reliable broadcast

- Reliable broadcast *with causal delivery order*

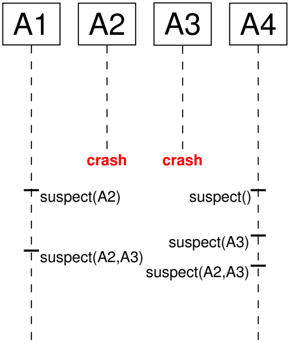
Total order can be implemented thanks to a consensus algorithm.
Consensus

- (Validity) The chosen value has been proposed
- (Uniform agreement) : Two different correct processes do the same choice
- (Termination) Any correct process eventually choose
- (Integrity) Any process choose once, at most

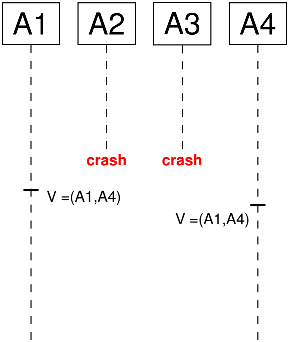
How can we know all processes involved in an interaction ?

- In case of failures
- When processes come and leave

How can we ensure all processes share the same view (list of involved processes).



No coordination



Coordination

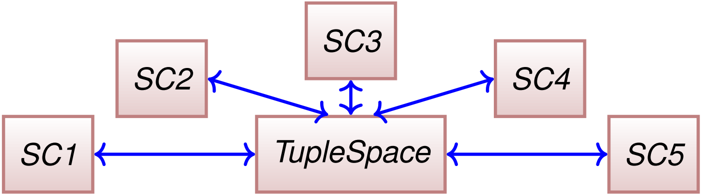
- Actors are informed of crashes, entries and exits ; actors are said to *install* views
- We assume no loss of information
- Actors install all the same sequence of views.

Taking into account only crashes (neither entries nor exits) :

- (local monotony) If an actor installs a view (j, M) after installing (k, N), then $j > k$ and $M \subsetneq N$
- (Agreement) No pairs of actors install views (j, M) and (j, M') such that $M \neq M'$
- (Completness) If an actor *a* crashes, then there exists *j* an integer such that any actor eventually install a view (j, M) such taht $a \notin M$
- (Precision) If an actor *a* installed a view (i, M) and $a \notin M$ then *a* crashed

- Coordination languages (à la Linda)
- Conversation langages (ex. RCA)

Original model : Linda [ea94]



Linda introduced 4 opérations :

- **in** read and remove atomically a tuple
- **rd** read, and keep unchanged, a tuple
- **out** add a tuple (possible replication)
- **eval** create a new process

A tuple describes a journey :

- (destination, date, duration, cost, properties).

Processes (travel agency) produce offers (out).

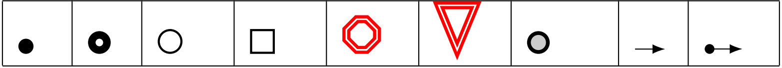
Processes (client, travel agency) consult them (rd) or book them (in).

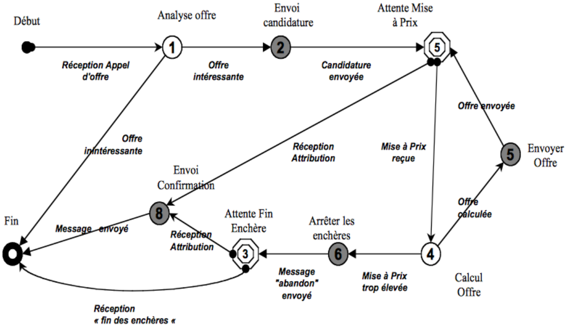
- Simple et abstract mechanism.
- No coupling among processes ; no need to know each others.
- The protocol is encoded in the tuple

Implementations : CppLinda, Erlinda, JavaSpace, PyLinda, etc.

Example : Graphes RCA [TE99]

État							Transition	
initial	final	elementary action	composite action	unbounded wait	bounded wait	communi-cation	internal	external





Good points

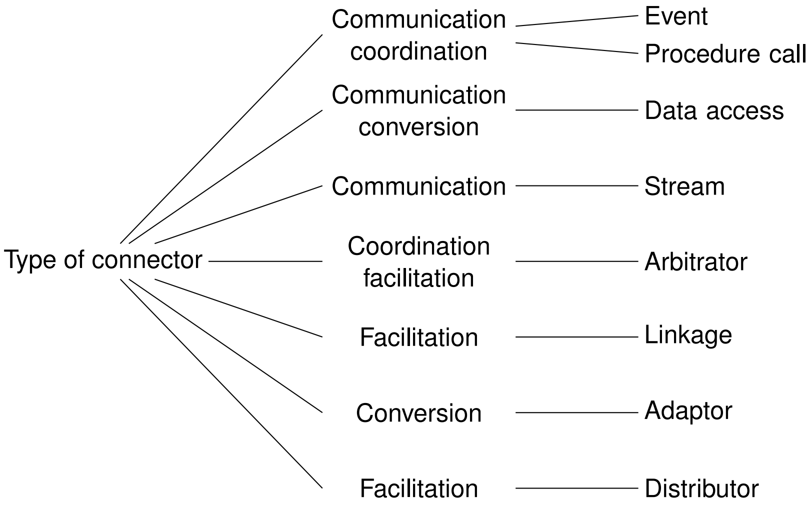
- Globale overview
- Vision of time (automata)

Negative points

- No roles
- No dynamic (numbers of actors)

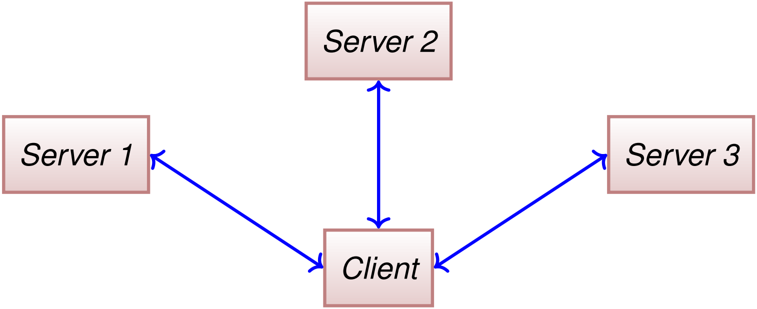
Connectors

- Number of actors, roles (*unicast, multicast, broadcast*)
- Direction
- Initiator (*push/pull*)
- Synchronous/asynchronous (blocking)
- Stream/unique
- Policy (exact, *best effort*, ACID, etc.)
- Safety, cyphered (kind of policy)
- Size, rhythm, jitter (*jitter*), bandwidth

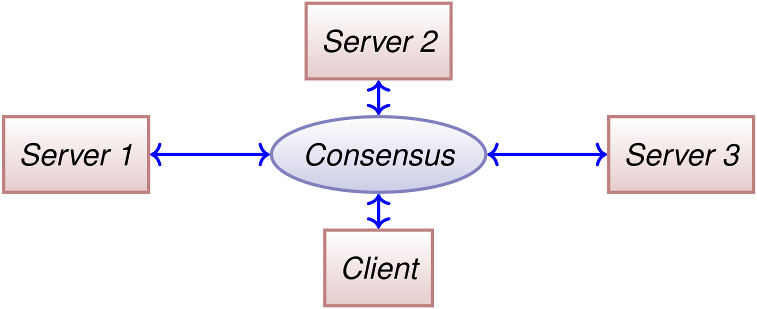

Type of connector
Communication coordination
Communication conversion
Communication
Coordination facilitation
Facilitation
Conversion
Facilitation
Event
Procedure call
Data access
Stream
Arbitrator
Linkage
Adaptor
Distributor

- Memory (register, table, stack, etc.)
- Protocol/language
- Transaction

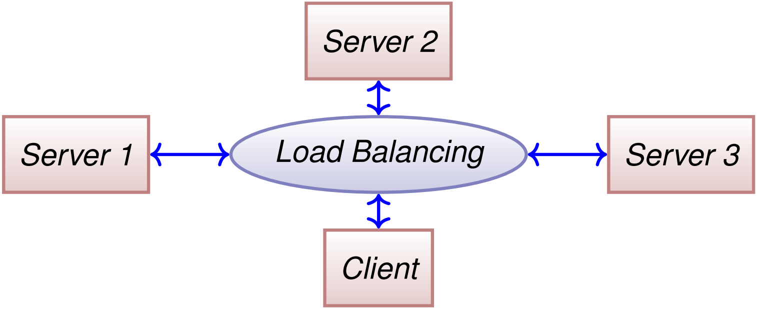
These means are interdependent (protocols and transactions use memory) ; it is the usage rules and policies that differentiate them.



Is it a client that can choose between 3 servers, a load balancing system or a load balancing system or a redundant system with consensus ?



Is it a client that can choose between 3 servers, a load balancing system or a load balancing system or a redundant system with consensus ? More ambiguity.



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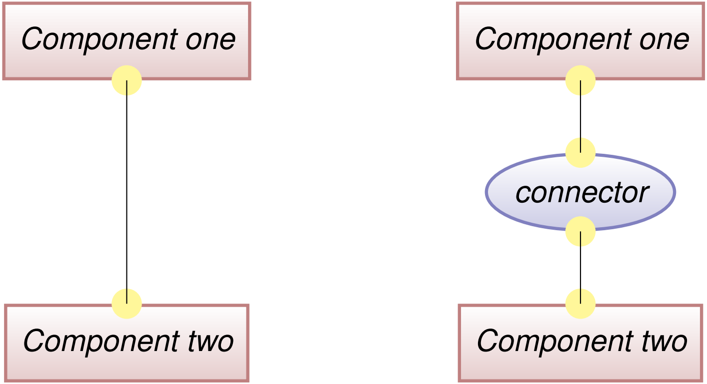
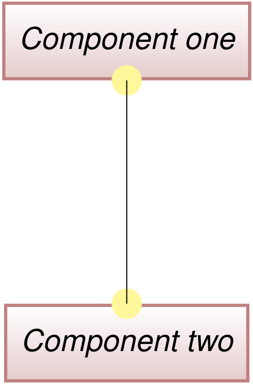

Component one
Component two
Component one
connector
Component two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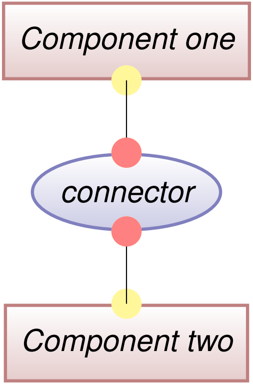
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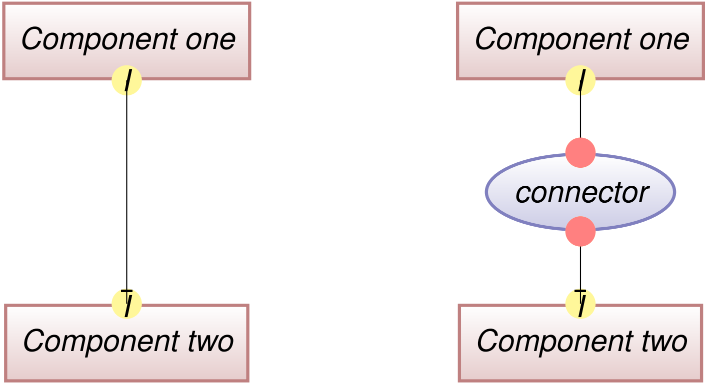
Component two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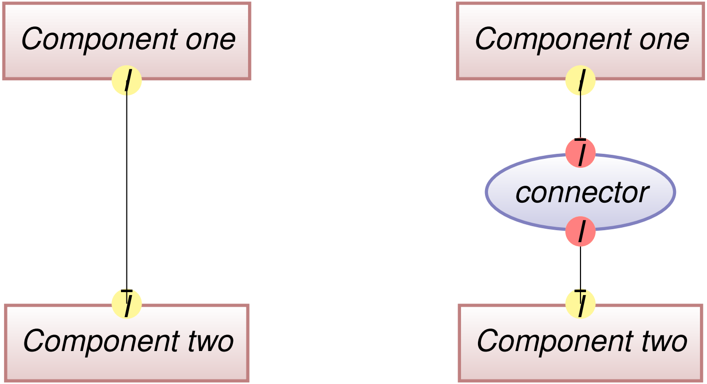
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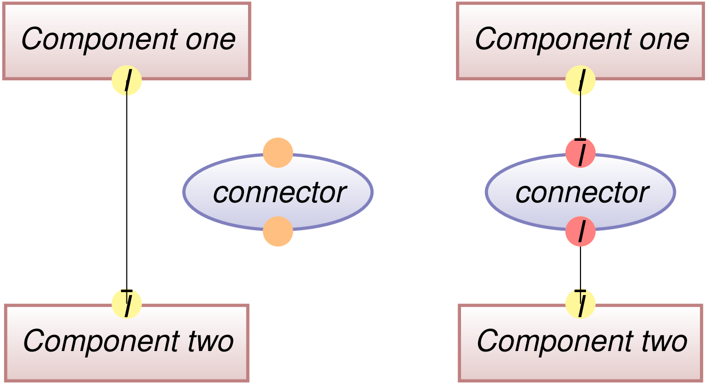
Component one
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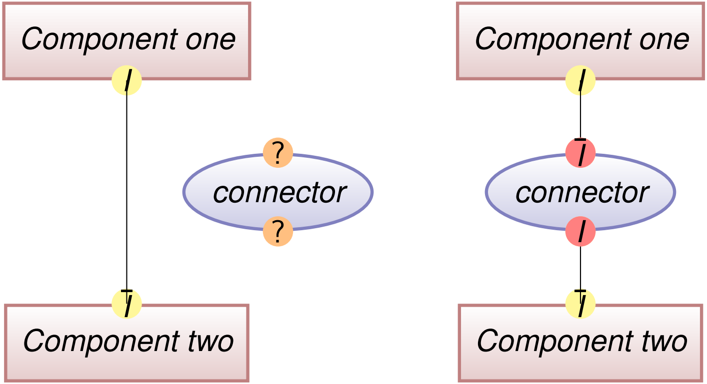
Component one
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connector
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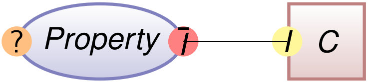
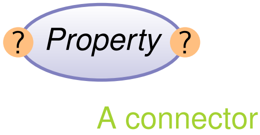
Component two
Component one
connector
Component two

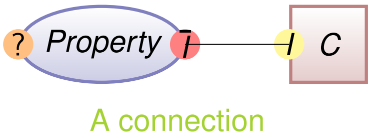
A connector

A connector



A connection


?
Property
?
A connector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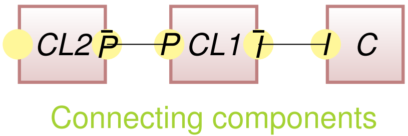
A connection


$CL2$
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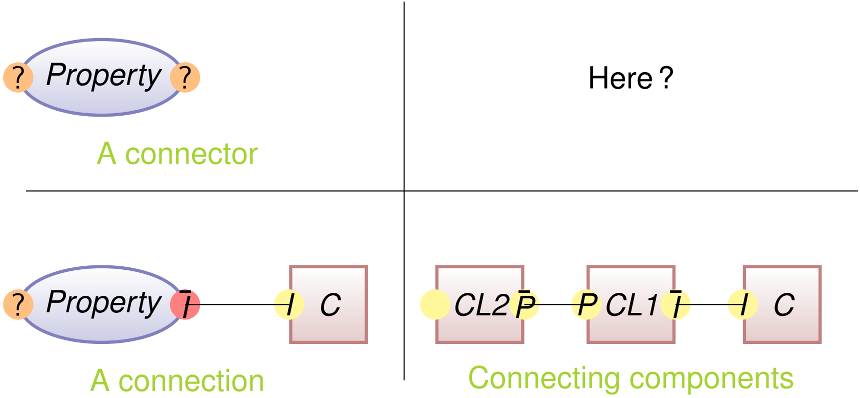
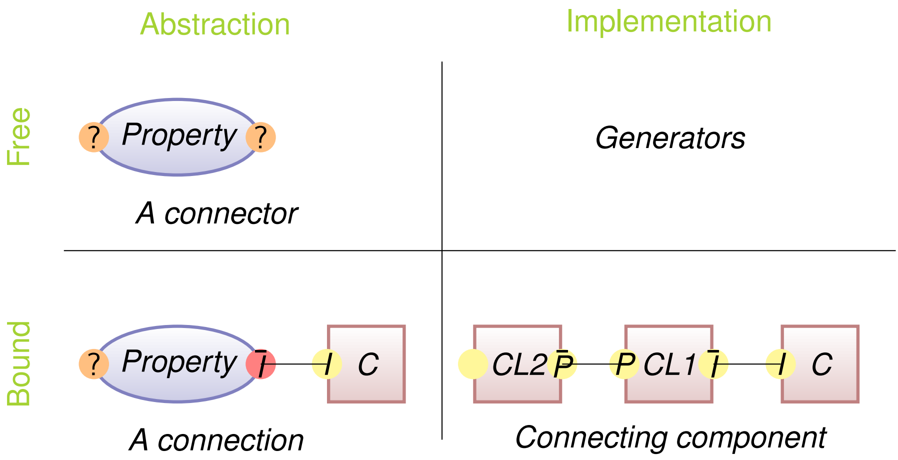
Connecting components


? Property ?
A connector
Here ?
? Property $\bar{I}$ — I C
A connection
CL2 $\bar{P}$ — P CL1 $\bar{I}$ — I C
Connecting components

Something that transforms a role, connected to a port – hence a socket – into a component that provides the complementary interface to the port and *ensures the property* of the connector.
Quelque chose qui *transforme* un rôle, relié à un port – donc une prise – en un composant qui offre l'interface complémentaire du port *et qui assure la propriété* du connecteur.

ex : en Corba, .NET, RPC, Java RMI. . .stub and skeleton generators
Stubs and skeletons are connecting components.


Abstraction
Implementation
Free
Bound
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Property
?
A connector
Generators
?
Property
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I
C
A connection
CL2
P̄
P
CL1
Ī
I
C
Connecting component

- Procedure calls (PC)
- Remote procedure call (RPC)
- CORBA, RMI, ...
- Client/server with load balancing
- Client/server with consensus
- etc

Many connectors exist ; sometime independant from the component model (ex. protocols), sometime associated to a model (CORBA RPC).

Protocols are“connectors” found on the shelves as components, with an explicit interface (port = API).

Using a component as connector requires to *adopt* its interface as a communicating protocol.

A connector is delivered as a generator.

D Caromel.
Toward a method of object-oriented concurrent programming.
Communications of the ACM, 1993.

Carriero et al.
The linda alternative to message-passing systems.
Parallel Computing, 2(4) :633—-655, April 1994.

P Eugster, P Felber, R Guerraoui, and A Kermarrec.
The Many Faces of Publish/Subscribe.
ACM Computing Surveys (CSUR), 2003.

N Mehta, Nenad Medvidovic, and S Phadke.
Towards a taxonomy of software connectors.
Proceedings of the 22nd international conference on Software Engineering (ICSE), pages 178–187, 2000.

OW2.
Proactive web site.
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Erwan Tranvouez and Bernard Espinasse.
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