# Advanced Component Models

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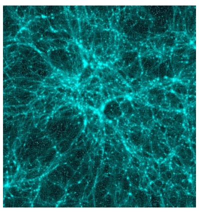
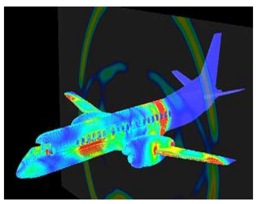
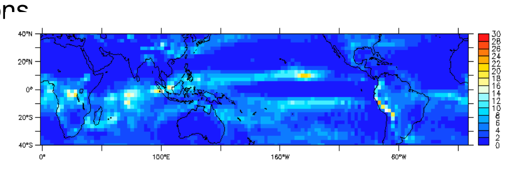
## Content

- Algorithmic skeletons
  - Master-worker
  - MapReduce
  - STKM
- Generic Components
- "Classical" Parallelism
  - Data sharing composition
  - NxM Components
  - Collective communications
- Connectors
  - "Classical" connector
  - "Open" connections
- Conclusion



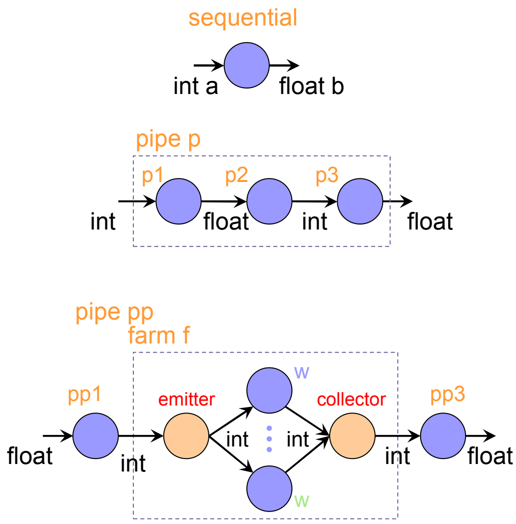




# Algorithmic Skeletons

## Algorithmic skeletons

```
compute in (int a) out (float b)
    $ sequential code $
end

pipe p in (int a) out (float b)
    p1 in (a) out (float b1)
    p2 in (b1) out (int b2
    p3 in (b2) out (b)
end pipe

farm f in (int af) out(int bf)
    w in (af) out(bf)
end farm
pipe pp in (float a) out(float b)
    pp1 in (b) out (int b1)
    f    in (b1) out (b2)
    pp3 in (b2) out (b)
end pipe
```



# Algorithmic skeletons [M. Cole '89]

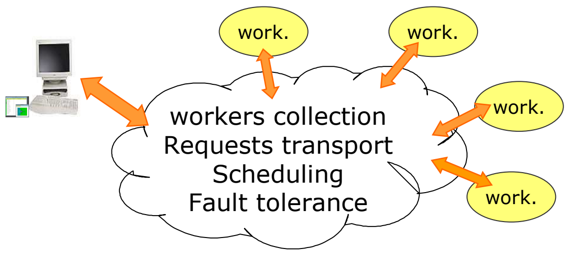
- Predefined patterns for parallel programming
  - Stream parallel
    - Pipeline, farm, if, while, etc
  - Data parallel
    - Fork, divide-and-conquere, Map (independent forAll), reduce, …

- Structured programming
  - Simplicity
  - Correctness of programs
- Hide the complexity of parallelism management
  - Creation of processes, data distribution, ..
- Behavioral skeletons add advanced management for adaptation

# Algorithmic Skeletons

Master-Worker Relationships

# Master-worker paradigm

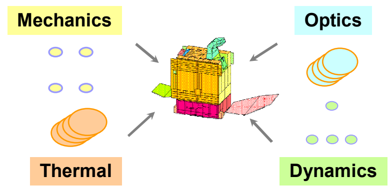



- Multiple independent computations (boucle ~ForAll)
- Dedicated environments/API
  - GridRPC : DIET, NetSolve, Ninf-G, …
  - *Desktop Grid* : BOINC, XtremWEB, …

# Characteristics of master-worker environments

- Advanced request transfer policies
- Transparent management of non-functional concerns

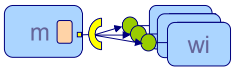
- Dedicated APIs
- Limited programming paradigms

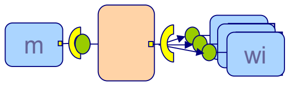


## Assembling a master-worker application in classical component models

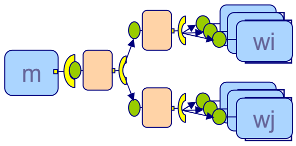
- Non-functional concerns
- Resources dependencies

(A)




(B)




(C)

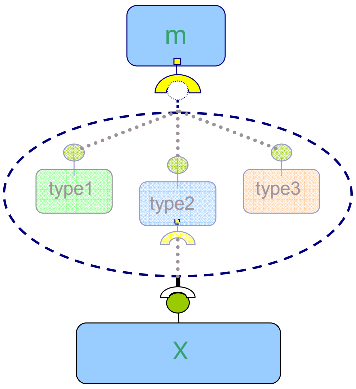
...

## Abstract assembly

Composition of components with collections

≈

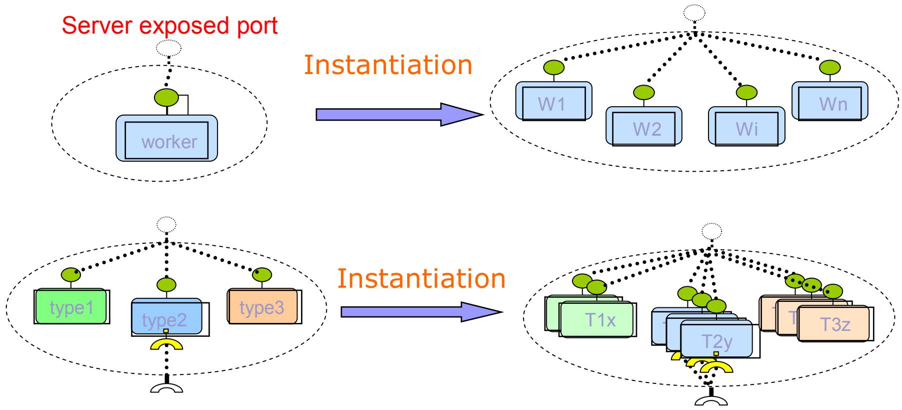
Composition of components



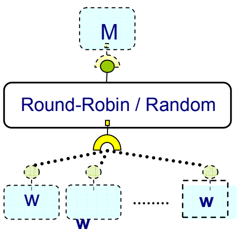
# Collection of components

Definition of a collection

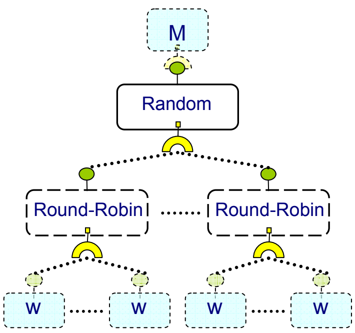
Collection at execution



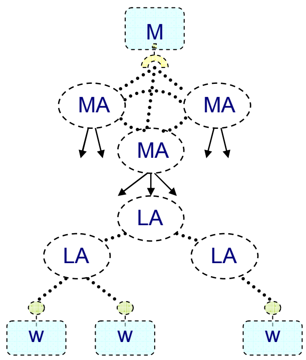

# Request transfer patterns




Simple Component base pattern

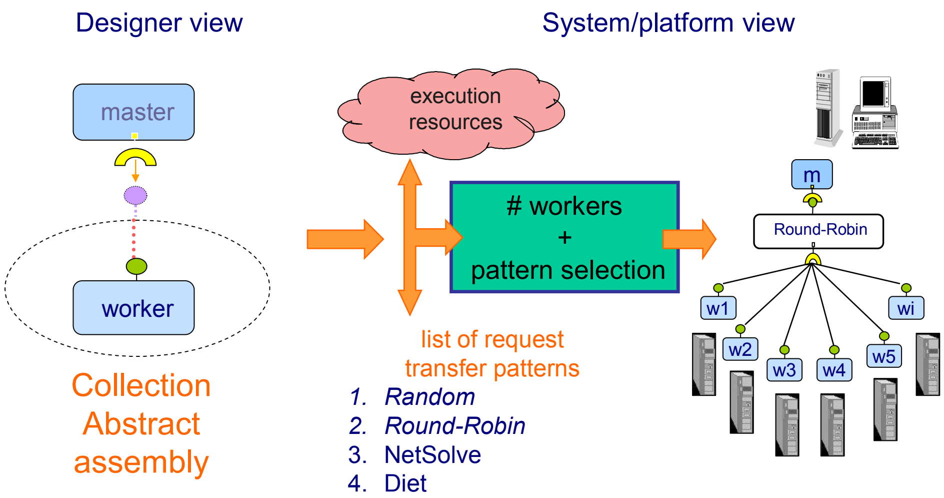



Hierarchical Component based pattern




DIET pattern

# Overview of the proposal




# Algorithmic Skeletons

MapReduce

## Motivation: Large Scale Data Processing

- Want to process lots of data ( > 1 TB)
- Want to parallelize across hundreds/thousands of CPUs
- … Want to make this easy

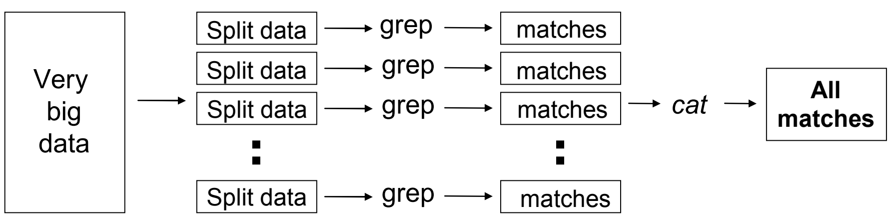
## MapReduce

- Automatic parallelization & distribution
- Fault-tolerant
- Provides status and monitoring tools
- Clean abstraction for programmers

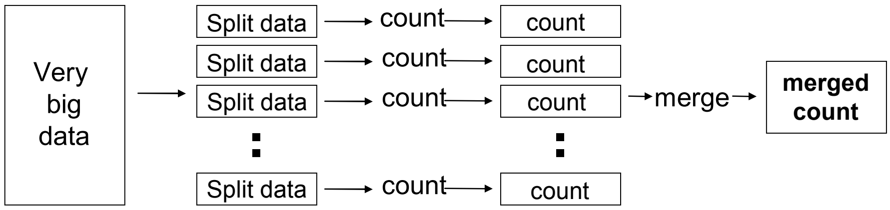
## Programming Model

- Borrows from functional programming
- Users implement interface of two functions:
  - `map (in_key, in_value) -> (out_key, intermediate_value) list`
  - `reduce (out_key, intermediate_value list) -> out_value list`

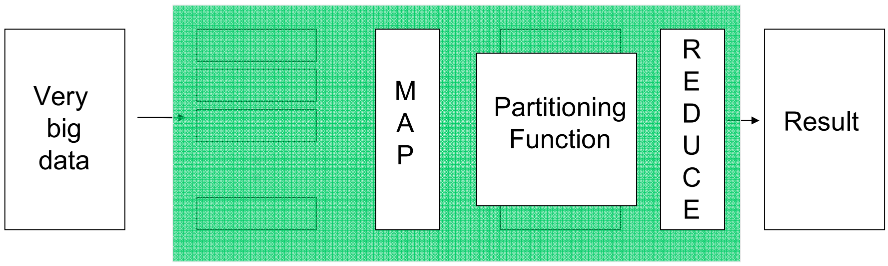
## Distributed Grep



# Distributed Word Count

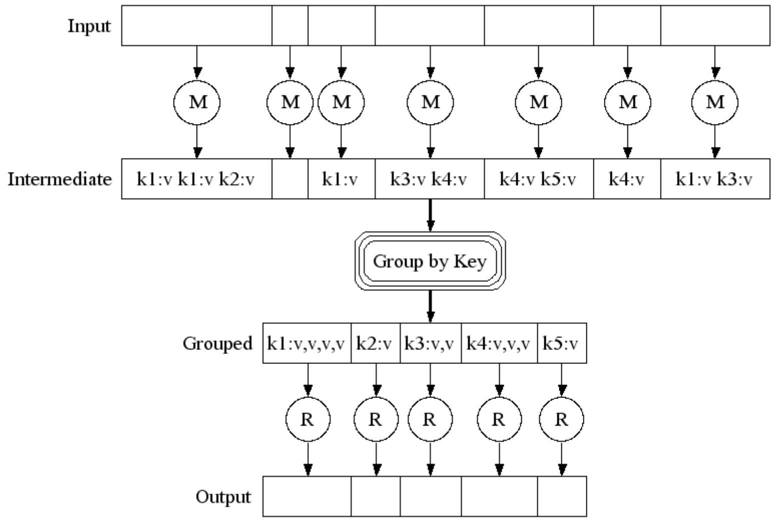



# Map Reduce




- Map:
  - Accepts *input* key/value pair
  - Emits *intermediate* key/value pair
- Reduce :
  - Accepts *intermediate* key/value* pair
  - Emits *output* key/value pair

## Partitioning Function (1/2)




## Partitioning Function (2/2)

- Default : `hash(key) mod R`
- Guarantee:
  - Relatively well-balanced partitions
  - Ordering guarantee within partition
- Distributed Sort
  - Map:
    `emit(key,value)`
  - Reduce (with R=1):
    `emit(key,value)`

## MapReduce

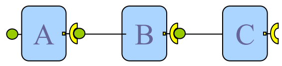
- Distributed Grep
  - Map:
    `if match(value,pattern) emit(value,1)`
  - Reduce:
    `emit(key,sum(value*))`

- Distributed Word Count
  - Map:
    `for all w in value do emit(w,1)`
  - Reduce:
    `emit(key,sum(value*))`

# Spatio-Temporal Skeleton Component Models

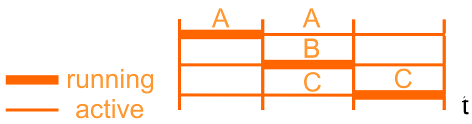
## Limitations of existing component models

- Assembly models close to the computing resources
  - Behavior hidden in the assembly




- "Over-consumption" of resources

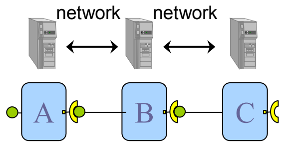
⇒ **Workflow models**




  - Simple spatial relations

- Resource dependencies
- Complex design
  - Parallel paradigms (e.g. master-worker)

⇒ **Algorithmic skeleton models**

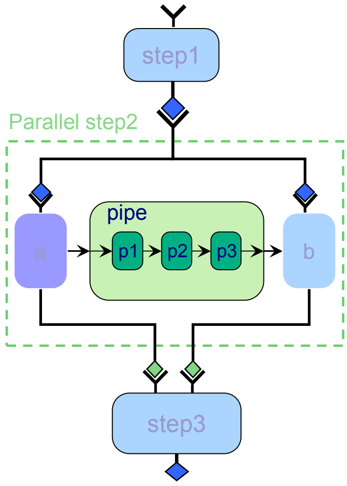



## Objectives

- Simplifying programming parallel parts of an application
- Offering a similar level of abstraction as in skeleton models
- Portability on different execution resources
  - Code reuse
  - Efficiency

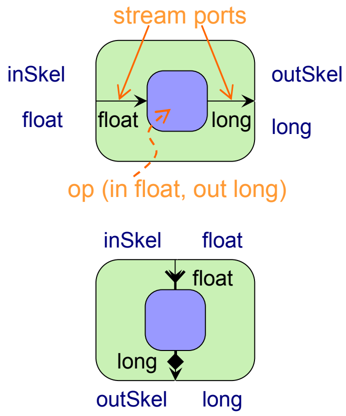
## Overview of STKM

- Assembly model
  - STCM assembly + skeleton constructs
  - An STKM skeleton is a composite with a predefined behavior
  - Parameterization
    - Wrapping components
  - Usage in spatial and temporal dimension
    - Port cardinality principle (temporal dimension)

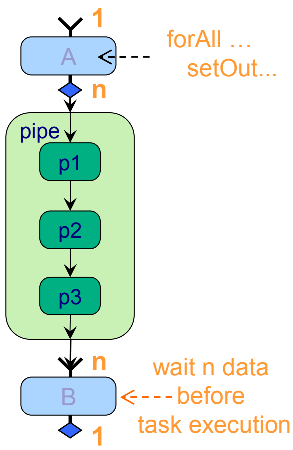



## Component wrapping and port cardinality principle

- A skeleton element is a wrapped component

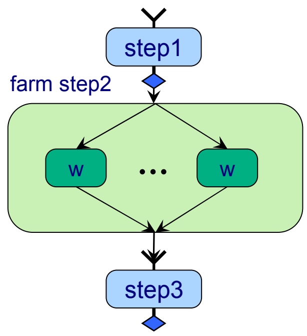



- Port cardinality

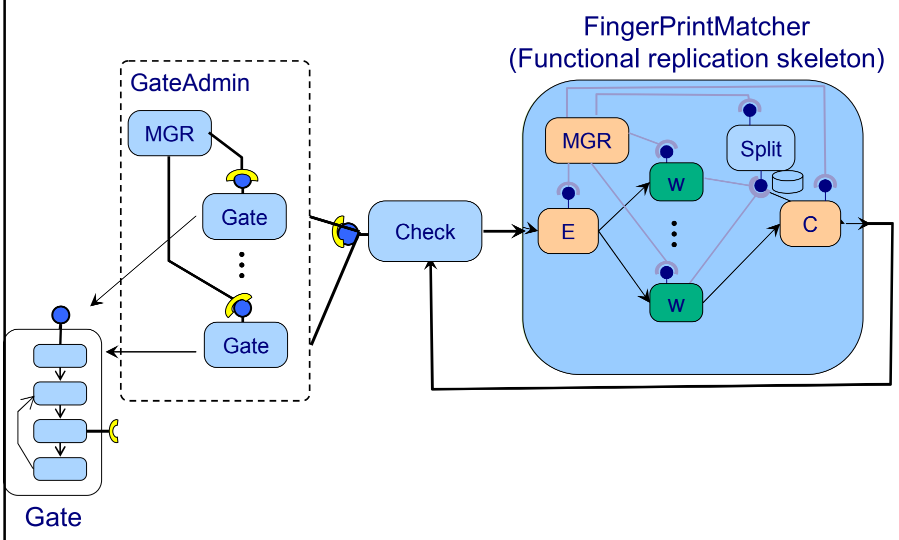


# STKM: Assembly model

```
component Example {
  … Step1 and Step3 components…

  farm Step2 {
    inputSkel double inS2;
    outputSkel string outS2;

    worker sequential w {
      inputSkel double inW;
      outputSkel string outW;
      component Worker {   streamIn double inW;
                           streamOut string outW;
      }
      connect outW to Worker.outW;
      connect Worker.inW to inW;
  }

 instances:  Step1 step1; Step2 step2; Step3 step3;
  … Connexions step1 <=> step2 <=> step3 …
  sequence ApplMain {
    exec step1; exec step2; exec step3;
} }
```



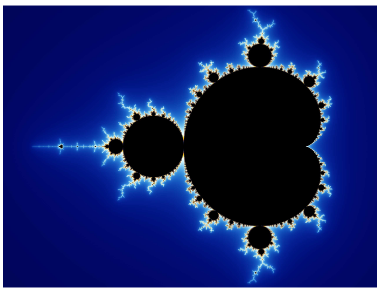

# STKM usage and benefits



# Generic Component Models

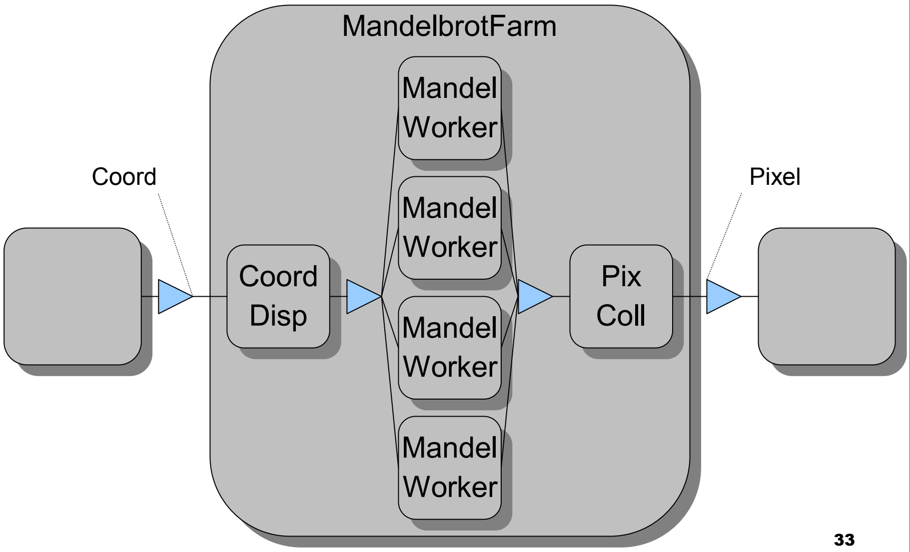
## Motivating example: Overview

- Goal: Generating Mandelbrot set pictures
  - Embarrassingly parallel
- Parallel hardware resources:
  - Ex: Quad-core computer
- Programming pattern: Task-farm skeleton
  - 1 data stream
  - n parallel workers



$C=(x,y)$
$Z_{n+1} = Z_n^2 + C$
- Bounded → black
- Unbounded → blue

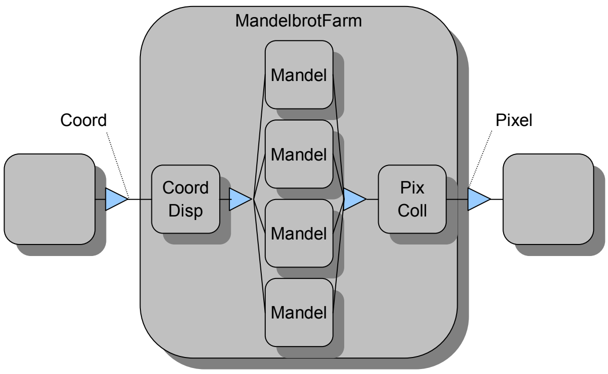
## Motivating Example:
## A component based implementation



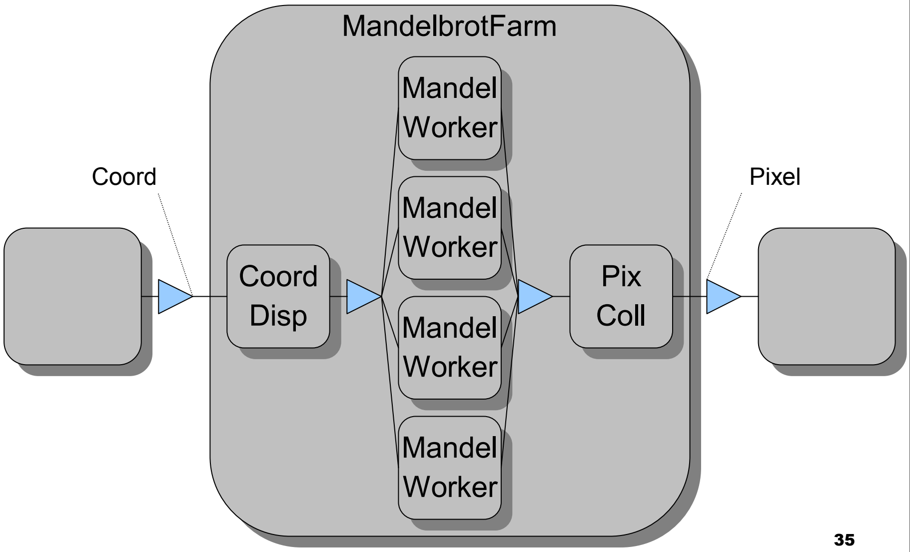



## Motivating example: Limitations to reuse

- Hard-coded in the composite
  - Transformation algorithm
  - Manipulated data-types
  - Number of workers

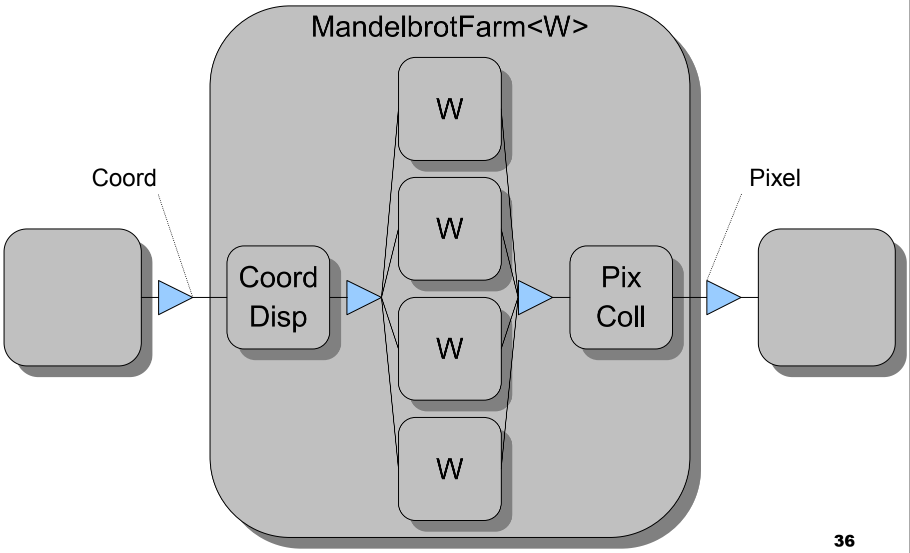


## Motivating Example: A generic farm



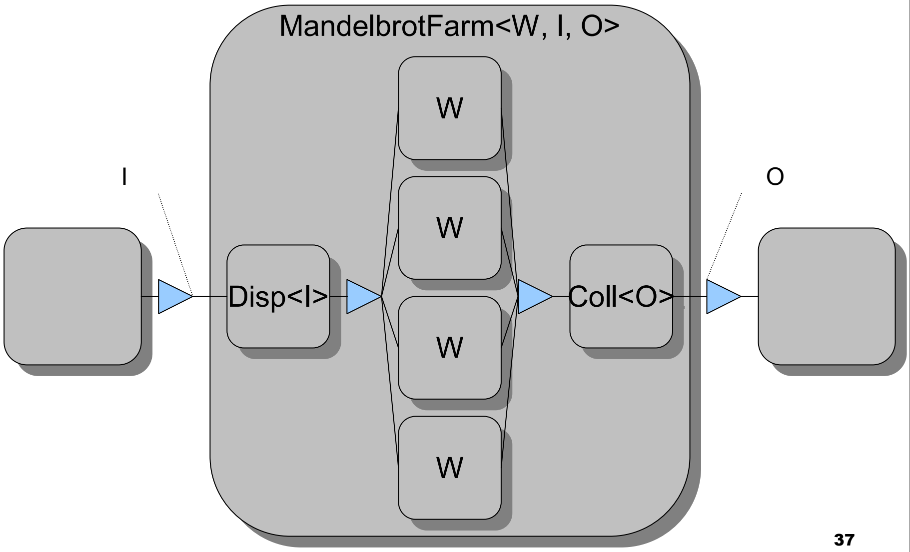

35

## Motivating Example: A generic farm



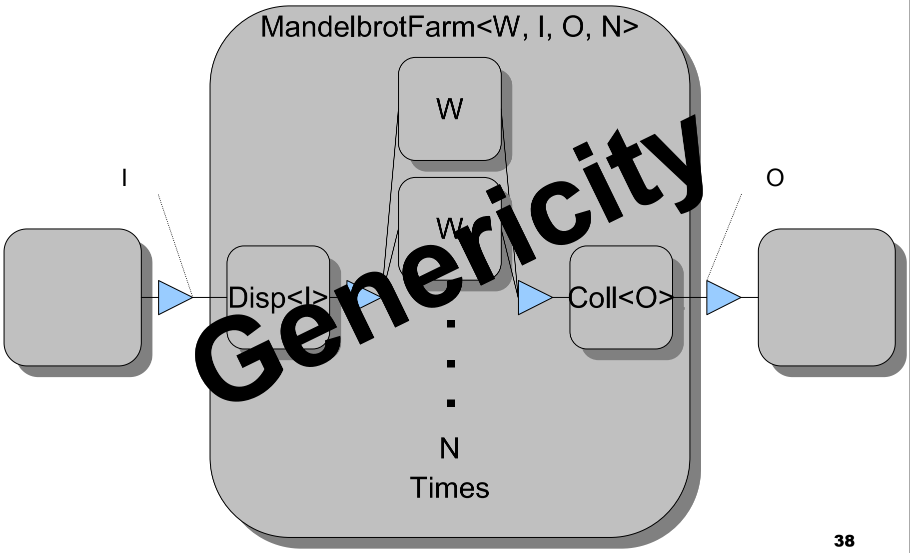

36

# Motivating Example: A generic farm




37

# Motivating Example: A generic farm




38

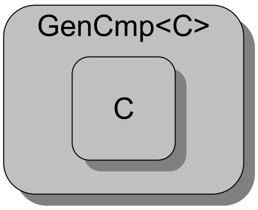
# Genericity study: Concepts definitions (1)

```
public class GenClass<T>
{
    T member;
    …
}
```

Java

```
template<typename T>
T genFunc () {
    T locvar;
    …
    Return locvar;
}
```

C++




**Generic artifacts**:

- Accept 2nd order **parameters**
- **Use the parameters** in their implementation / body

39

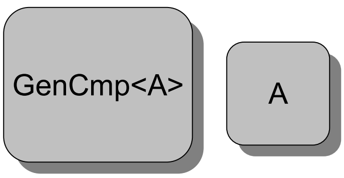
# Genericity study: Concepts definitions (2)

```
GenClass<String> l = new GenClass<String>();
```

Java

```
int i = genfunc<int>();
```

C++




**Specializations:**

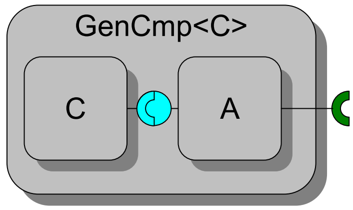
- Use of generic artifacts
- **Arguments** bind parameters to a value

40

## Genericity study: Concepts definitions (3)

```
Template<>
void* genFunc<void*>() {
    …
}
```

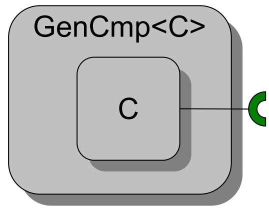
C++




**Explicit Specializations:**

- Distinct implementation for a range of specializations
- When some constraints on the parameters are fulfilled

When C.p instanceof G






## Toward a generic component model

- Generic concepts
  - Component types
  - Port types
- Concepts as parameters
  - Component types
  - Port interfaces
  - Data types
  - Data values
- Instantiation of parameter types
- Meta-programming
  - Ex: N times replication
- Reuse existing component models
  - Extension of existing models

## Genericity study:
## Type erasure vs. Specialized compilation

- Type erasure : (ex. Java)
  - Type parameters used for checking
  - Only one code compiled, manipulates Object ptrs

+ Compiled code is smaller
- Limited use of parameter types (no instantiation, limited access to methods, …)

- Specialized compilation (ex. C++)
  - Type parameters replaced in the code
  - One code compiled / specialization

- No dynamic instantiation of specializations
+ Explicit specializations & template metaprogramming

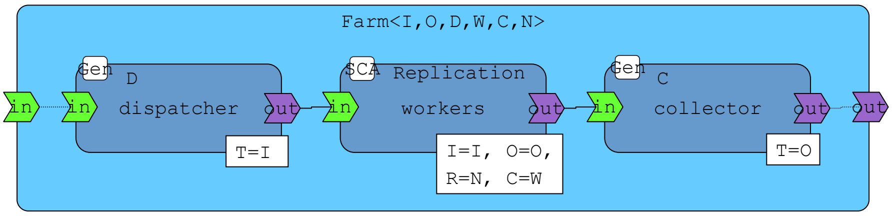
# GenericSCA: Introduced features

- Concepts made generic :
  - Composite component implementations
  - Java component implementations
  - Java port interfaces

- Concepts that can be parameters
  - Component implementations
  - Port interfaces
  - Data-types
  - (Data-values) : properties are already part of SCA

## Task Farm in GenericSCA: Modeling the Farm

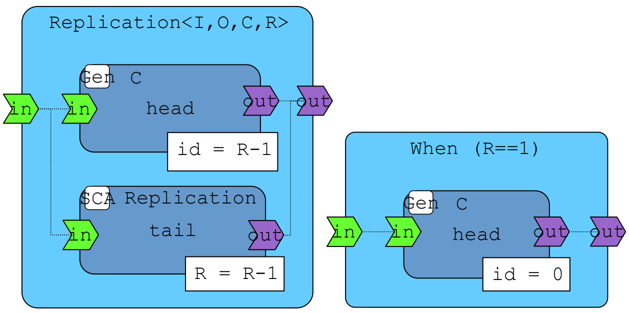
- Six parameters:
  - **I**, **O**: type of input & output data
  - **D**,**W**,**C**: Dispatcher, Worker & Collector implementations
  - **N**: number of Workers
- Default values for **D** & **C**
- Flow simulated by a DataPush<T> interface
  - Single method: void push(T data);




45

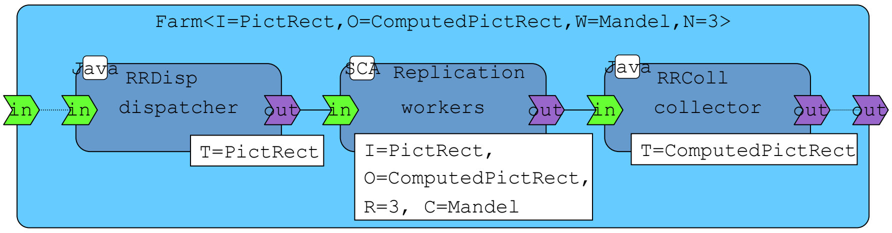
## Task Farm in GenericSCA: The Replication Component

- Recursive implementation
  - When R = 1
    - 1 C instance only
  - When R > 1
    - 1 C instance
    - 1 Replication instance with R decreased by 1




46

# Task Farm in GenericSCA: Transformation Example



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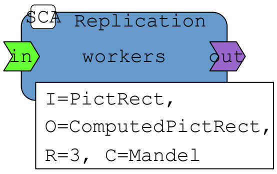

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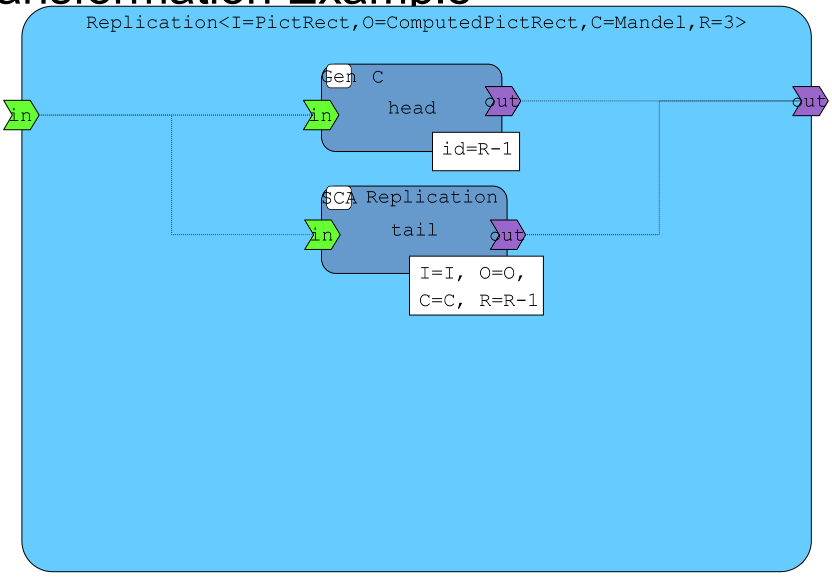


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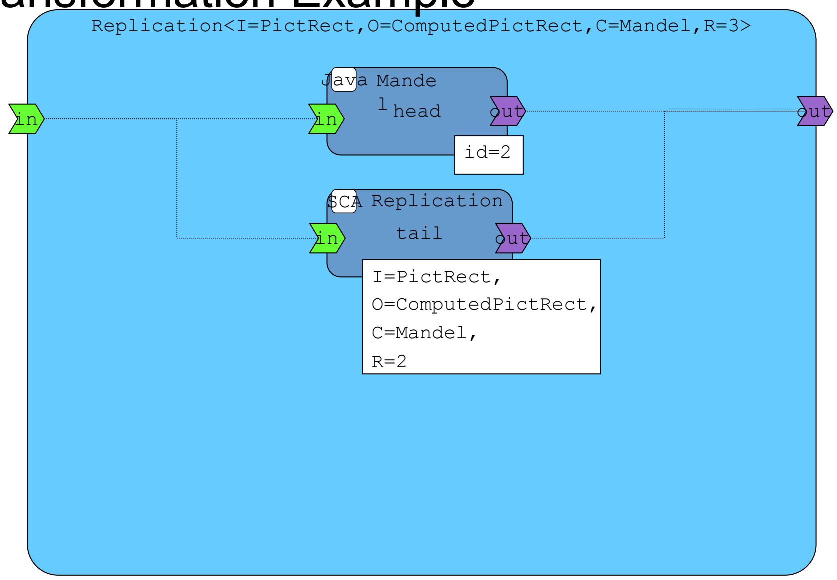

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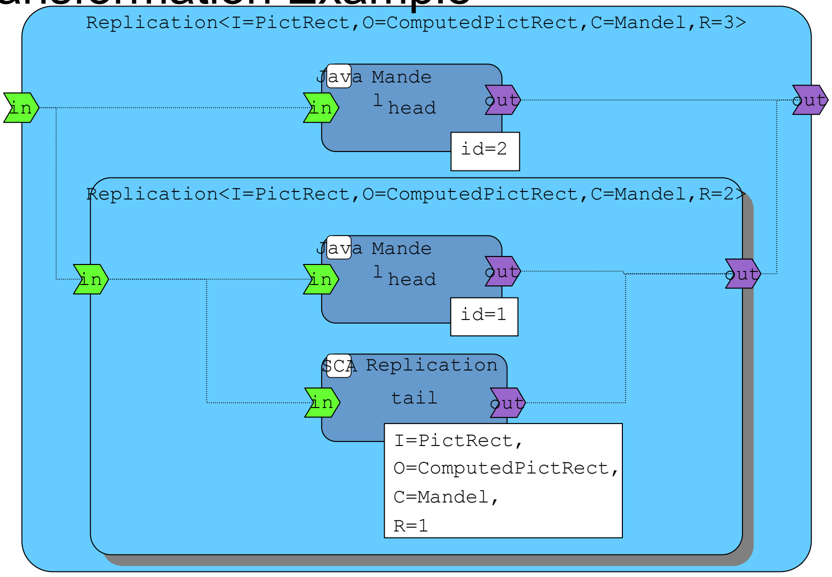


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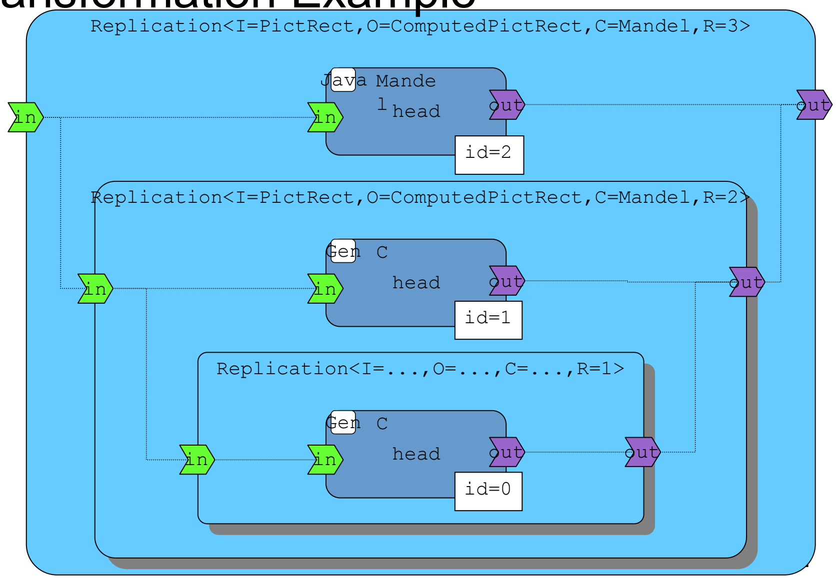


## “Classical” Parallelism in Component Models

Data sharing

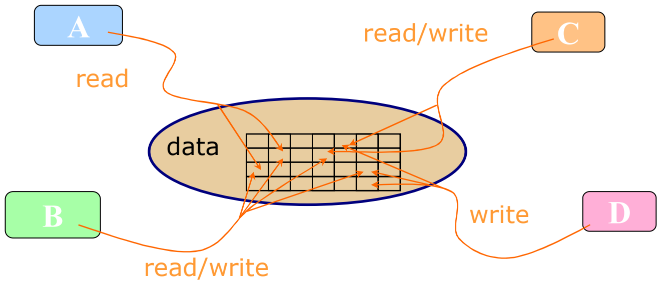
NxM

Collective Communications

## “Classical” Parallelism in Component Models

Data-sharing Composition

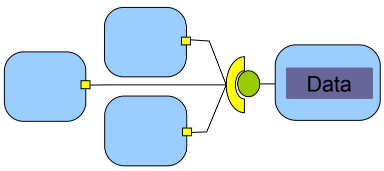
## Data sharing



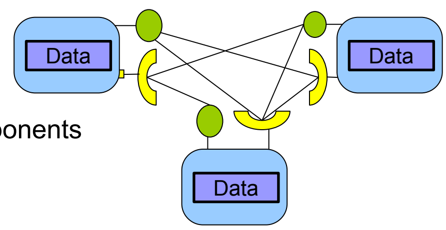

- Multiple concurrent accesses to a data
- Localization and concurrent accesses management
  - Intra-machine: OS
  - Intra-cluster: Distributed shared memory (DSM)
  - Intra-grid: sharing data service (JuxMem/PARIS)

## Limits with data sharing in component models

- Ports: active communication operation
  - Data must be part of a message
- Centralized approach
  - Bottleneck for the performance
  - Single point of failure



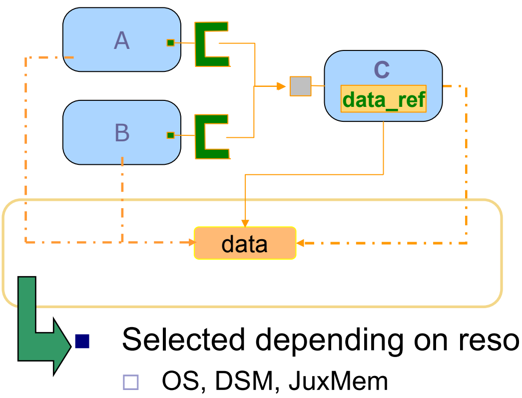

- Distributed approach
  - Explicit management of data replication/migration by components
  - Functional code mixed with data management code



# Overview of the Model

- Principle : transparent access to a shared data

*accesses* float port   *shares* float port




```
interface SharesPort {
  float* allocate_space(in ling size);
  void free_space();
  float* get_pointer();
  long get_size ();
  void acquire();
  void release ();
  void acquire_release();
};
```

- Selected depending on resources and comp. placement
  - OS, DSM, JuxMem

# Example of data sharing ports

```
class CompImpl {
  Services srv;
  AccessPort myPort;

  …
  void computeSum(){
    myPort = srv.getPort("myPort");
    myPort.acquireR();
    ptr = myPort.getPointer();
    size = myPort.get_size();
    for ( i = 0; i < size; i++)
       sum += ptr[i];
    myPort.release ();
  }
}
```

```
interface ExtendedServices : Services {

interface AccessPort : Port {
  opaque get_pointer();
  long get_size();
  void acquire();
  void acquireR();
  void release();
}
interface SharesPort : AccessPort {
  void associate (in opaque ptr,  in long
size);
  void disassociate();
}
```

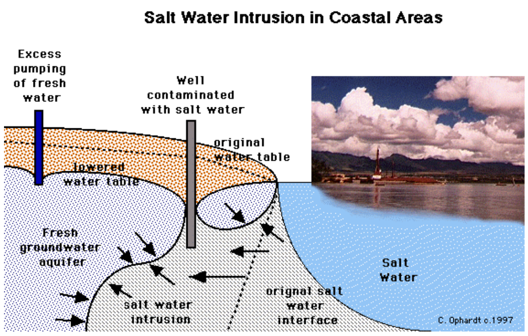
# "Classical" Parallelism in Component Models

MxN Communications

## Application in hydrogeology: Saltwater intrusion

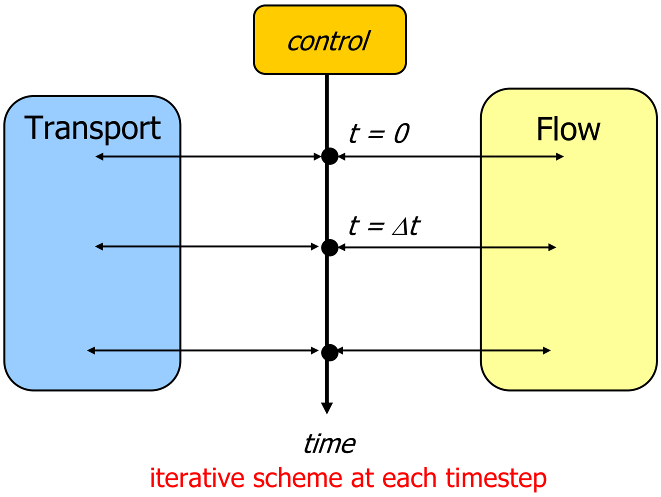
- Coupled physical models
- One model = one software
- Saltwater intrusion
  - Flow / transport
- Reactive transport
  - Transport / chemistry

- Hydrogrid project, supported by the French ACI-GRID

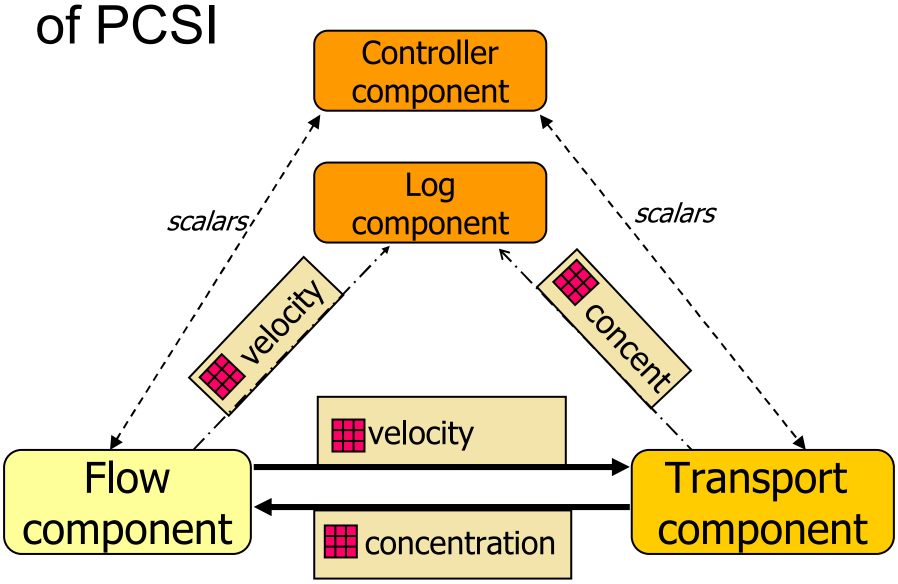



flow : velocity and pressure function of the density
Density function of salt concentration
Salt transport : by convection (velocity) and diffusion

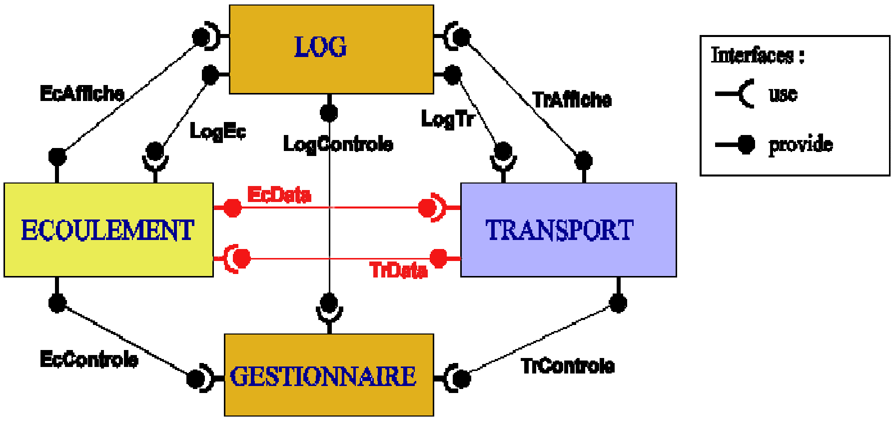
## Numerical coupling in saltwater intrusion



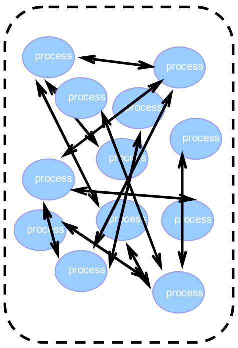

## Components and communications of PCSI



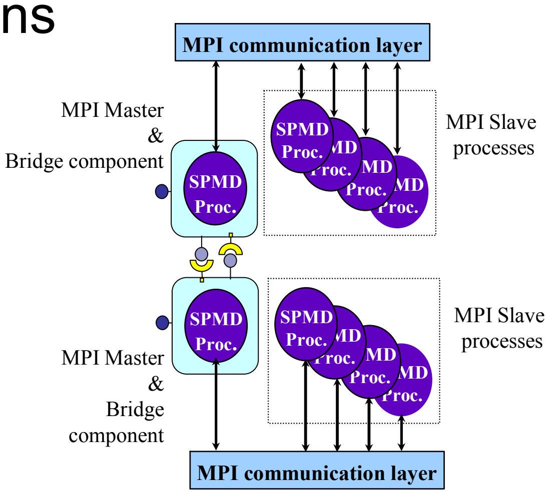
# Components and interfaces of PCSI




# Limits to MxN code communications



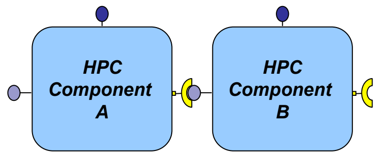
Flat programming model
(à la MPI)



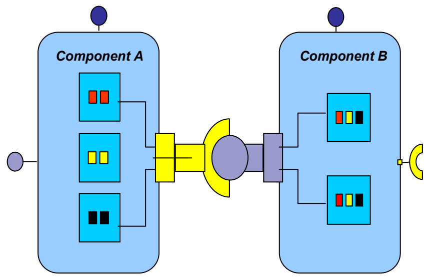

Bridge based solution

# SPMD Components

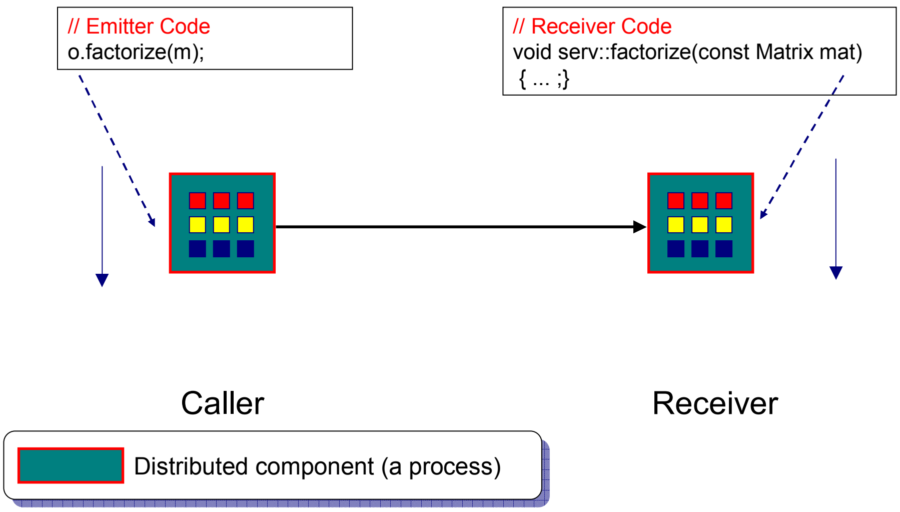
What the application designer should see…



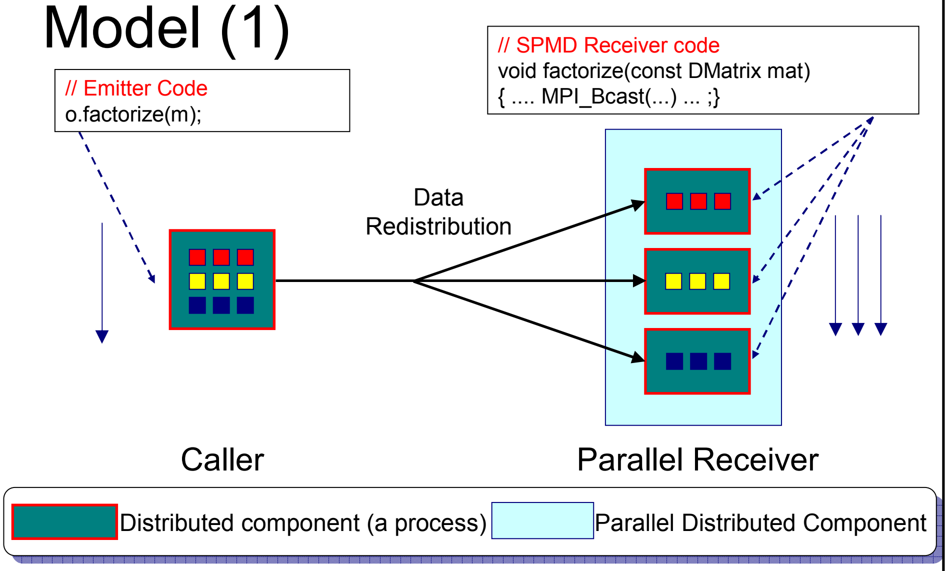

… and how it must be implemented !



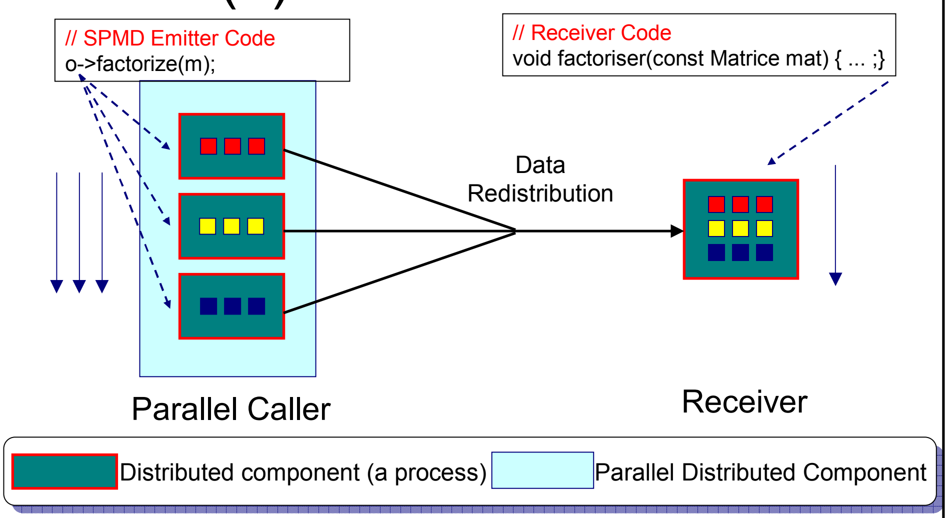

# Distributed Component Model



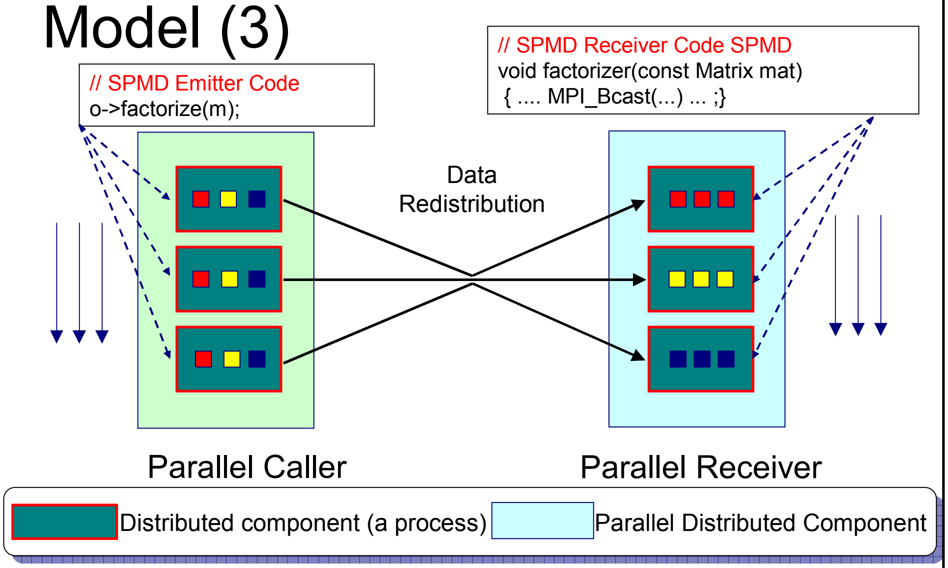
# SPMD Parallel Component Model (1)




# SPMD Parallel Component Model (2)



# SPMD Parallel Component Model (3)




# GridCCM Component

IDL2

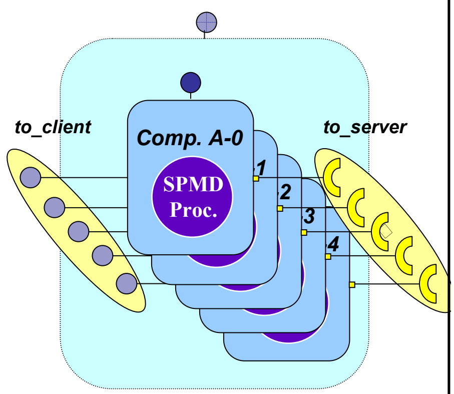
```
interface IExample
}
   void factorise(in Matrix mat);
};
```

IDL3

```
component CoPa
{
   provides IExample   to_client;
   uses     Itfaces2   to_server;
};
```

XML

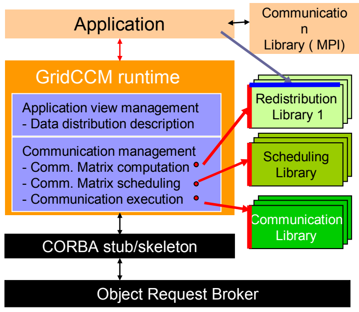
```
Component: CoPa
Port: to_client
Name: IExample.factorise
Type: Parallel
Argument1: Basic_BC[*, bloc]
ReturnArgument: noReduction
```

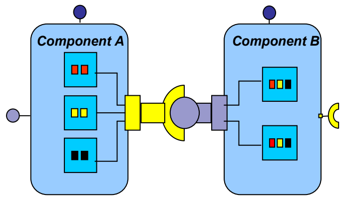


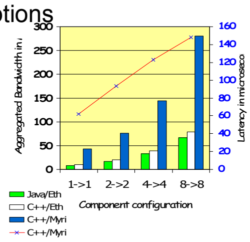

Non functional property of
a component implementation

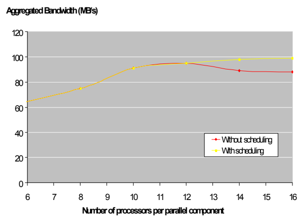
# Components for code coupling: SPMD paradigm in GridCCM

- SPMD component
  - Parallelism is a non-functional property of a component
    - It is an implementation issue
  - Collection of sequential components
    - SPMD execution model
  - Support of distributed arguments
    - API for data redistribution
    - API for communication scheduling w.r.t. network properties
  - Support of parallel exceptions



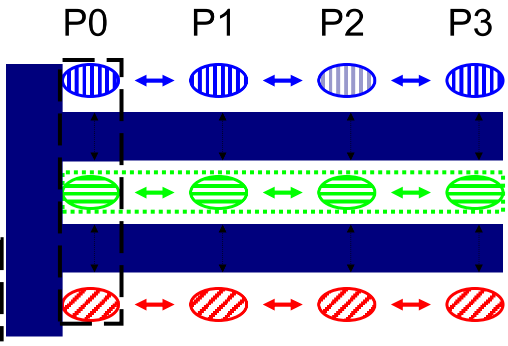




# "Classical" Parallelism in Component Models

## Parallelism in Common Component Architecture

# CCA Supports Parallelism by "Staying Out of the Way" of it

- Single component multiple data (SCMD) model is component analog of widely used SPMD model
  - Each process loaded with the same set of components wired the same way
  - Different components in same process "talk to each" other via ports and the framework
  - ***Same component in different processes talk to each other through their favorite communications layer (i.e. MPI, PVM, GA)***



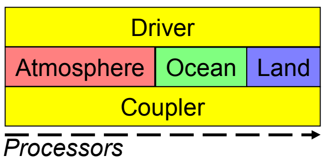

Components: Blue, Green, Red

Framework: Gray

Any parallel programming environments that can be mixed outside of CCA can be mixed inside

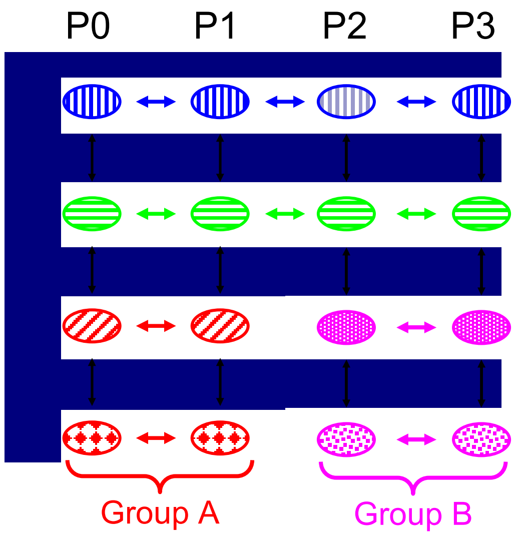
# "Multiple-Component Multiple-Data" Applications in CCA

- Simulation composed of multiple SCMD sub-tasks
- Usage Scenarios:
  - Model coupling (e.g. Atmosphere/Ocean)
  - General multi-physics applications
  - Software licensing issues
    - i.e. limited number of instances




- Approaches
  - Run single parallel framework
    - Driver component that partitions processes and builds rest of application as appropriate (through BuilderService)
  - Run multiple parallel frameworks
    - Link through specialized communications components
    - Link as components (through AbstractFramework service)

# MCMD Within A Single Framework




- Framework
- Application driver & MCMD support component
- Components on all processes
- Components only on process group A
- Components only on process group B

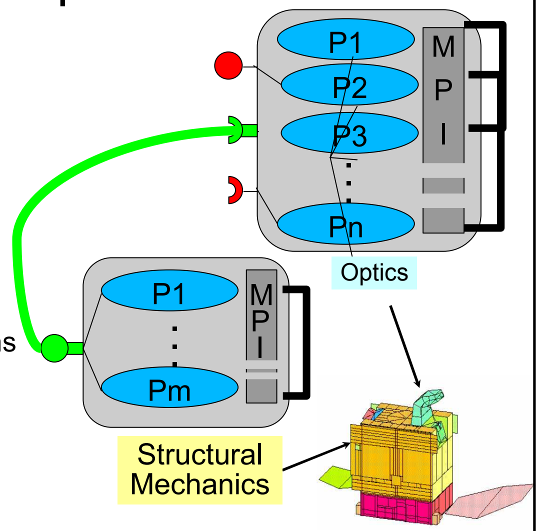
# "Classical" Parallelism in Component Models

Collective Communications

# Parallelism in component models

- Using message passing libraries (ex. MPI) inside components
- Using parallel ports (NxM) between components

- No collective communications at higher level
- Two communication models to handle

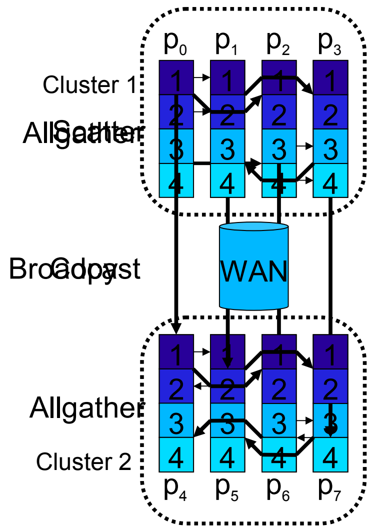



# Collective communications

- Most effective algorithm depend on the resources

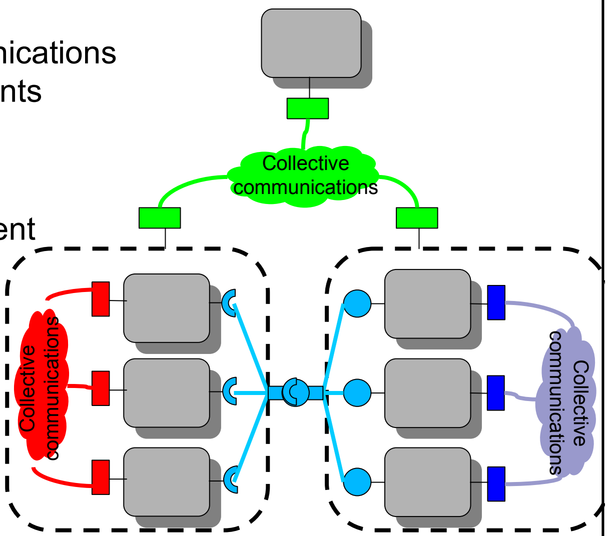
- On hierarchic resources
  - hierarchic algorithms

M. Matsuda, T. Kudoh, Y. Kodama, R. Takano et Y. Ishikawa. Efficient MPI collective operations for clusters in long-and-fast networks. in *Cluster2006*. IEEE, 2006



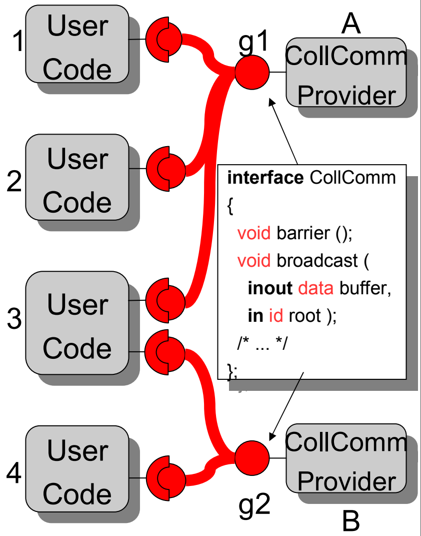
## Goals : Overview

- Collective communications between components
  - Efficient
  - Transparent
  - Fits in component model



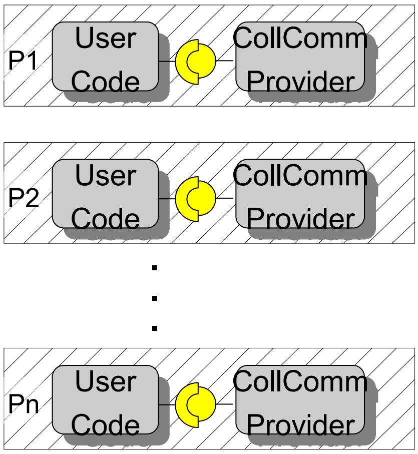

## Goals: From the user point of view

- Collective communications are a service
  - Provided by a component
- Communications groups are a way to connect component instances
  - Described in the assembly



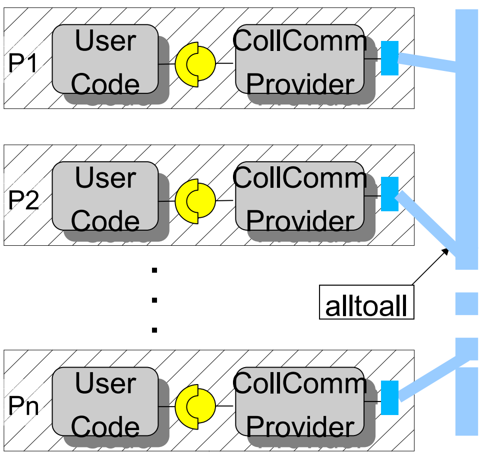
## Goals: From the developer point of view

- Efficiency
  - Decentralized implementation



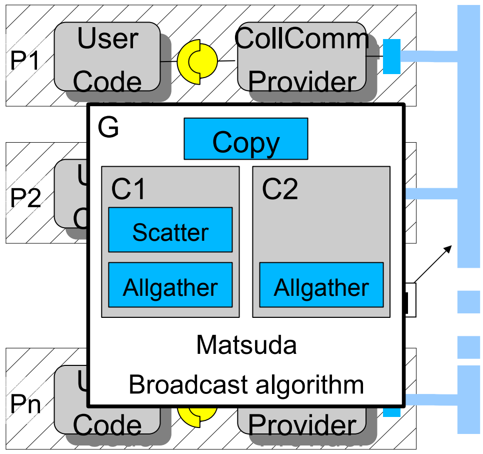

## Goals : From the developer point of view

- Efficiency
  - Decentralized implementation
- Communications between processes
  - Alltoall connection

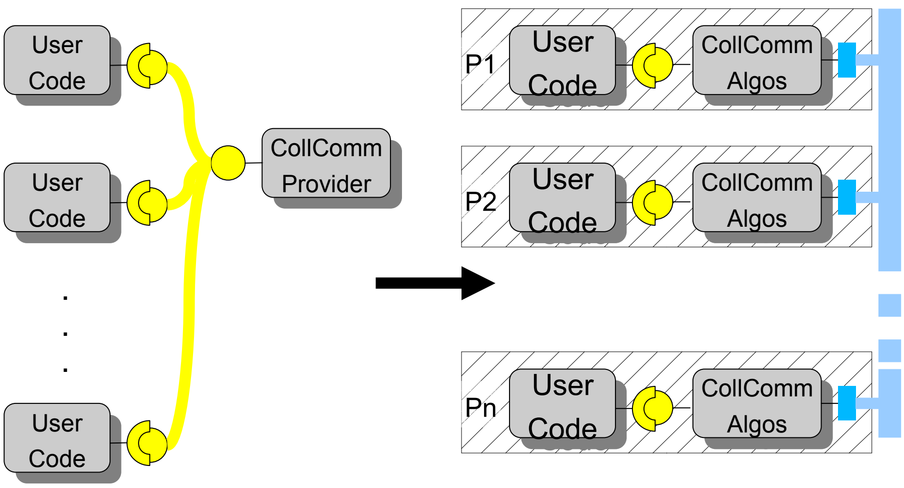


## Goals: From the developer point of view

- Efficiency
  - Decentralized implementation
- Communications between processes
  - Alltoall connection
- Hierarchical resources & algorithm
  - Hierarchical assembly




## Goals: Need for an automatic transformation



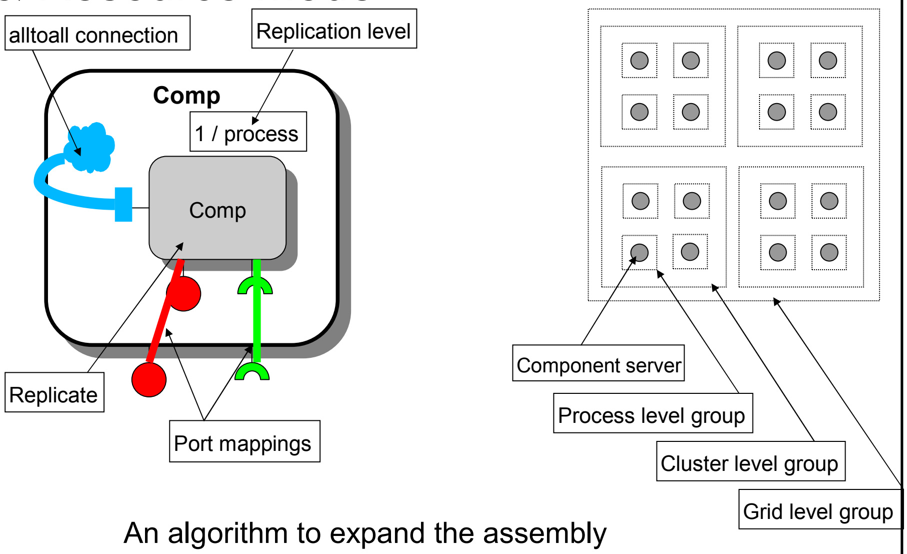
# Collective Communications

A component model with replicating component

## Generic model: Assumptions

- A component model with
  - Components with multiple implementations
  - Primitive & composite component
  - **Replicating component**
  - An ADL to describe the assembly
- A resource model
- **An algorithm to expand the assembly**

## Generic model: Replicating component & Resource model

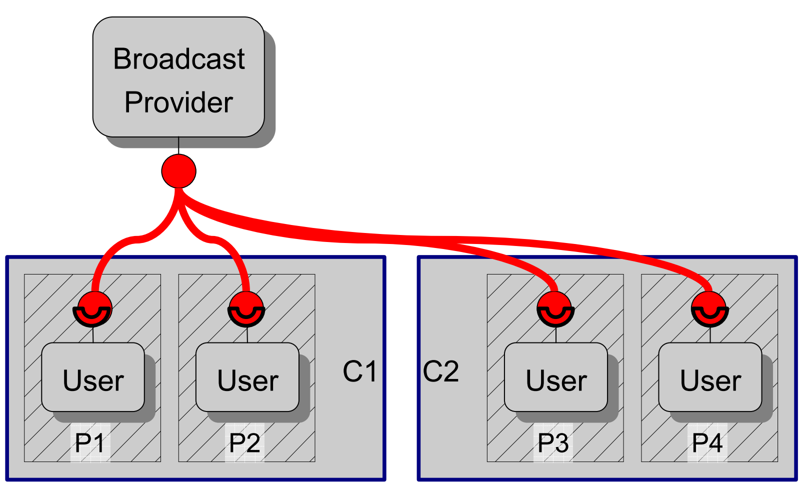



An algorithm to expand the assembly

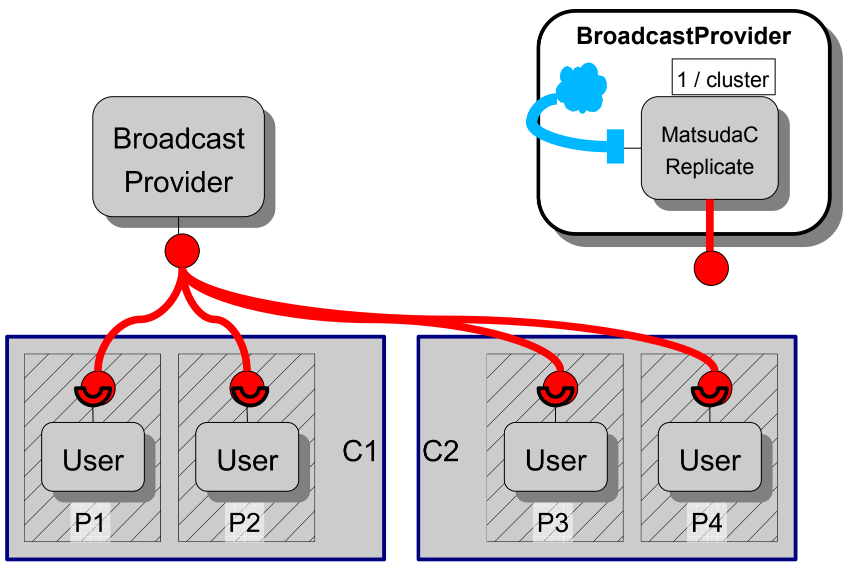
# Collective Communications

Usage example

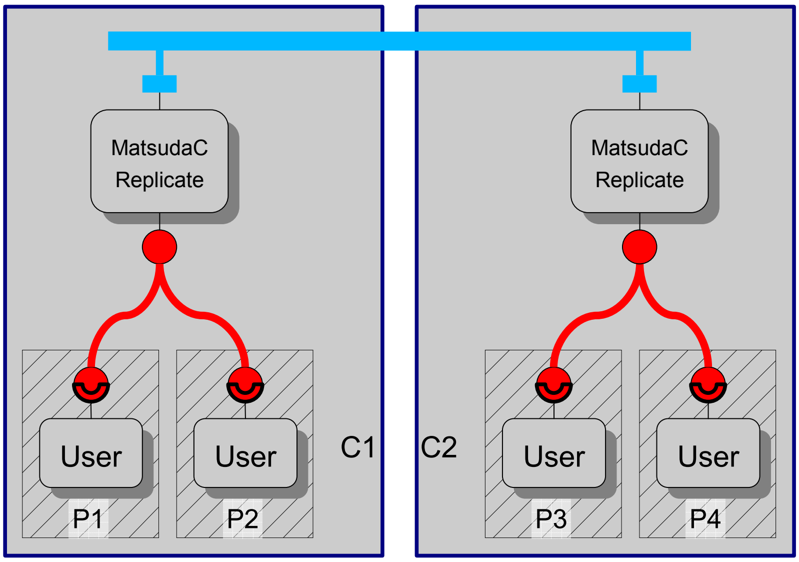
## Usage example: hierarchic broadcast



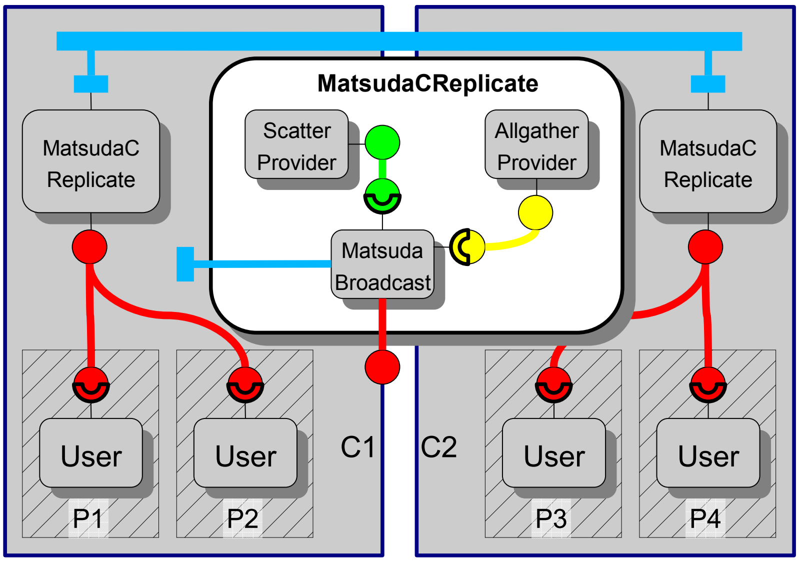

## Usage example: hierarchic broadcast



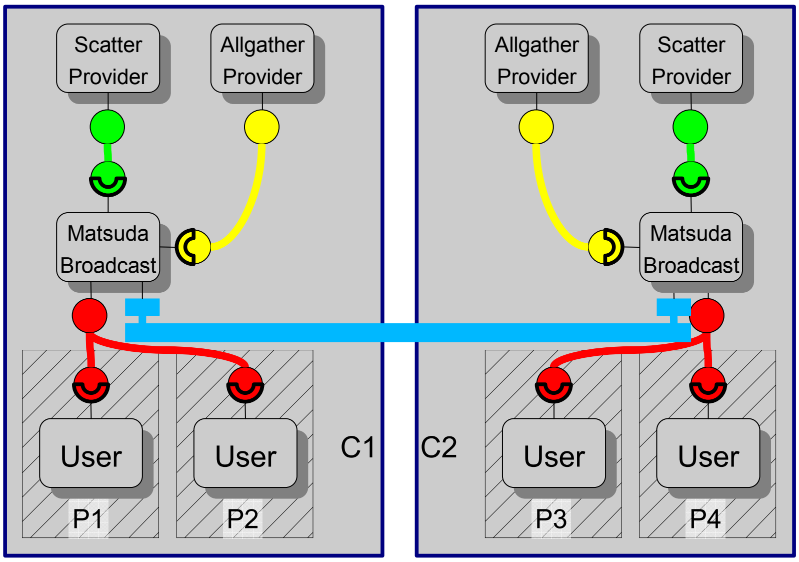
# Usage example: hierarchic broadcast



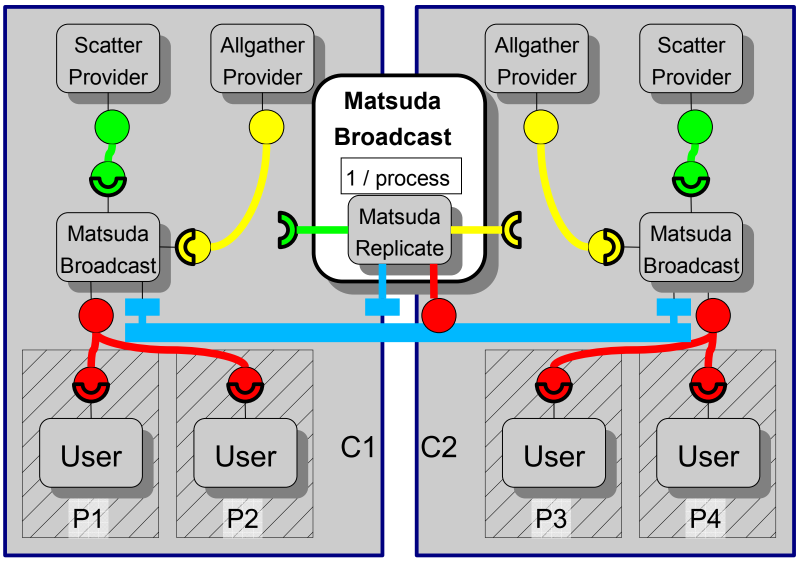

# Usage example: hierarchic broadcast



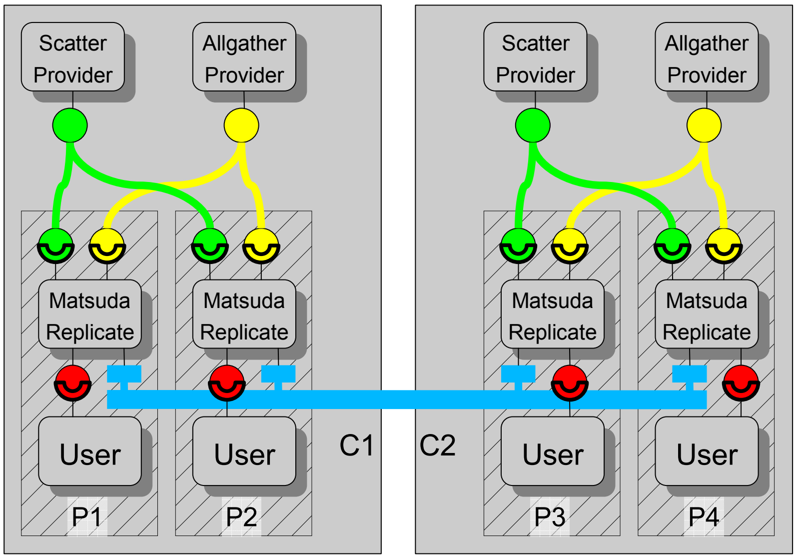
# Usage example: hierarchic broadcast



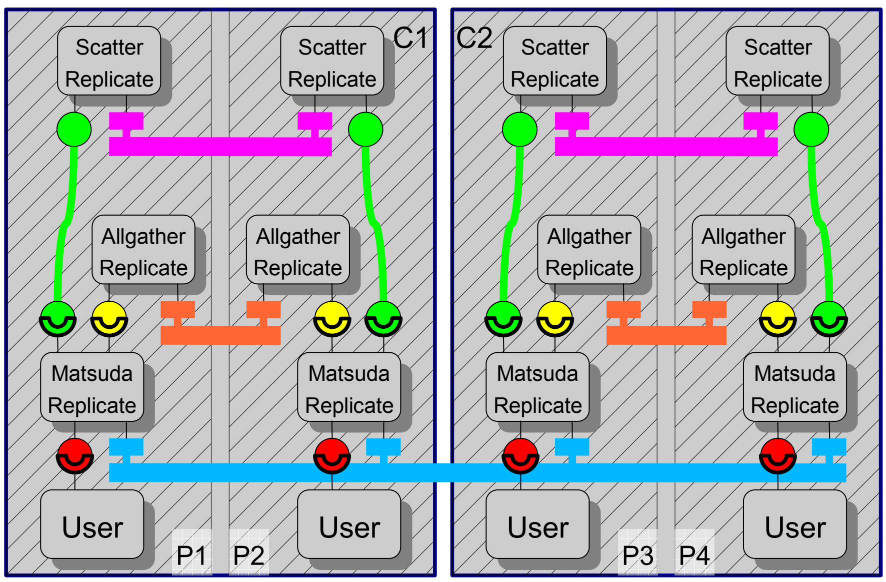

# Usage example: hierarchic broadcast



## Usage example: hierarchic broadcast

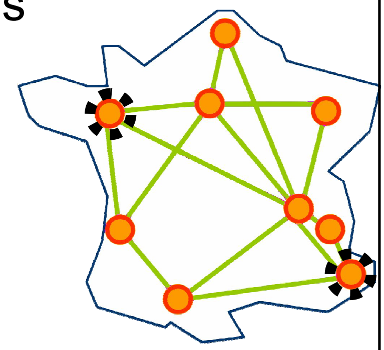



## Usage example: hierarchic broadcast

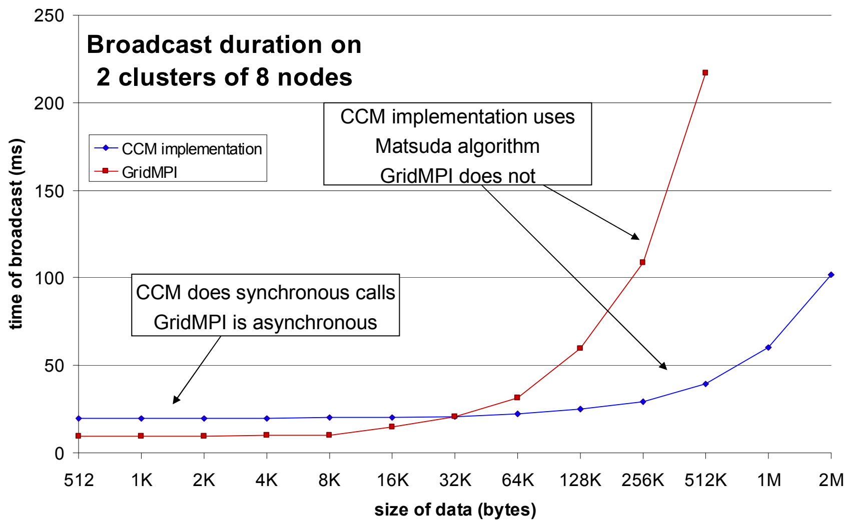


# Preliminary experiments : The underlying resources

- Software
  - Projection on CCM
    - Homemade CCM -> CORBA compiler
    - OmniORB 4.1
  - Handmade ADL transformation
  - Comparison with GridMPI
- Hardware
  - Grid5000, French experimental platform
  - 2 clusters: Rennes & Sophia Antipolis
  - Latences:
    - Inside cluster: 50µs
    - Between clusters: 10ms
  - Bandwith:
    - Node network card: 1Gb/s
    - Backbone: 10Gb/s



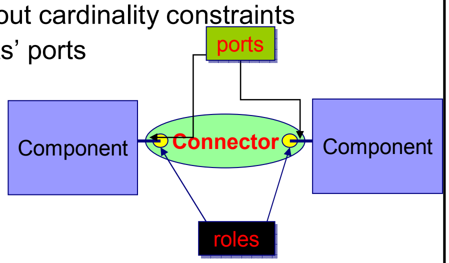
# Preliminary experiments: Performances & analysis



# Connector-based Composition

## Notion of connector

- Introduced in ADL
  - Architecture Description Language
- First class entities
  - List of named roles, with or without cardinality constraints
  - Roles are fulfilled by components' ports
- Instantiated by connection
- Implemented by generator
- Example
  - Connector mpi<role participant>
  - Connector UP<role user<br>role provider>
  - Connector consensus<…>

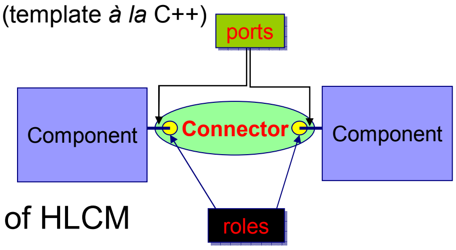


# High Level Component Model

Hierarchy, Genericity,
Template Meta-Programming &
Connectors

# High Level Component Model

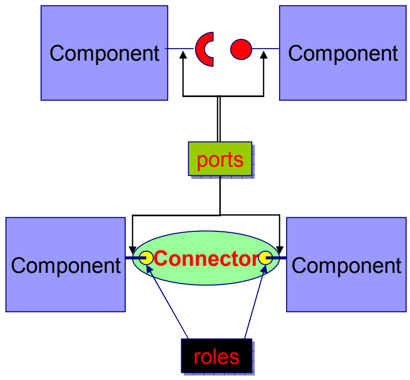
- Major concepts
  - Hierarchical model
  - Generic model
    - Support meta-programming (template *à la* C++)
  - Connector based
    - Primitive and composite
  - Currently static




- HLCMi: an implementation of HLCM
  - Model-transformation based
  - Already implemented connectors
    - Use/Provide, Shared Data, Collective Communications, “MxN” RMI, Irregular Mesh

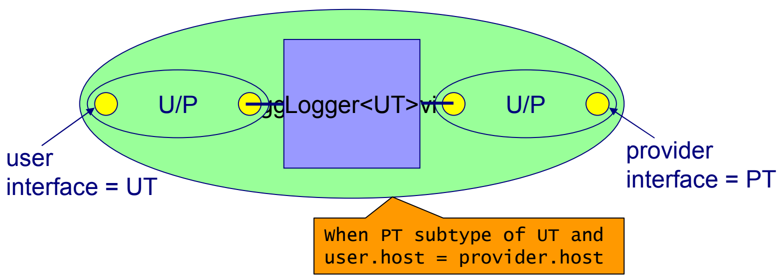
# Connectors

- Without connectors
  - Direct connection between ports
  - Limitation to 1-1 connection
- With connectors
  - Connectors reify connections
    - A name
    - A set of roles
  - Any number of roles
  - Can be 1st class entities
    - Implemented by the user



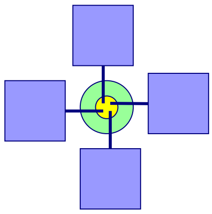

# Connector implementations

- Intrinsically generic
  - Types of roles fulfillment ⇔ parameters for the implementation
- 1 connector ⇔ multiple implementations
  - For distinct placement on hardware resources
- Two possible kinds
  - Primitive connectors
    - Directly supported by the model
  - Composite connectors
    - An assembly

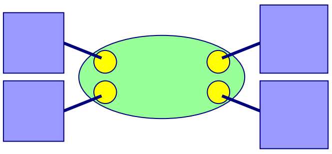


## Example of More Complex Interactions as Connectors

- Shared data between components
  - One single role
  - Multiple fulfillments

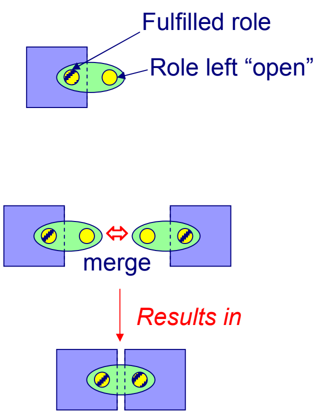


- Parallel method calls
  - Provides the redistribution
  - An example
    - 2x2 Matrix multiplication
    - 2 roles for users (top/bottom)
    - 2 roles for providers (right/left)

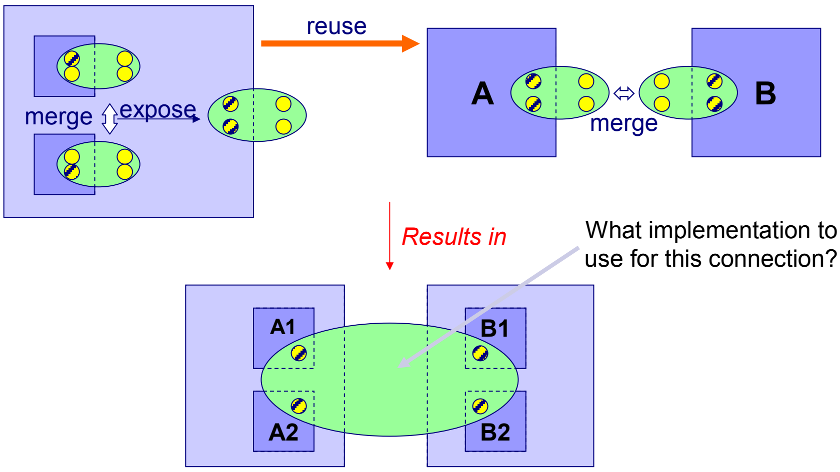


## Notion of Open Connections

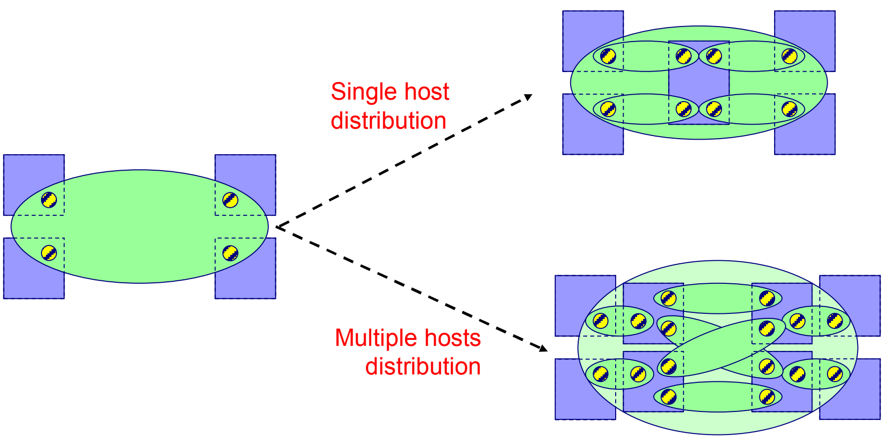
- Components expose “open connections”
  - Some roles fulfilled
  - Some roles left “open”
- Interactions are defined by “merging” connections
  - Union of the role fulfillments
  - A single logical connection



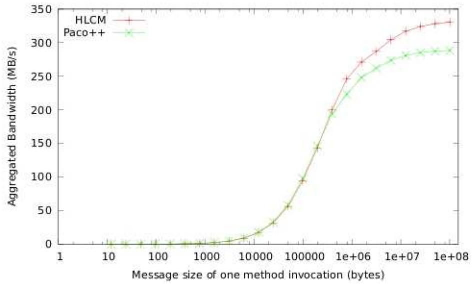
## Expressing Parallel Matrix Multiplication with HLCM




## Connection Implementation: a Planning Choice



# HLCM/CCM/MxN vs PaCO++




# Conclusion

- From « simple » to « complex » composition operators
- Need of models with open composition support
  - Component, connector, hierarchy, genericity, etc.
- Need of models/algorithms to derive actual implementation from an abstract declaration
- Need of models/algorithms to support dynamicity
  - Adaptability : reaction to environment modifications
  - « workflow » : reaction to programmed modifications