Autonomic QoS Control with Behavioral Skeleton

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Outline

- Motivation
  - why adaptive and autonomic management
  - why skeletons
- Behavioural Skeletons in GCM
  - parametric composite component with management
  - functional and non-functional description
  - families of behavioural skeletons
  - distributed overlay of management
- GCM implementation
  - preliminary experiments and performances

Why Autonomic Computing

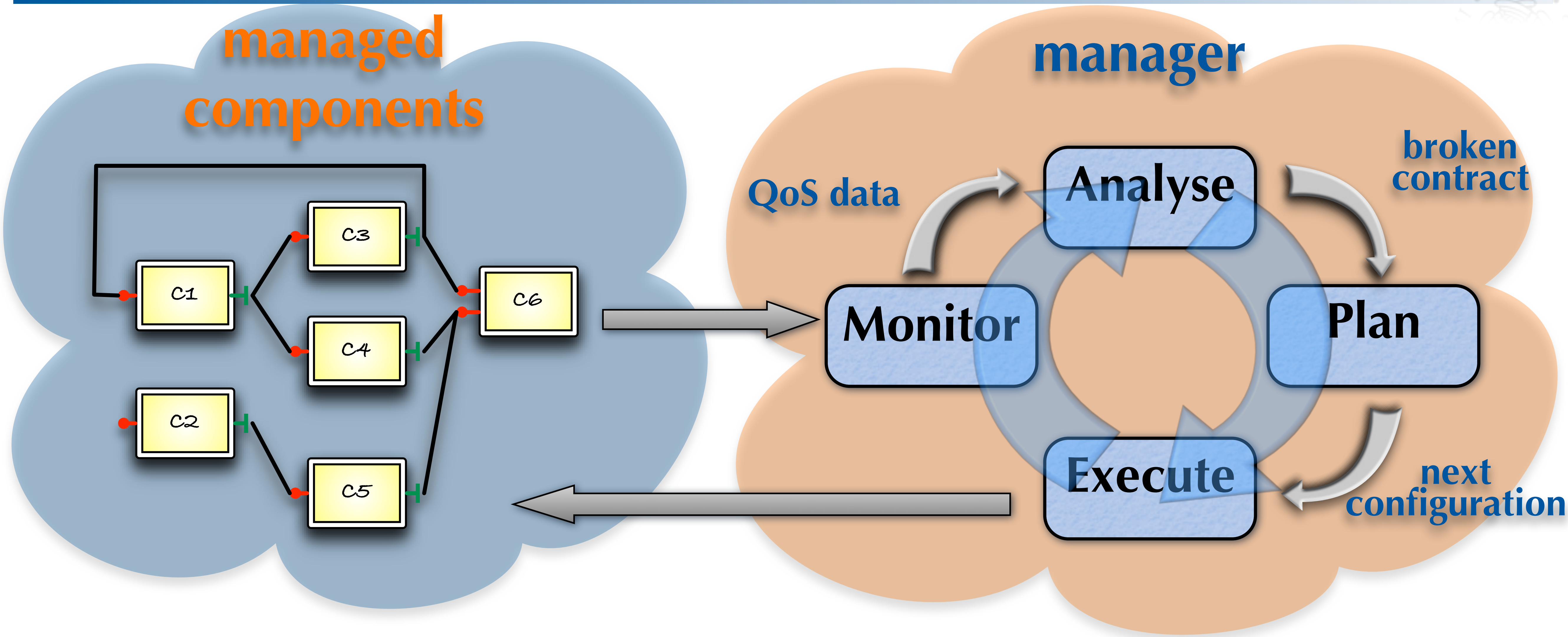
- Scientific and industrial applications **do require** QoS control
  - QoS figures of a distributed application **can hardly be** predicted in static way
    - unstable platforms, irregular applications, dynamically changing requirements ...
  - QoS is often **contractually** specified; infringement of it may be fined
  - industry need to **dynamically size** application QoS to expand market share while keeping design and tuning cost limited
    - design application once in a scalable way, sell it to many clients of different size
  - **QoS is a first-class concept** of the emerging services/utility business
    - cloud, SaaS, PaaS, etc.
    - business/price may greatly depend by QoS, and vice-versa

Why Autonomic Computing (User-defined QoS requirements for Apps)

- Performance
  - the app should sustain ***x*** transactions per second
  - the app should complete each transaction in ***t*** seconds
- Security
  - the link between ***P1*** and ***P2*** should be secured with ***k****-strong* encryption
  - the *DB* service is exposed by platform ***P3***
- Fault-tolerance
  - the parallel server should survive to the failure of *y* platforms

... then consider that **x**, **t**, **P1**, **P2**, **P3**, **k**, **y** can dynamically change as may dynamically change the performance and the state of the running environment ...

Autonomic Computing paradigm



- monitor: collect execution stats: machine load, service time, input/output queues lengths, ...
- analyse: instantiate performance models with monitored data, detect broken contract, in and in the case try to detect the cause of the problem
- plan: select a (predefined or user defined) strategy to re-convey the contract to validity. The strategy is actually a "program" using execute API
- execute: leverage on mechanism to apply the plan

Why skeletons

- Management is difficult
  - application change along time (ADL not enough)
    - how "describe" functional, non-functional features?
  - the low-level programming of component and its management is simply too complex
- Component development is already too difficult
  - how much of your time do you spend in run-time debugging and performance tuning?
- Component reuse is already a problem
  - specialising component yet more with management strategy would just worsen the problem
  - especially if the component should be reverse engineered to be used (its behaviour may change along the run)

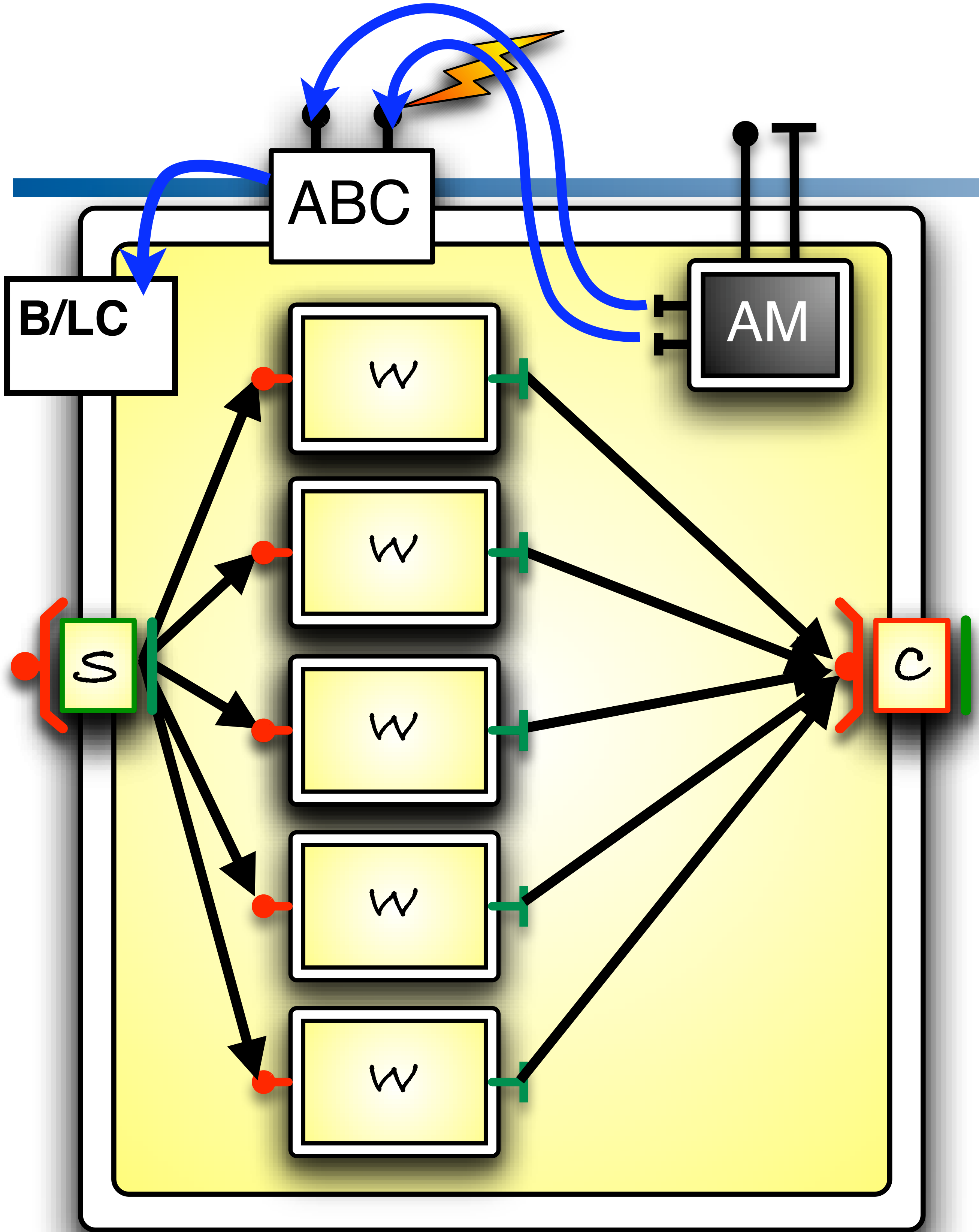
Behavioural Skeletons idea

- Represent an evolution of the algorithmic skeleton concept for component management
  - abstract parametric paradigms of component assembly
  - specialised to solve one or more management goals
    - self-configuration/optimization/healing/protection.
  - carry a semi-formal/formal description and an implementation
    - they are higher-order components (or factories), actually
- Are higher-order components
- Are not exclusive
  - can be composed with non-skeletal assemblies via standard components connectors
    - overcome a classic limitation of skeletal systems

Be-Skeletons families

- Functional Replication
  - **Farm/parameter sweep (self-optimization)**
  - **Stateless Data-Parallel (self-configuring map-reduce)**
    - e.g. one server port (n of server ports is a parameter)
  - **Stateful Data-Parallel (self-configuring stateful map-reduce)**
    - e.g. two server ports: set_state and execute
  - Active/Passive Replication (self-healing)
- Proxy
  - Pipeline (coupled self-protecting proxies)
- Wrappers

Functional replication



ABC = Autonomic Behaviour Controller (implements mechanisms)
AM = Autonomic Manager (implements policies)
B/LC = Binding + Lifecycle Controller

1. **Choose a schema**
   e.g. functional replication
   ABC API is chosen accordingly

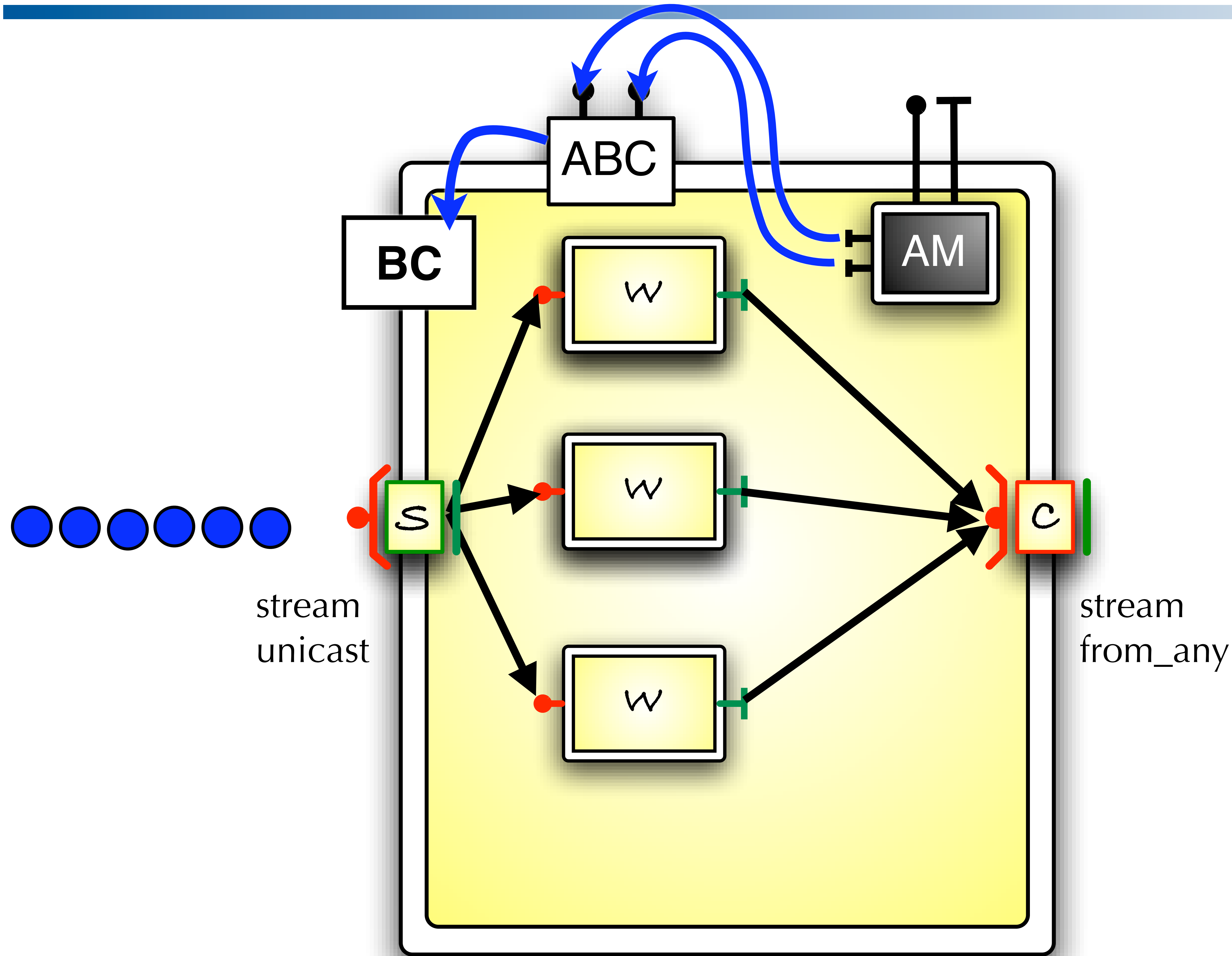
2. **Choose an inner component**
   compliant to BeSke constraints

3. **Choose behaviour of ports**
   e.g. unicast/from_any, scatter/gather

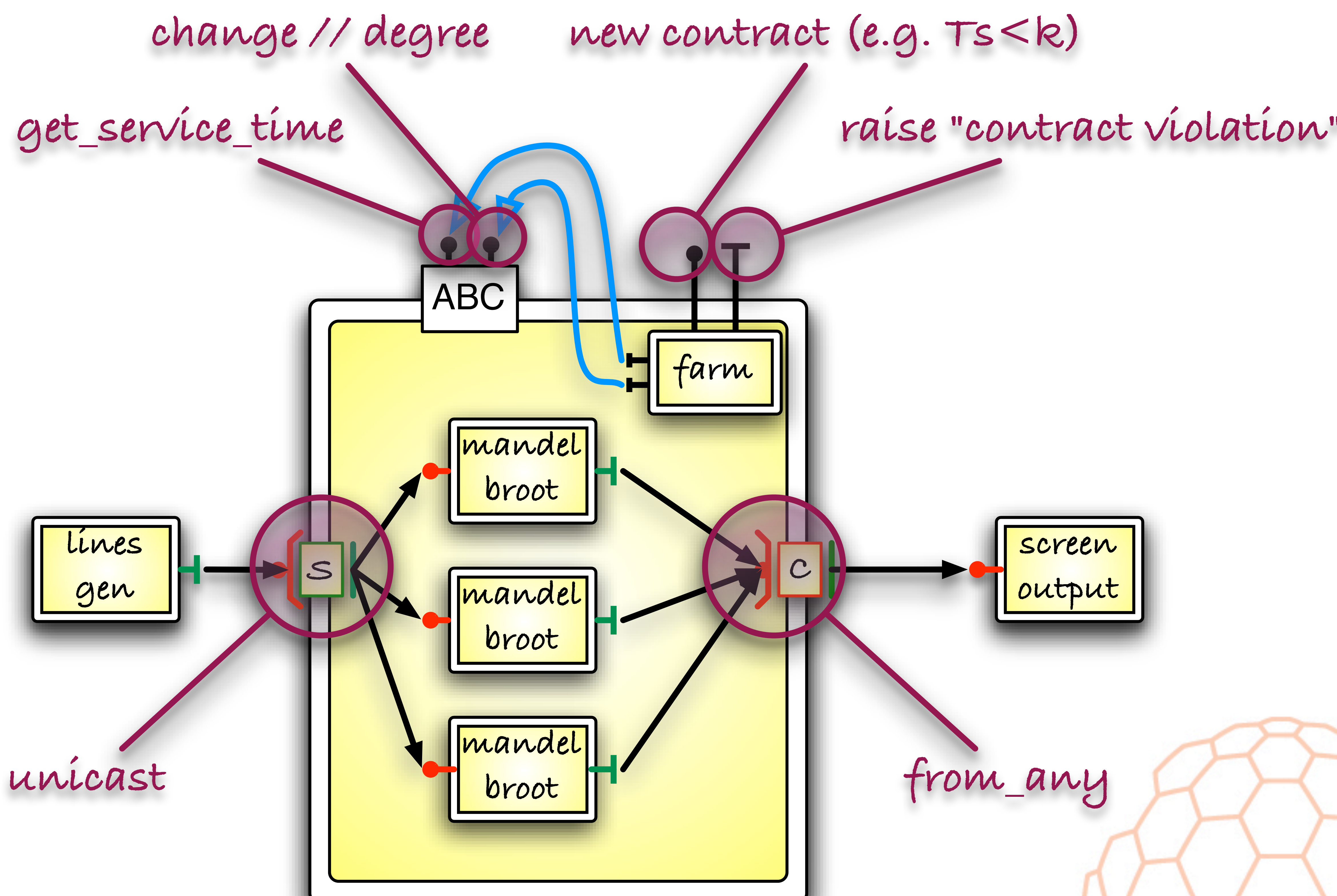
4. **Run your application**
   then trigger adaptations

5. **Automatise the process**
   with a Manager

Farm BeSke



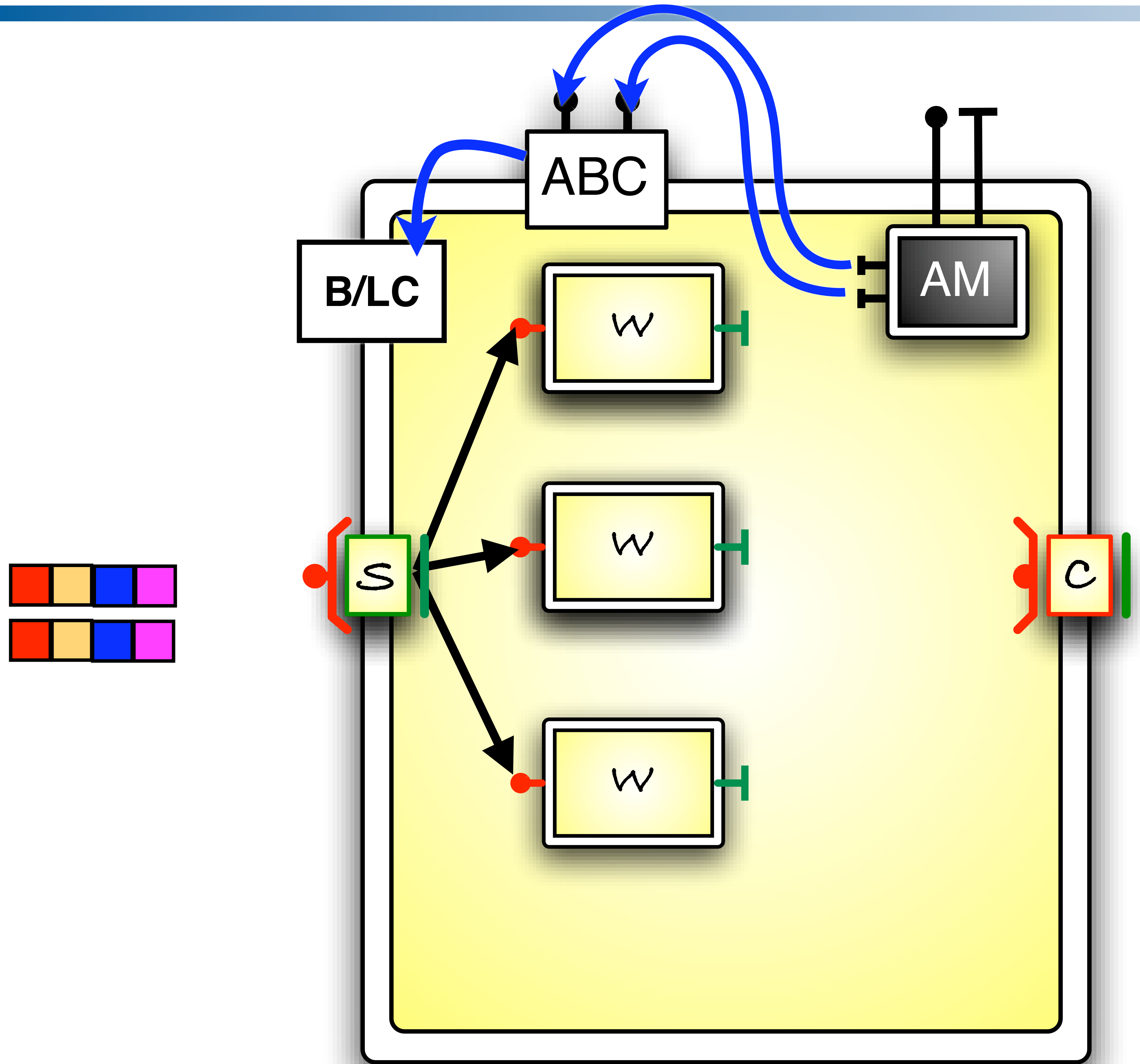
Farm BeSke (e.g. Mandelbrot)



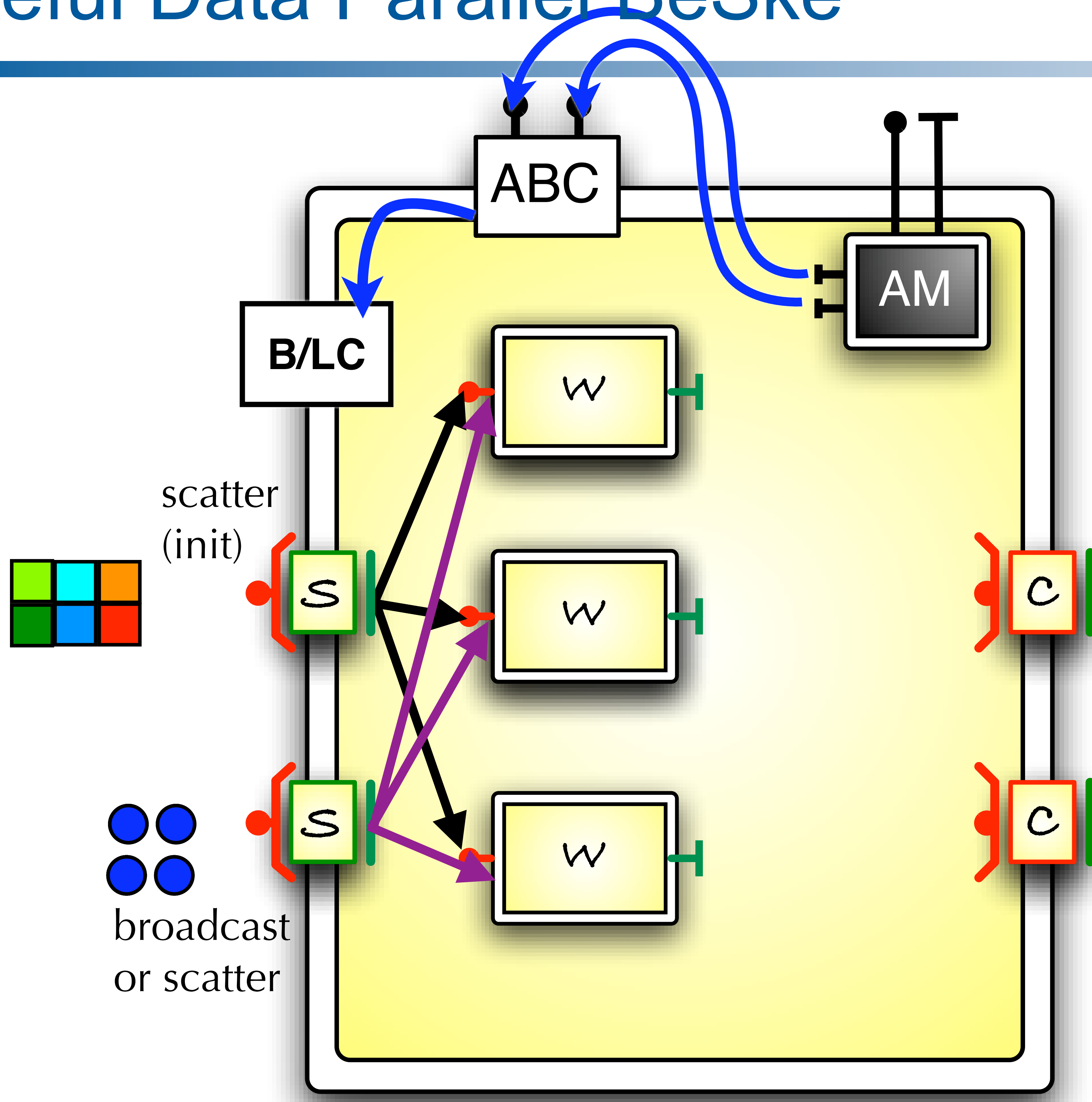
Farm BeSke contract (e.g. Mandelbrot)

```
rule "CheckInterArrivalRate"
  salience 5
  when
     $arrivalBean : ArrivalRateBean( value <  ManagersConstants.LOW_PERF_LEVEL)
  then
     $arrivalBean.setData(ManagersConstants.notEnoughTasks_VIOL);
     $arrivalBean.fireOperation(ManagerOperation.RAISE_VIOLATION);
     System.out.println( "InterArrivalTime not enough - Raising a violation");
end
rule "CheckRateLow"
  when
     $departureBean : DepartureRateBean( value < ManagersConstants.LOW_PERF_LEVEL )
     $parDegree: NumWorkerBean(value <= ManagersConstants.MAX_NUM_WORKERS)
  then
     $departureBean.fireOperation(ManagerOperation.ADD_WORKER);
     $departureBean.fireOperation(ManagerOperation.BALANCE_LOAD);
     System.out.println( "Adding "+ManagersConstants.ADD_WORKERS+ "workers");
end
rule "CheckRateHigh"
  when
     $departureBean : DepartureRateBean( value > ManagersConstants.HIGH_PERF_LEVEL )
     $parDegree: NumWorkerBean(value > ManagersConstants.MIN_NUM_WORKERS)
  then
     $departureBean.fireOperation(ManagerOperation.DEL_WORKER);
     $departureBean.fireOperation(ManagerOperation.BALANCE_LOAD);
     System.out.println( "Rate "+$departureBean.getValue()+" (Removing 1 workers)");
end
```

Stateless Data Parallel BeSke



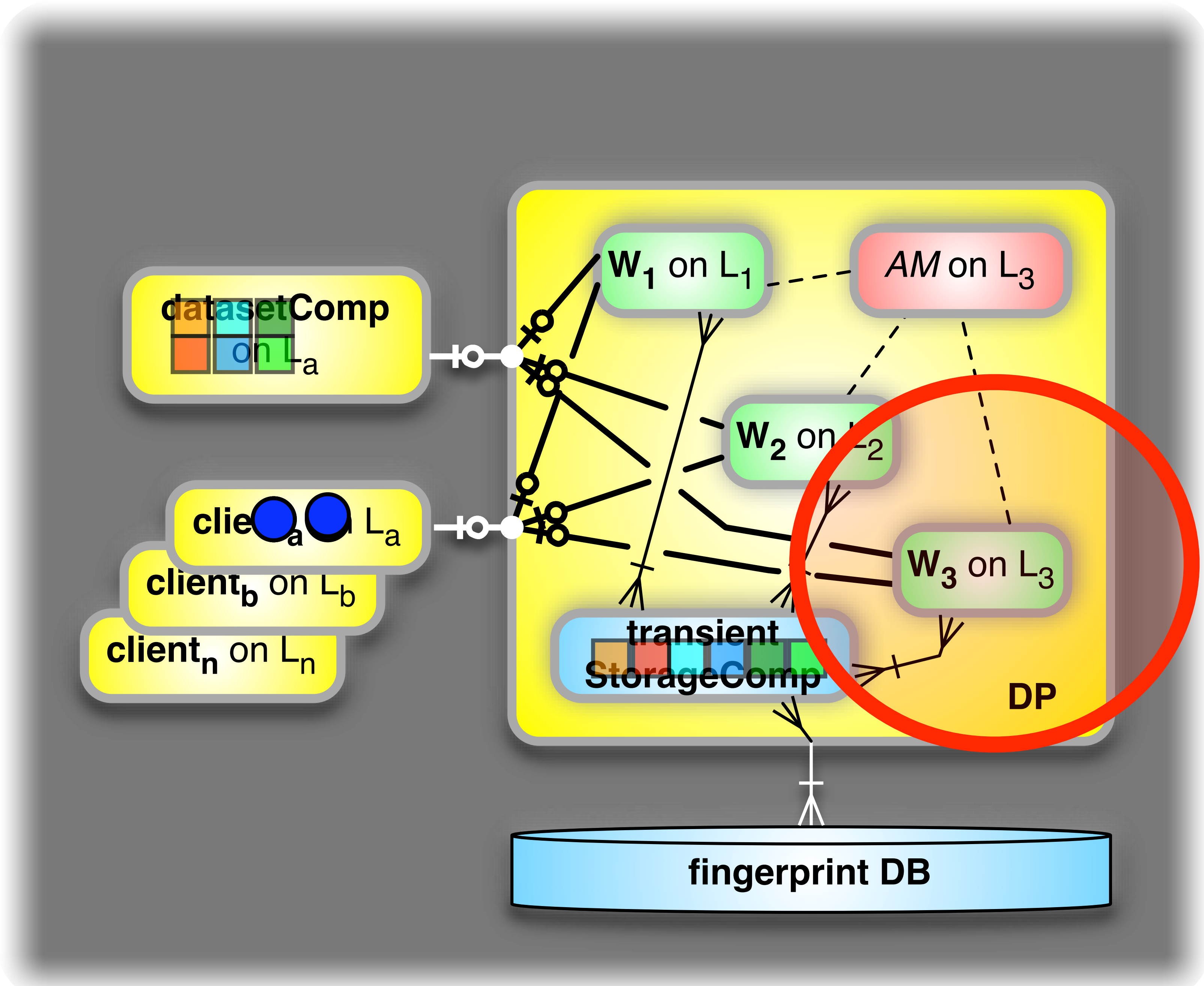
Stateful Data Parallel BeSke



Notes

- any number of server and client ports (either RPC or stream, in theory)
- the model cannot (structurally) enforce init happens before requests on other ports
- port reconfiguration and data redistribution should be atomic (no tasks should be distributed in the middle.
- data can be reconfigured in a distributed way (provided a suitable data port abstraction is defined)

Stateful Data Parallel BeSke (e.g. IBM mockup)



7) *AM reacts (e.g. increasing // degree):*
   copying W1;
   bindings (external, AM, StorageComp) should be preserved;
   DB partitions (Wx state) should be redistributed via StorageComp

6) *AM may sense a changed answer time (e.g. increased), due to a dataset size/kind and/or platform status change*

5) ***repeat 2-3-4 ... 2-3-4 ...***

4) *clients get the answer OR(W1,W2,...)*

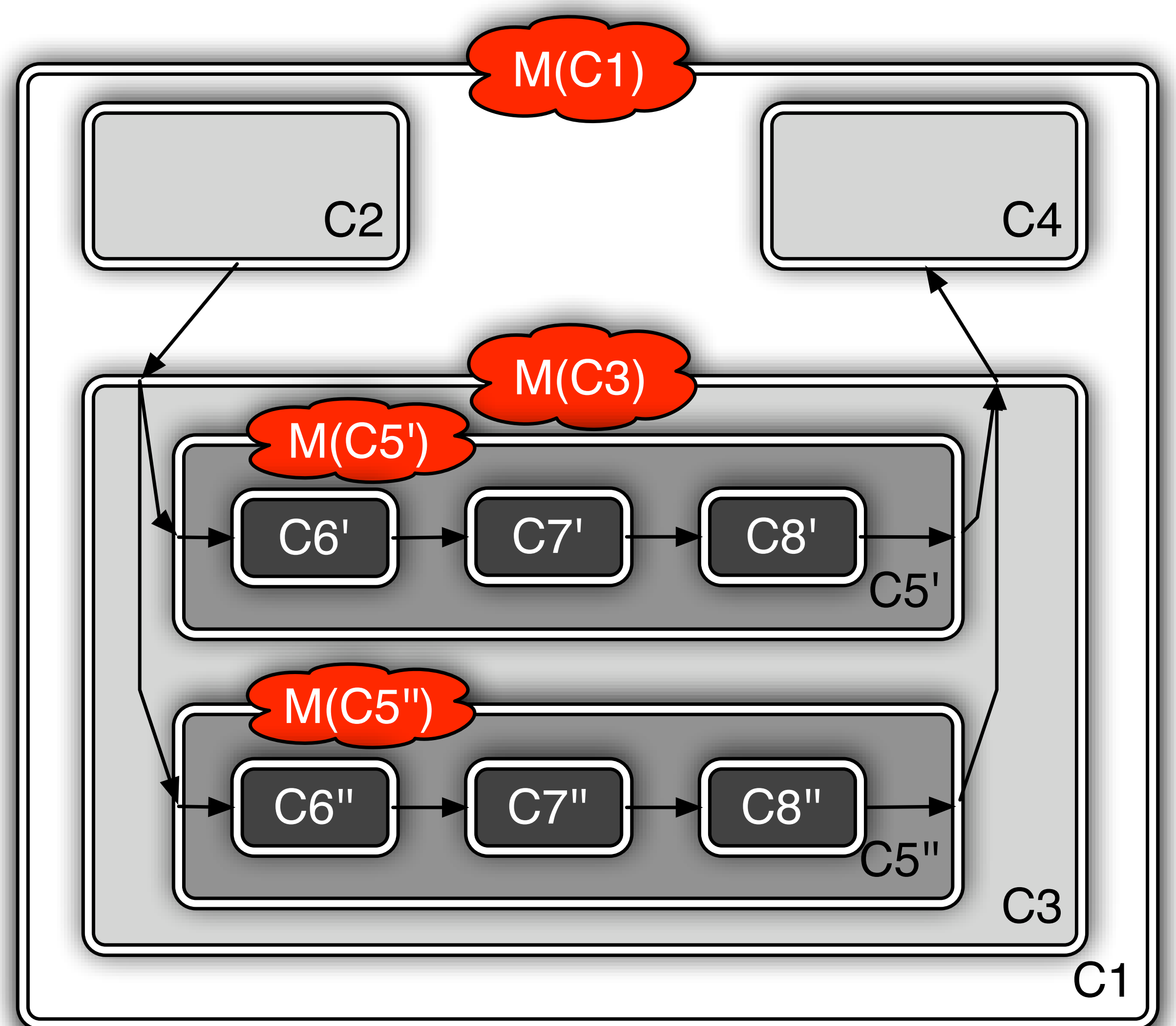
3) *each worker matches the fingerprint against its DB partition*

2) *clients broadcast requests to all workers*

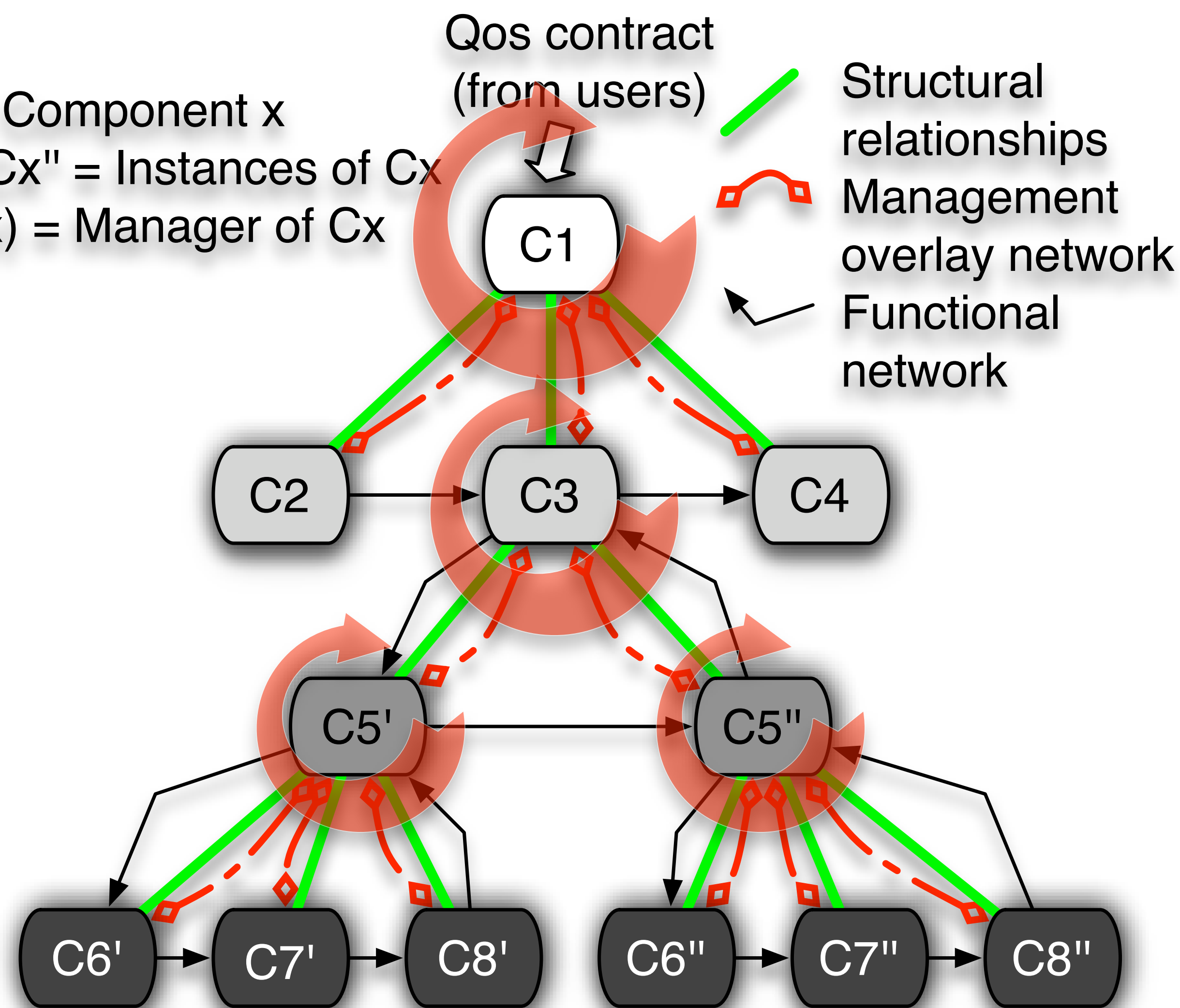
1) *references to DB slices are scattered*

RPC or dataflow bindings — management bindings — data sharing port bindings

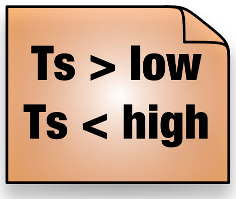
Overlay of Management



Cx = Component x
Cx', Cx'' = Instances of Cx
M(Cx) = Manager of Cx

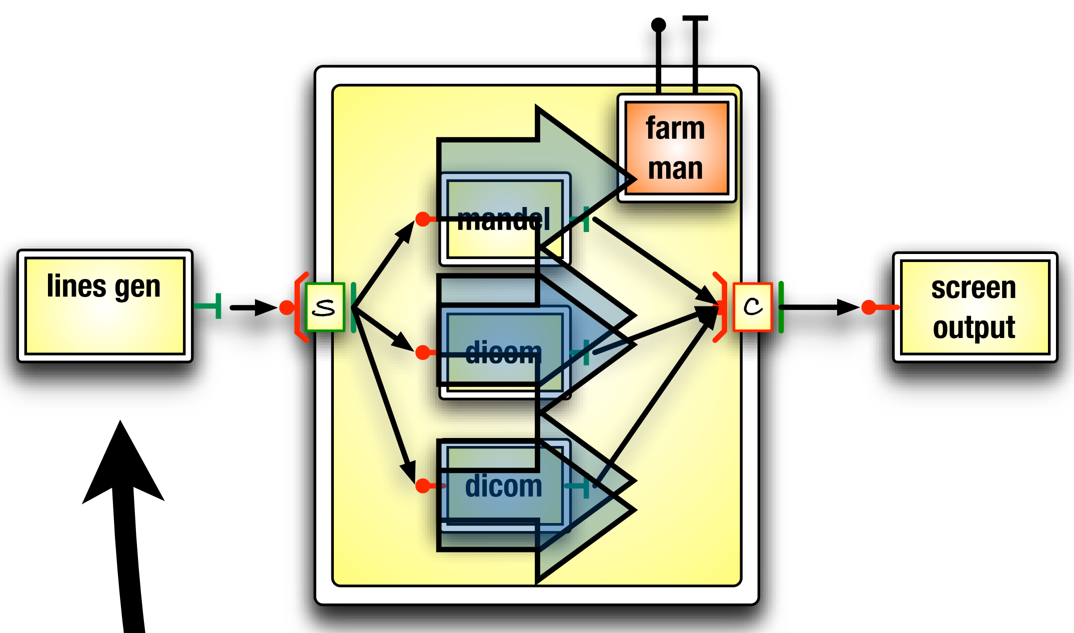


Overlay of management: motivation



1) push a QoS contract, e.g. *low < Ts < high*

2) run the application



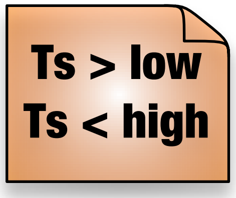
3) suppose *low > Ts*

4) farm man react adding one or more workers to increase farm **potential** power

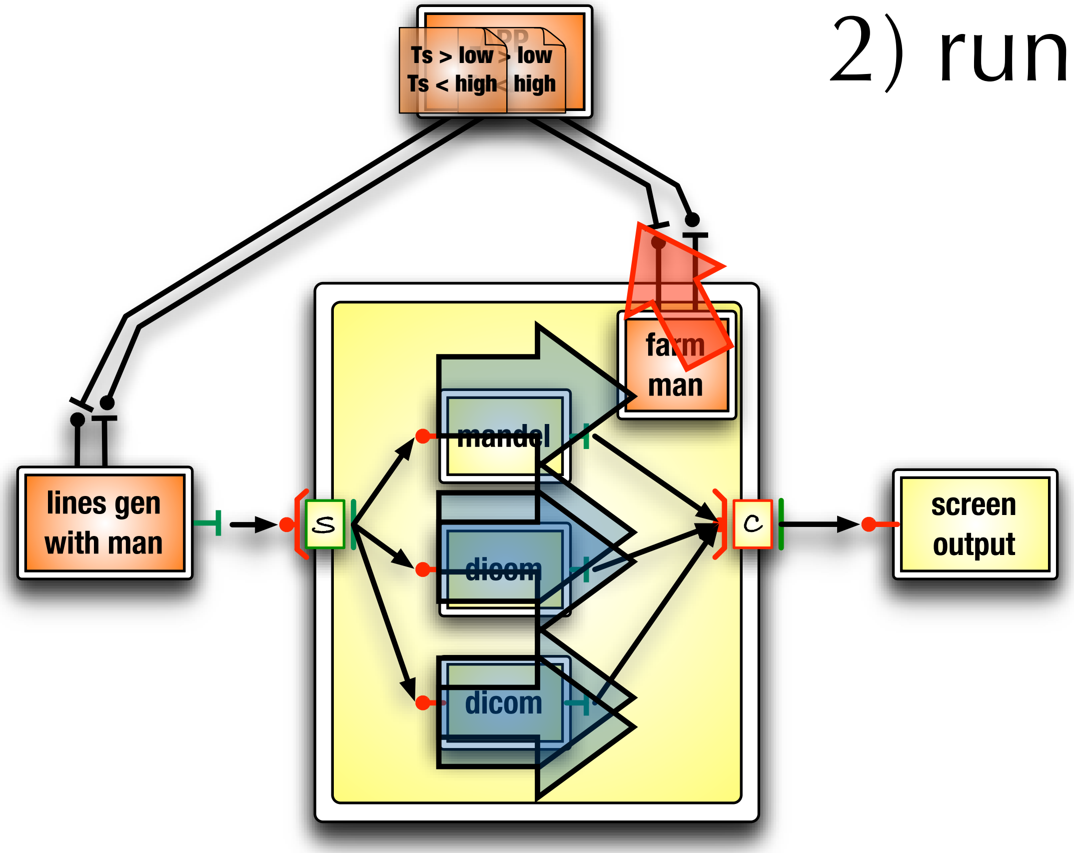
5) that is ok in many case, not always ...

6) if the farm is not receiving enough tasks the **reaction is simply wrong**

Overlay of management: example



1) push a QoS contract, e.g. *low < Ts < high*



2) run the application

3) suppose *low > Ts*

4) farm man react as follows:
if *Tarrival > low* **then** *add_w*
else *raiseup(not_enough_tasks)*

5) man. now involve a global decision

6) as an example APP manager manager may ask lines gen manager to increase the task rate

Two tiers management demo (Mandelbrot)

Conclusions

- Behavioural Skeletons in GCM
  - templates with built-in management for the App designer
  - methodology for the skeleton designer
    - management can be changed/refined
    - just prove your own management is correct against skeleton functional description
  - can be freely mixed with standard GCM components
    - because once instanced, they are standard
- Overlay of management
  - relying on JBoss drools for manager policy
  - now supporting distributed overlay of management
    - e.g. hierarchical management