Branch-and-Bound with Peer-to-Peer for Large-Scale Grids

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The Big Picture

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- Objective

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Solving combinatorial optimization problems with Grids

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- Approach

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Parallel Branch-and-Bound and Peer-to-Peer

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1. Branch-and-Bound framework for Grids

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  1. Branch-and-Bound framework for Grids

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1. Branch-and-Bound framework for Grids

2. Peer-to-Peer Infrastructure for Grids

3. Large-scale experiments

Agenda

- Context, Problem, and Related Work
- Contributions
  - Branch-and-Bound Framework for Grids
  - Desktop Grid with Peer-to-Peer
  - Mixing Desktops & Clusters
- Perspectives & Conclusion

Context

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  - well adapted for solving COPs
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- Grid Computing
  - large pool of resources
  - large-scale environment

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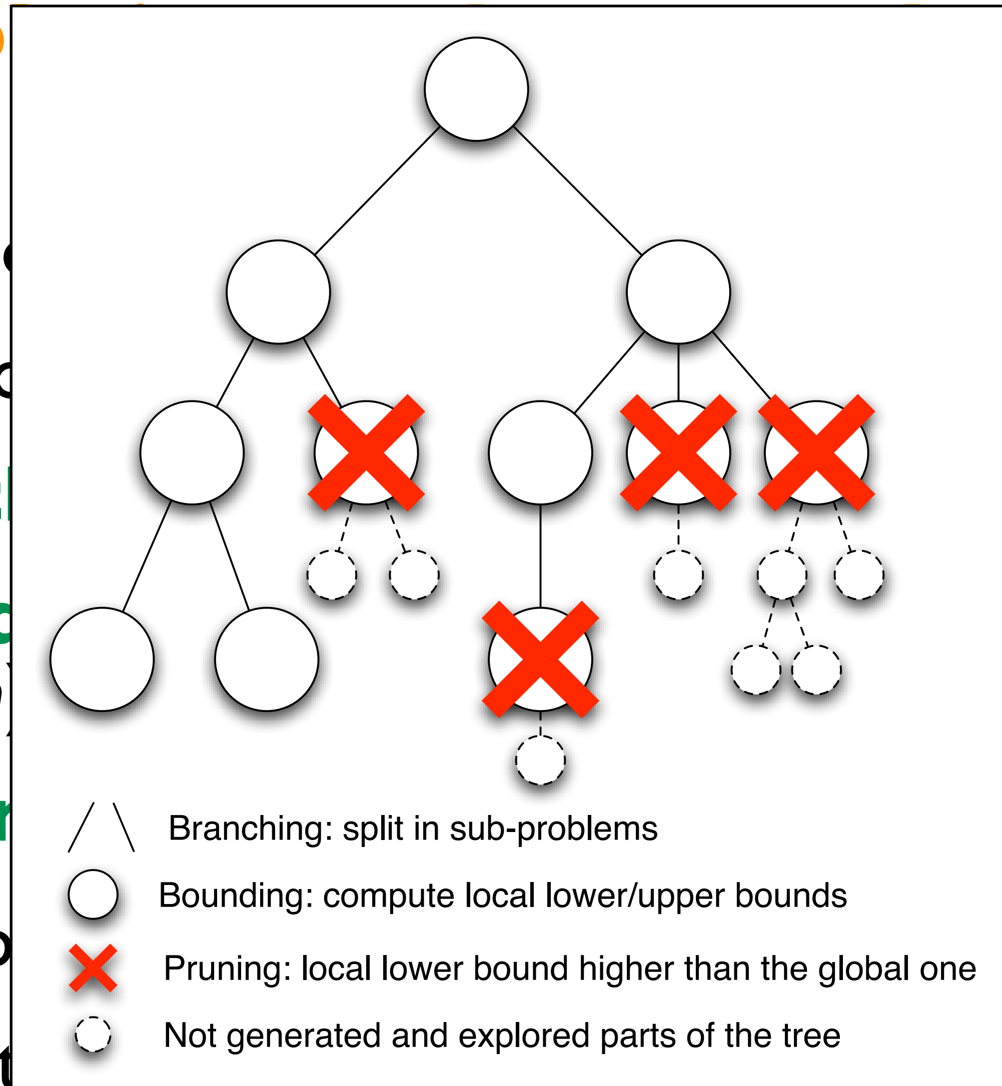

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Proposition: Parallel BnB + Grid

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Related difficulties are known

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BnB Related Work

Frameworks	**Algorithms**	**Parallelization**	**Machines**
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BOB++	Low-level, Basic B&B	SPMD	Cluster/MPI
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Metacomputing MW	Basic B&B	master-worker	Grids/Condor
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Most Previous work are based on SPMD and target clusters

better for sharing bounds

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  - multiple administrative domains, heterogeneity, high performance, programming model, *etc.*

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Parallel BnB related work: SPMD

Grids are not adapted for SPMD (heterogeneity, latency, *etc.*)

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Use Branch-and-Bound on Grids for solving COPs

Efficient communications with Grids is difficult
Problem with sharing bounds

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- Skeletons with farm or divide-and-conquer
- Satin for divide-and-conquer

BnB on Grids: Problems and Solutions

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Latency	

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Objective: hide Grid difficulties to users
Especially communication problems

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- Worker:
  - computes tasks

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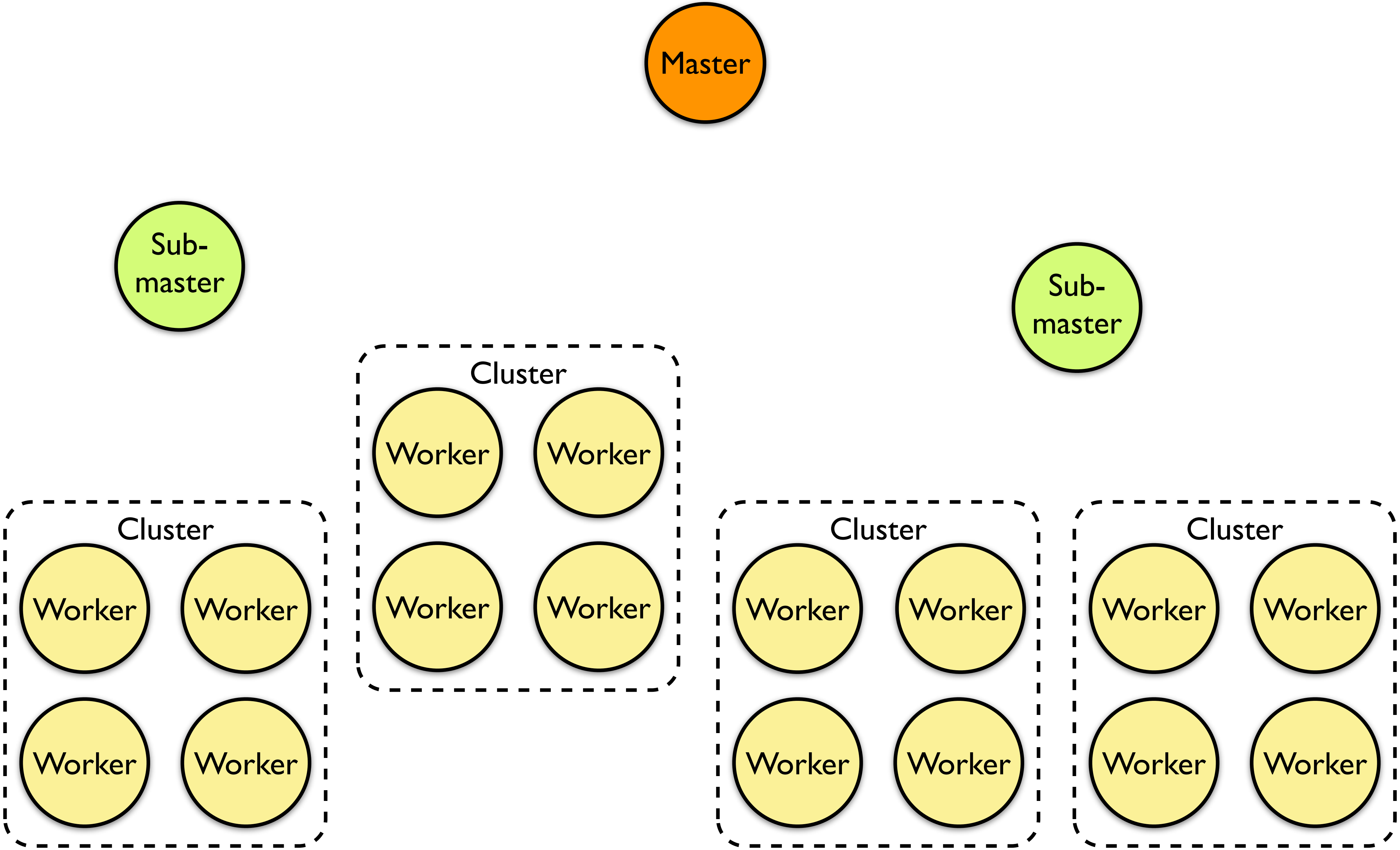

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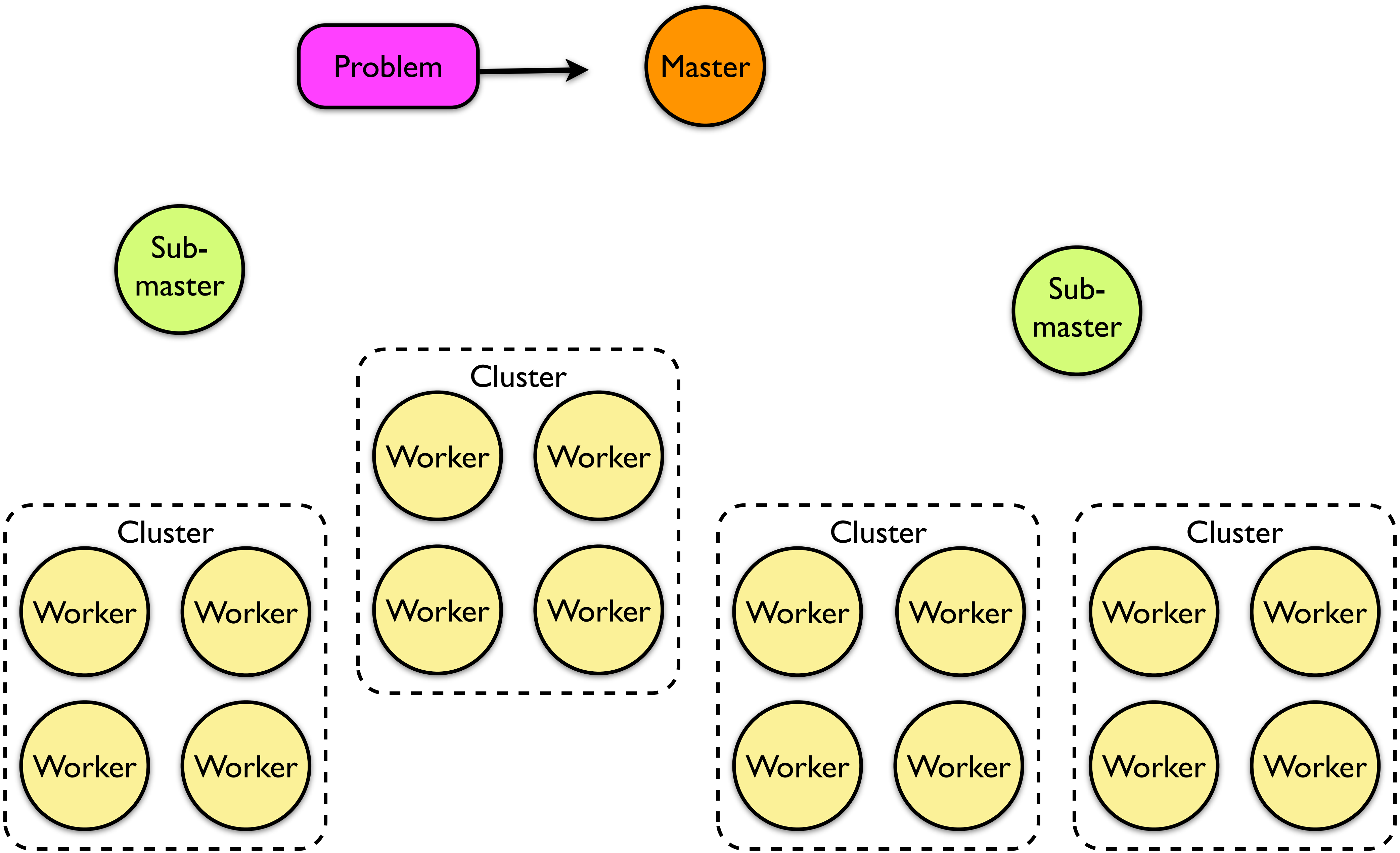

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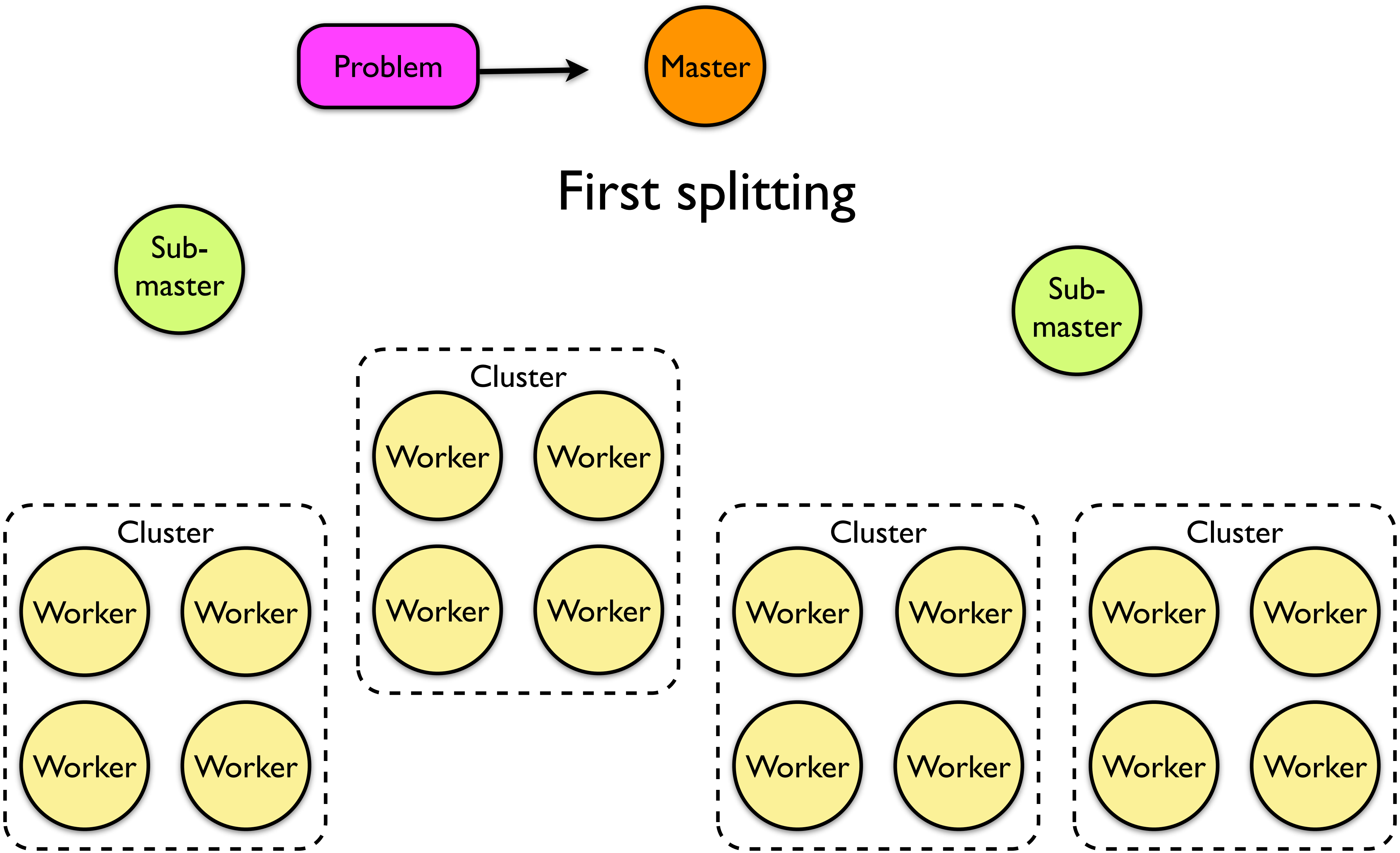

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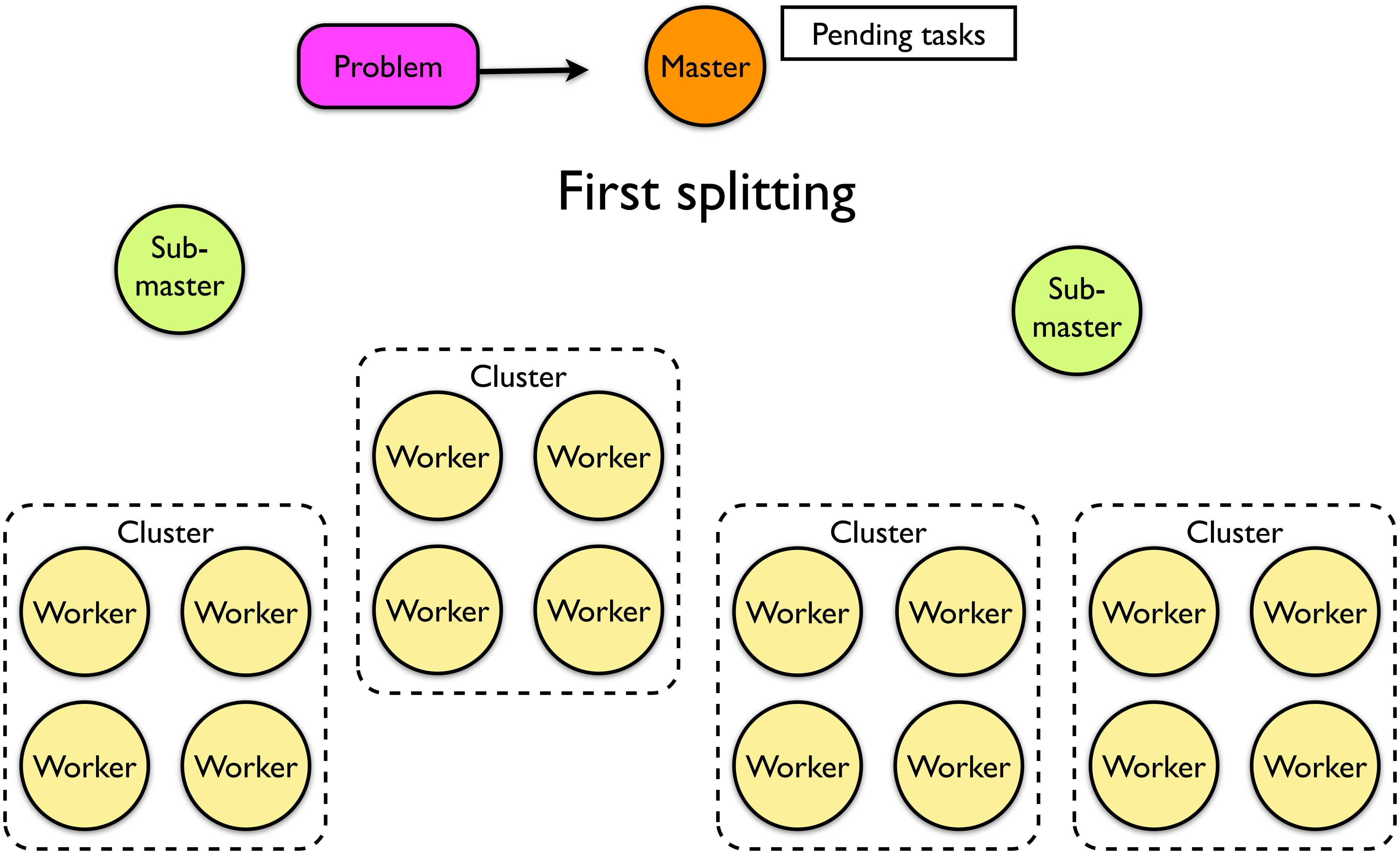

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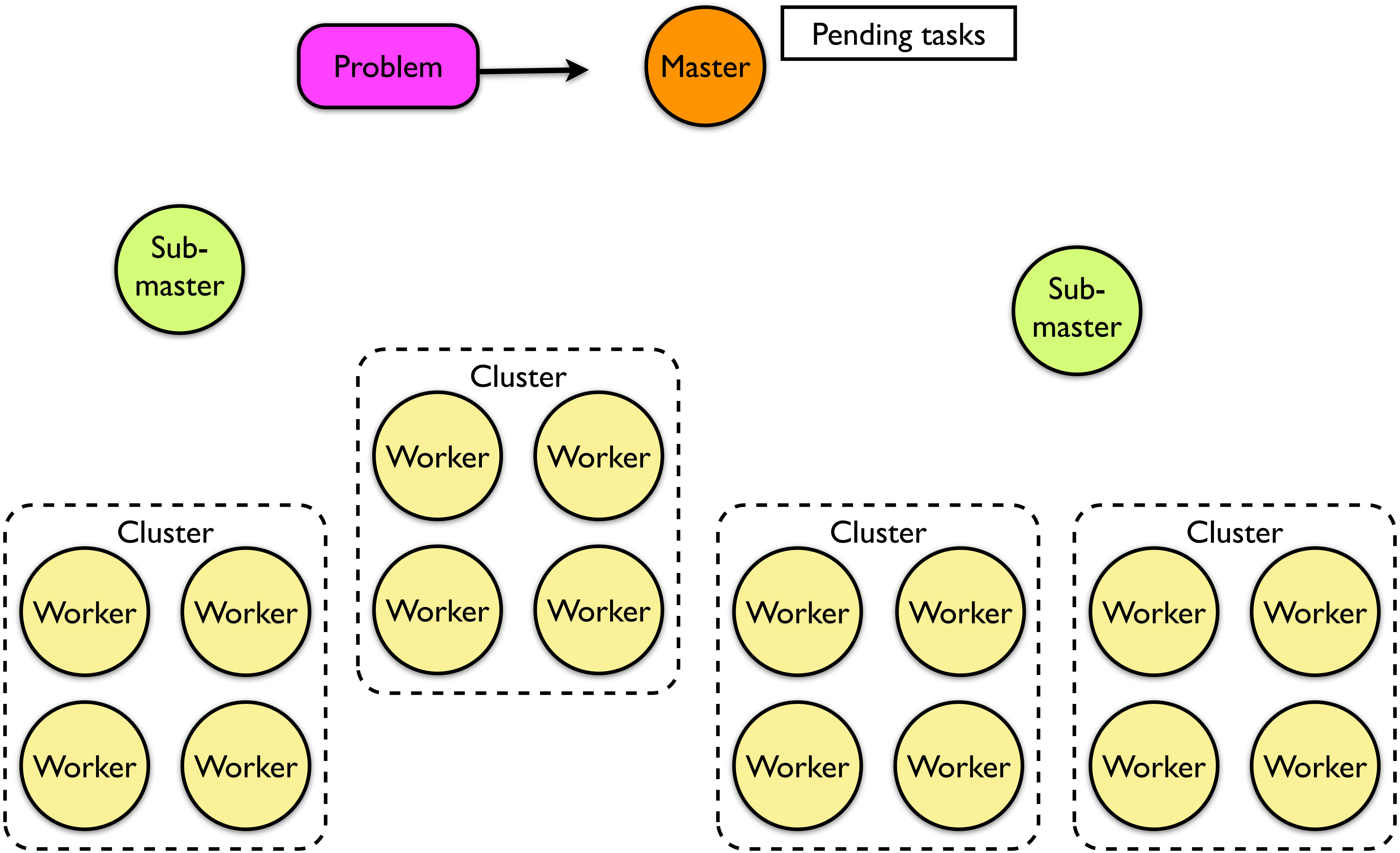

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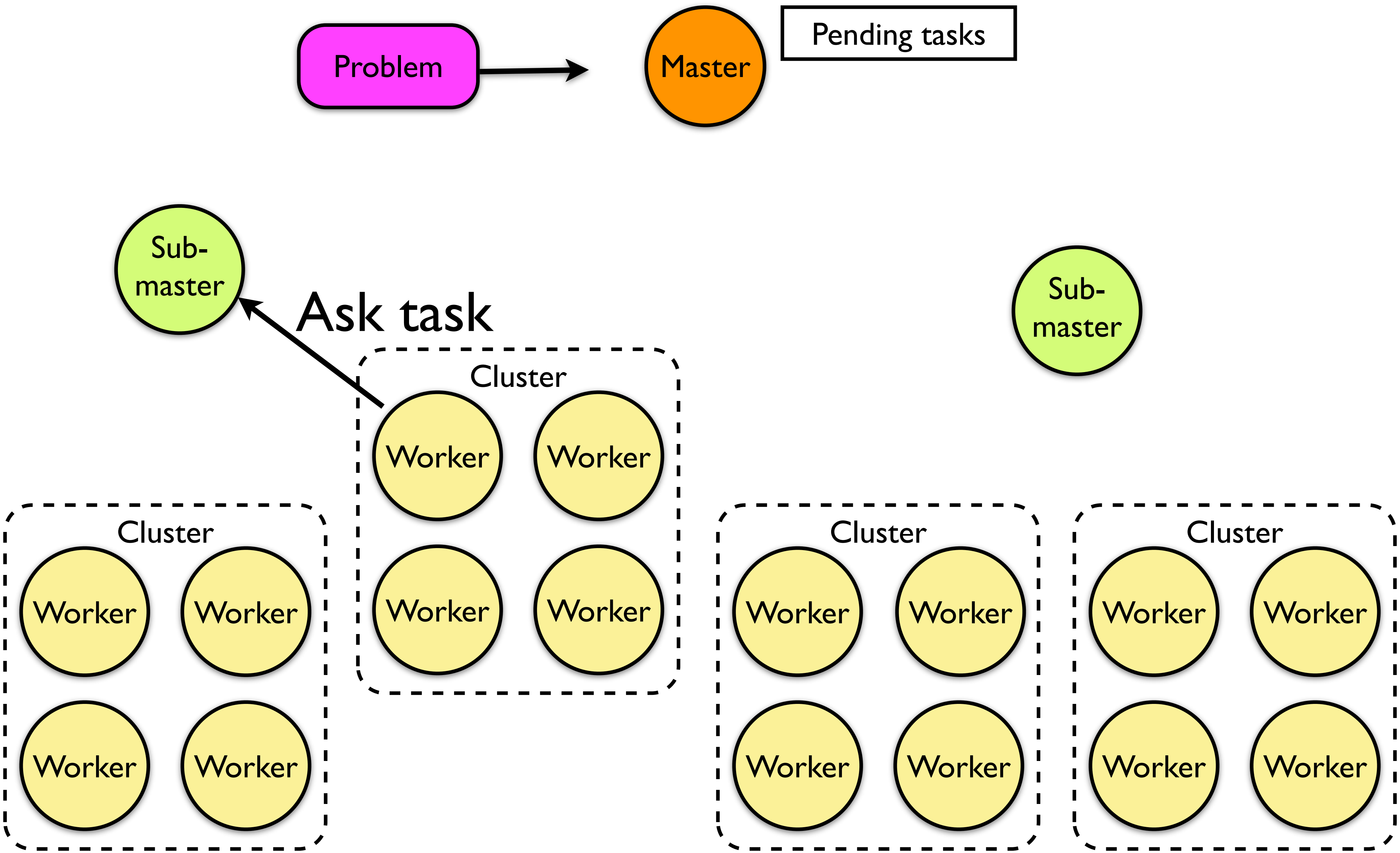

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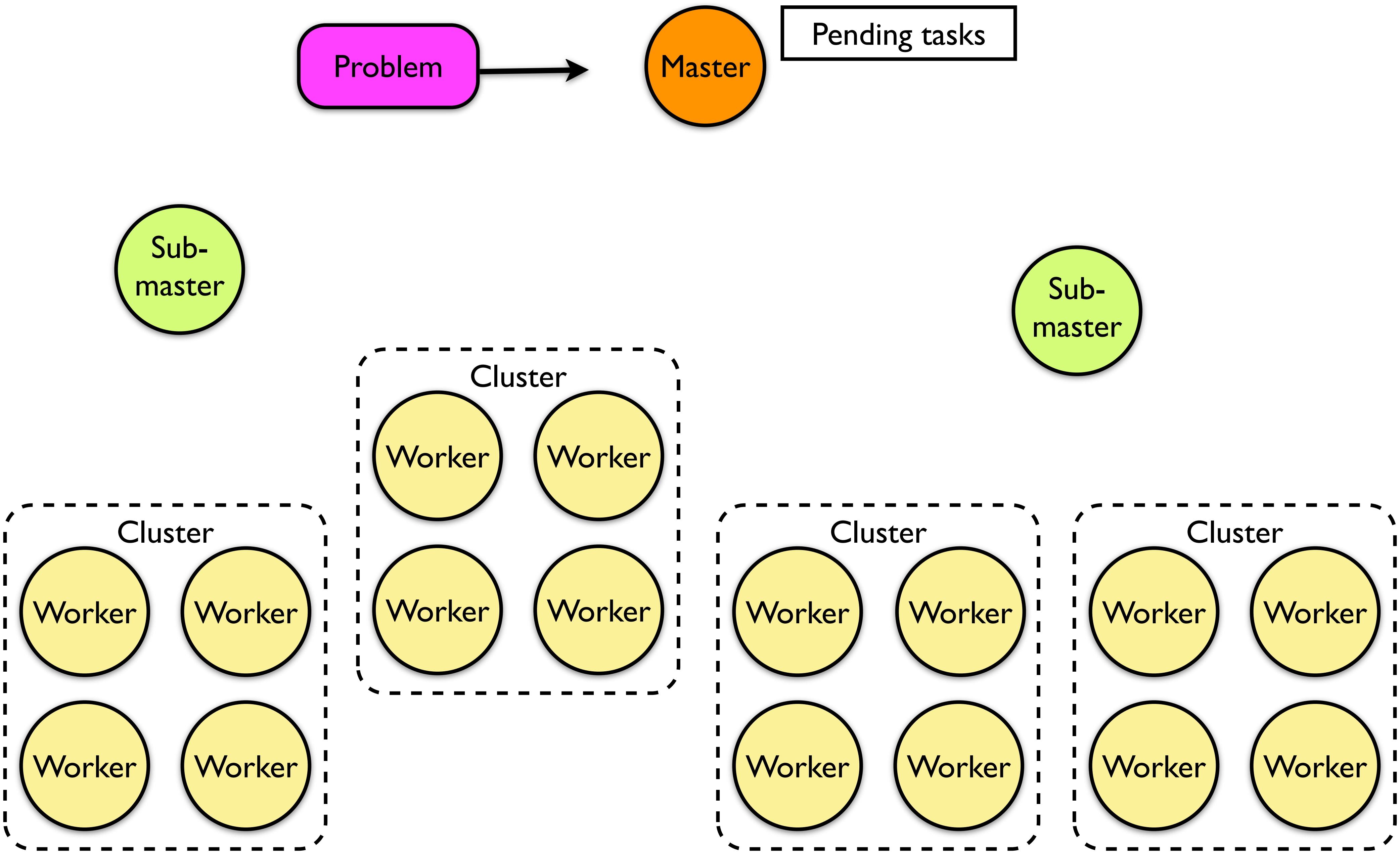

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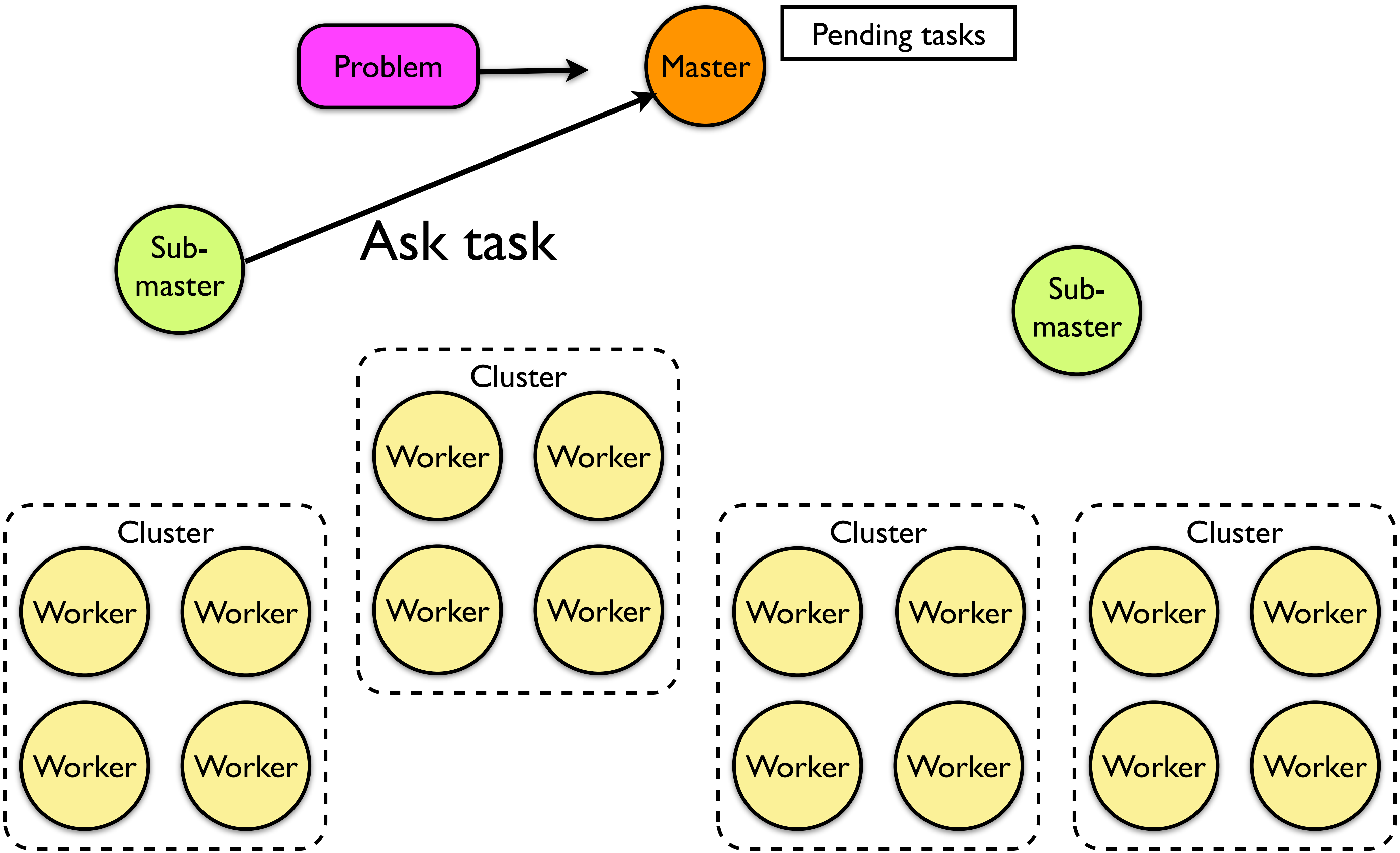

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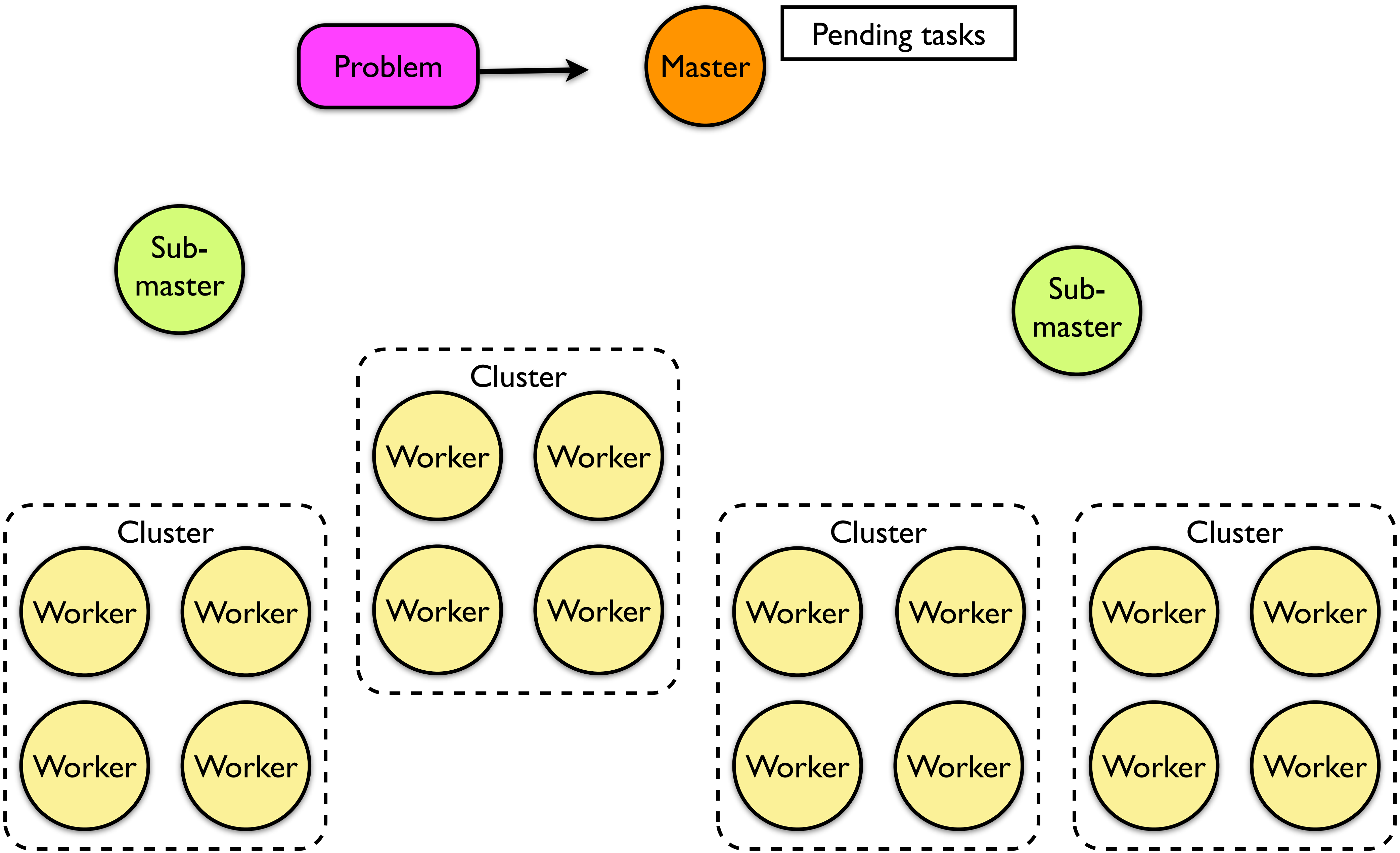

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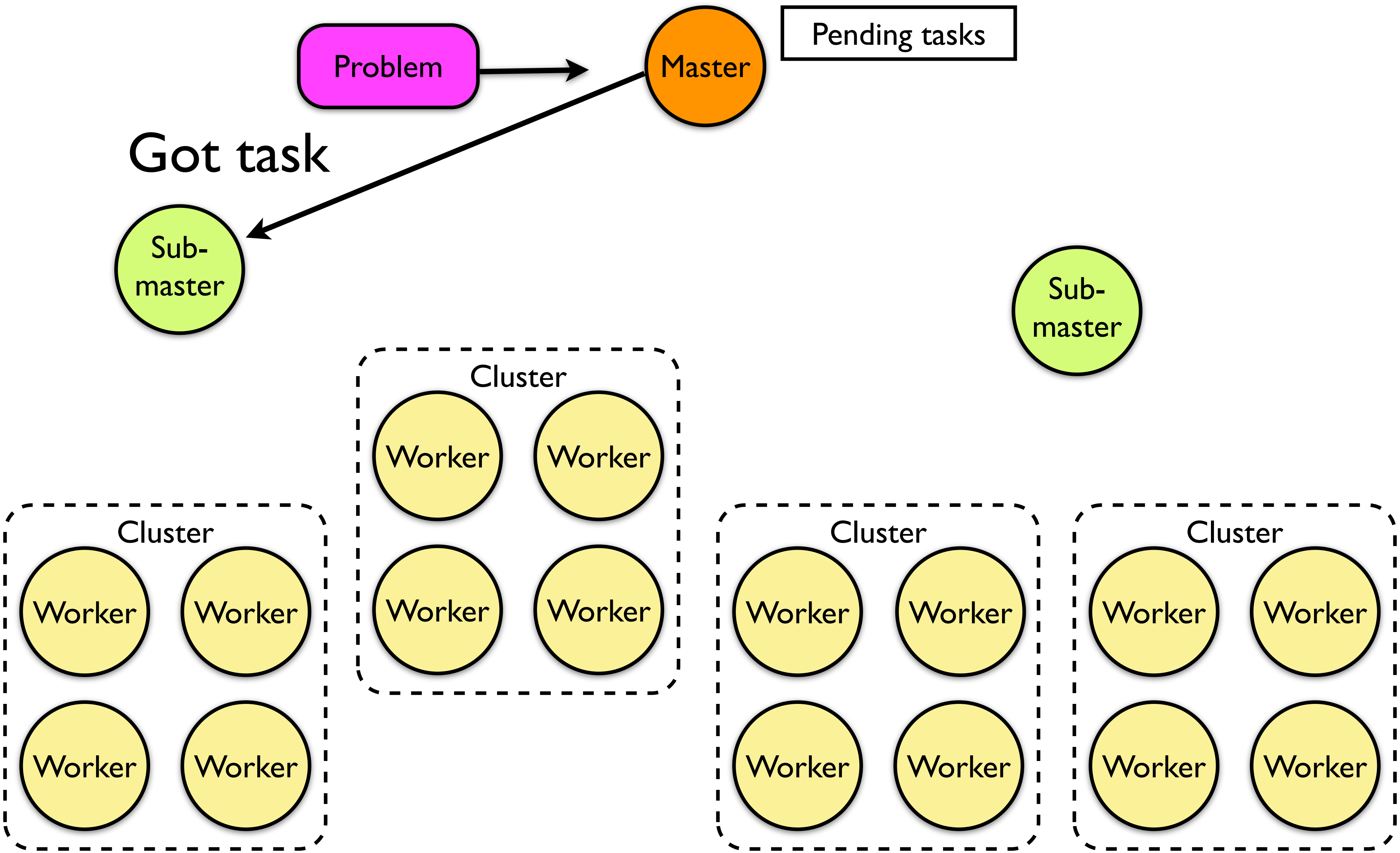

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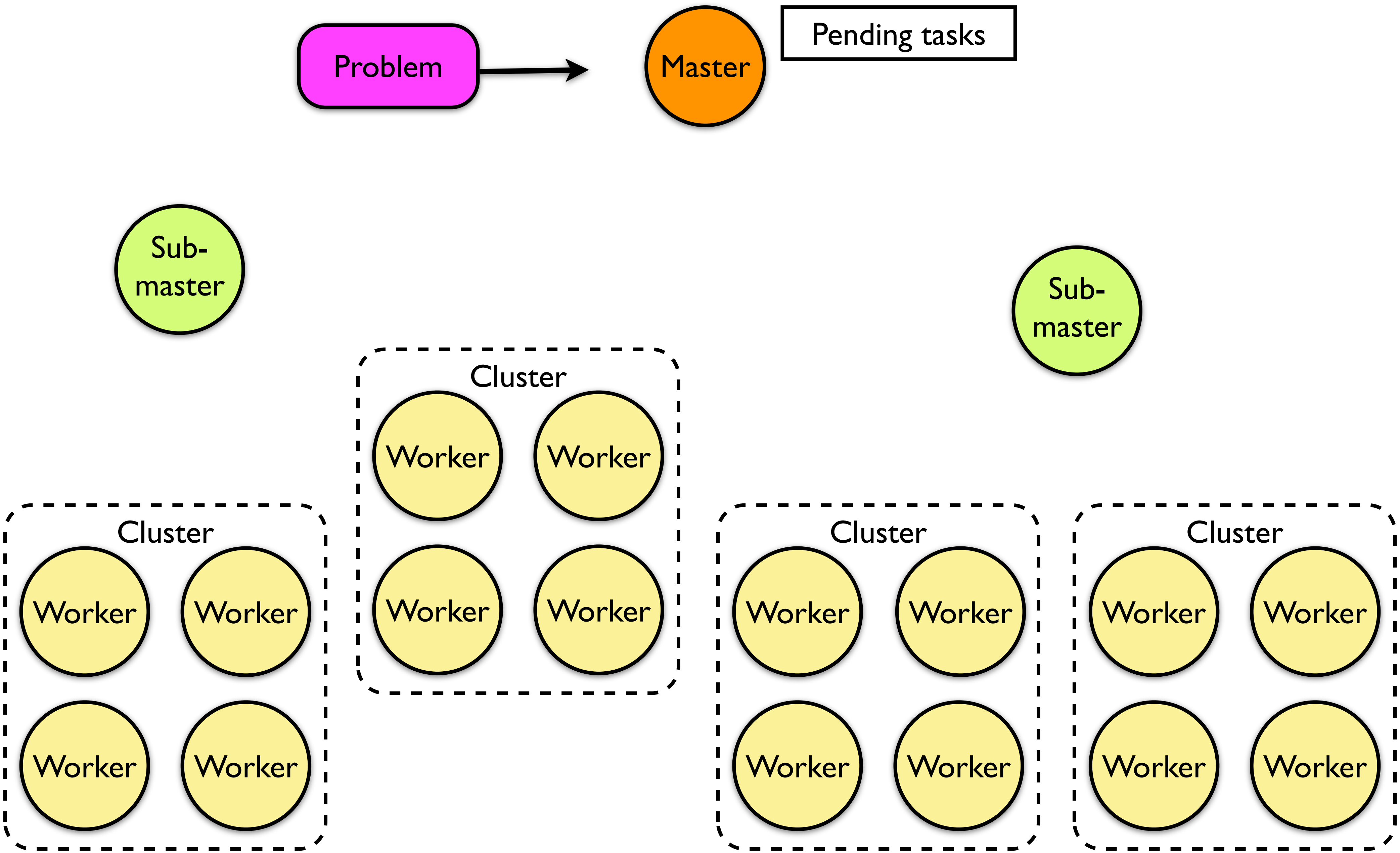

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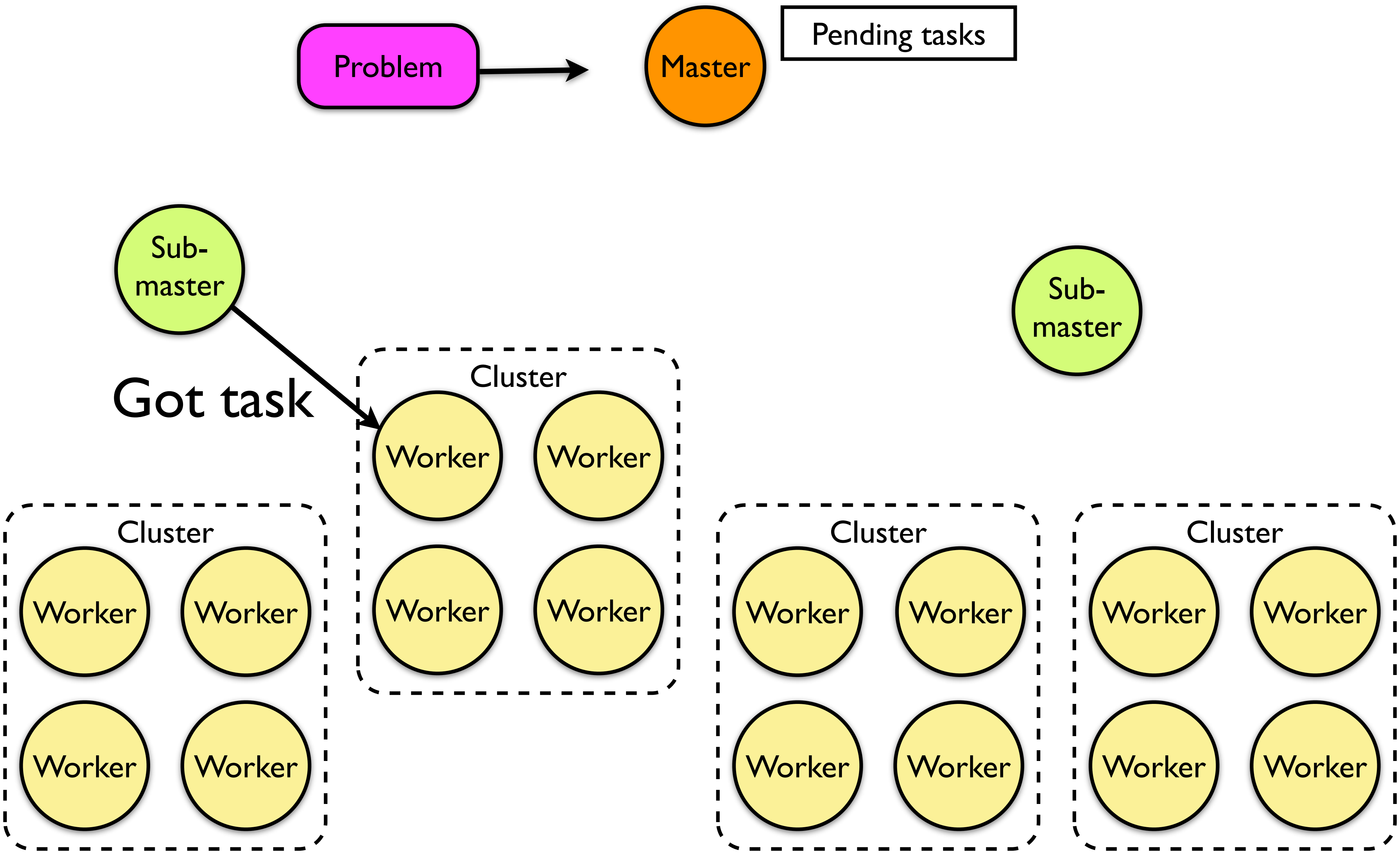

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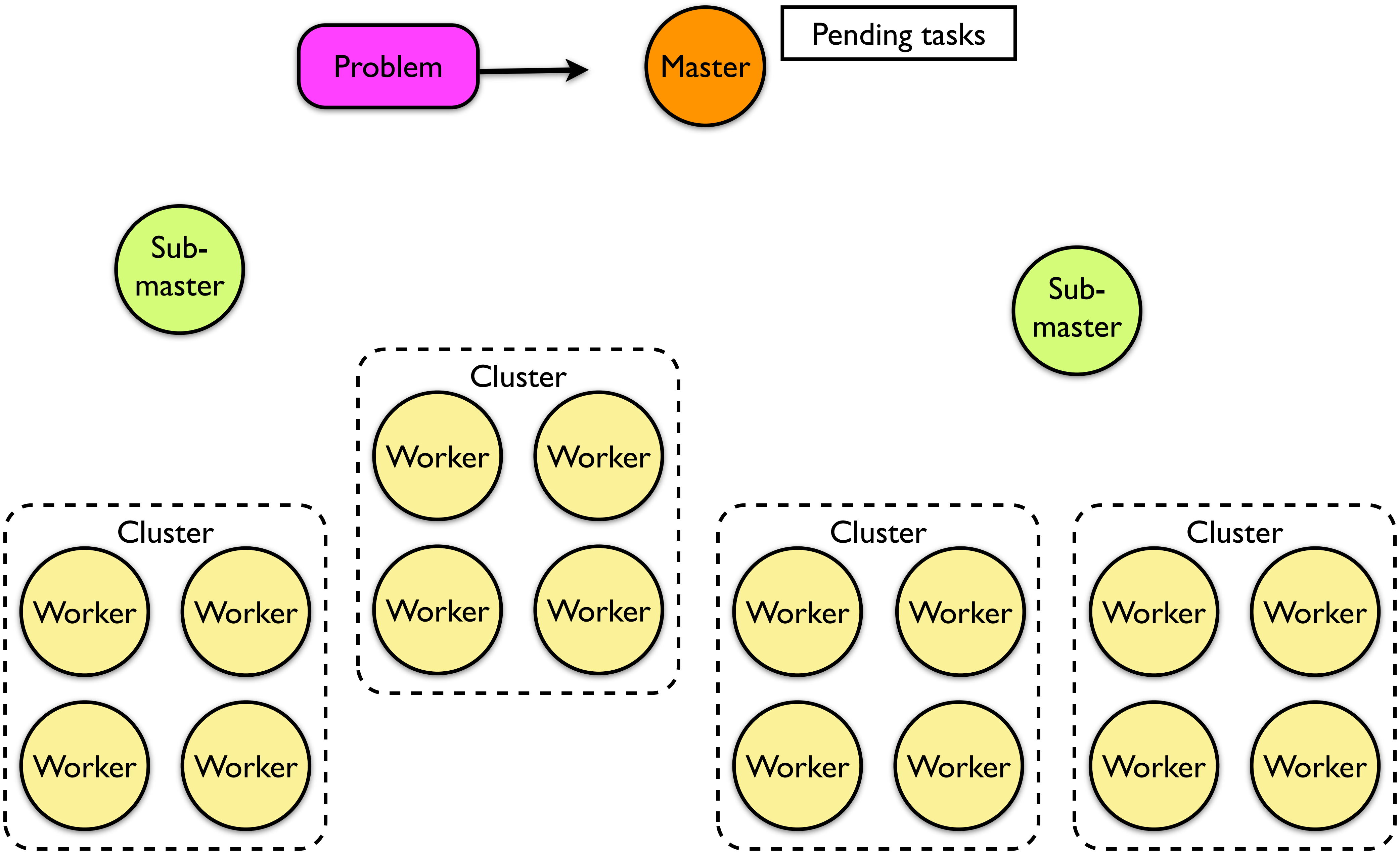

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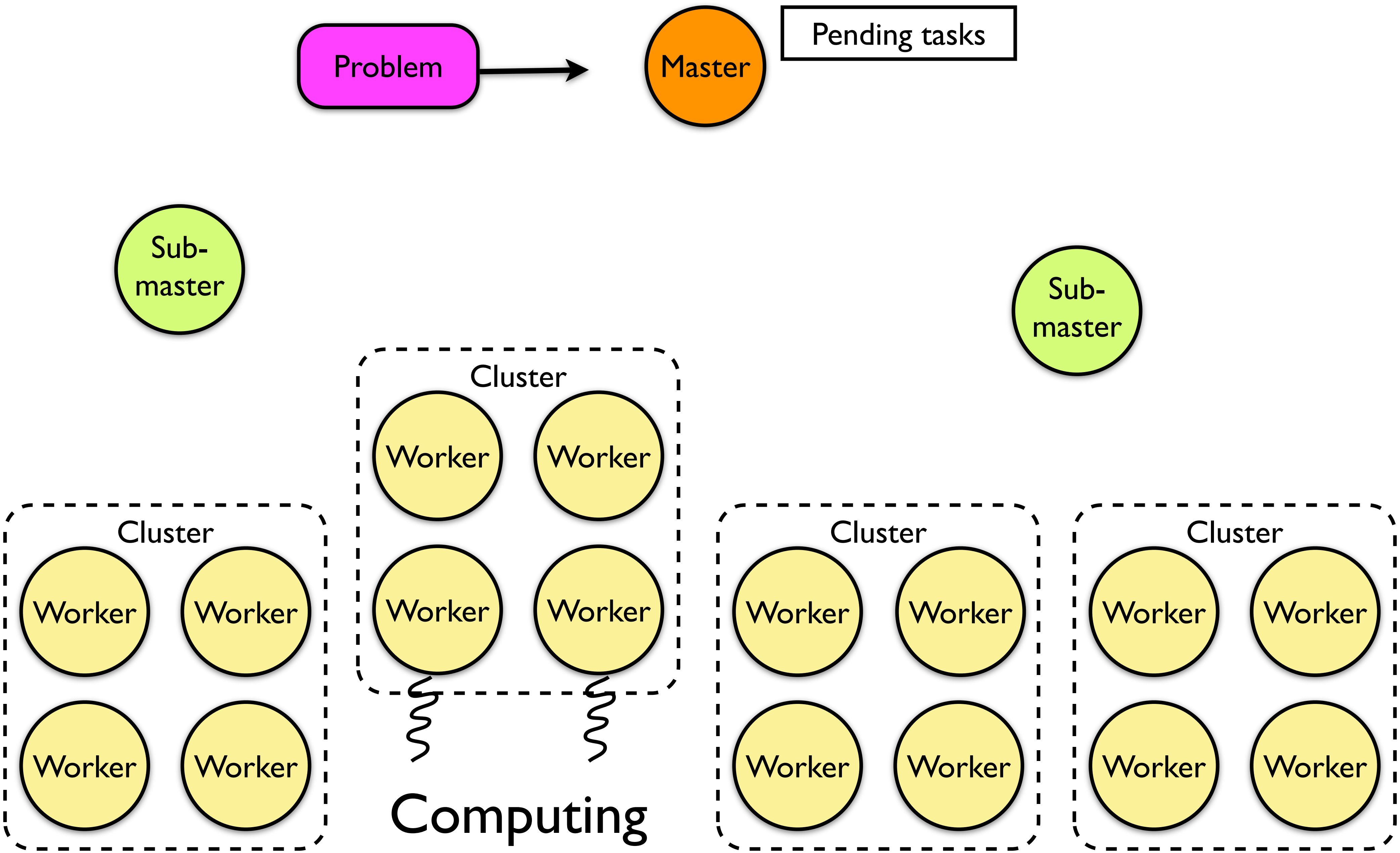

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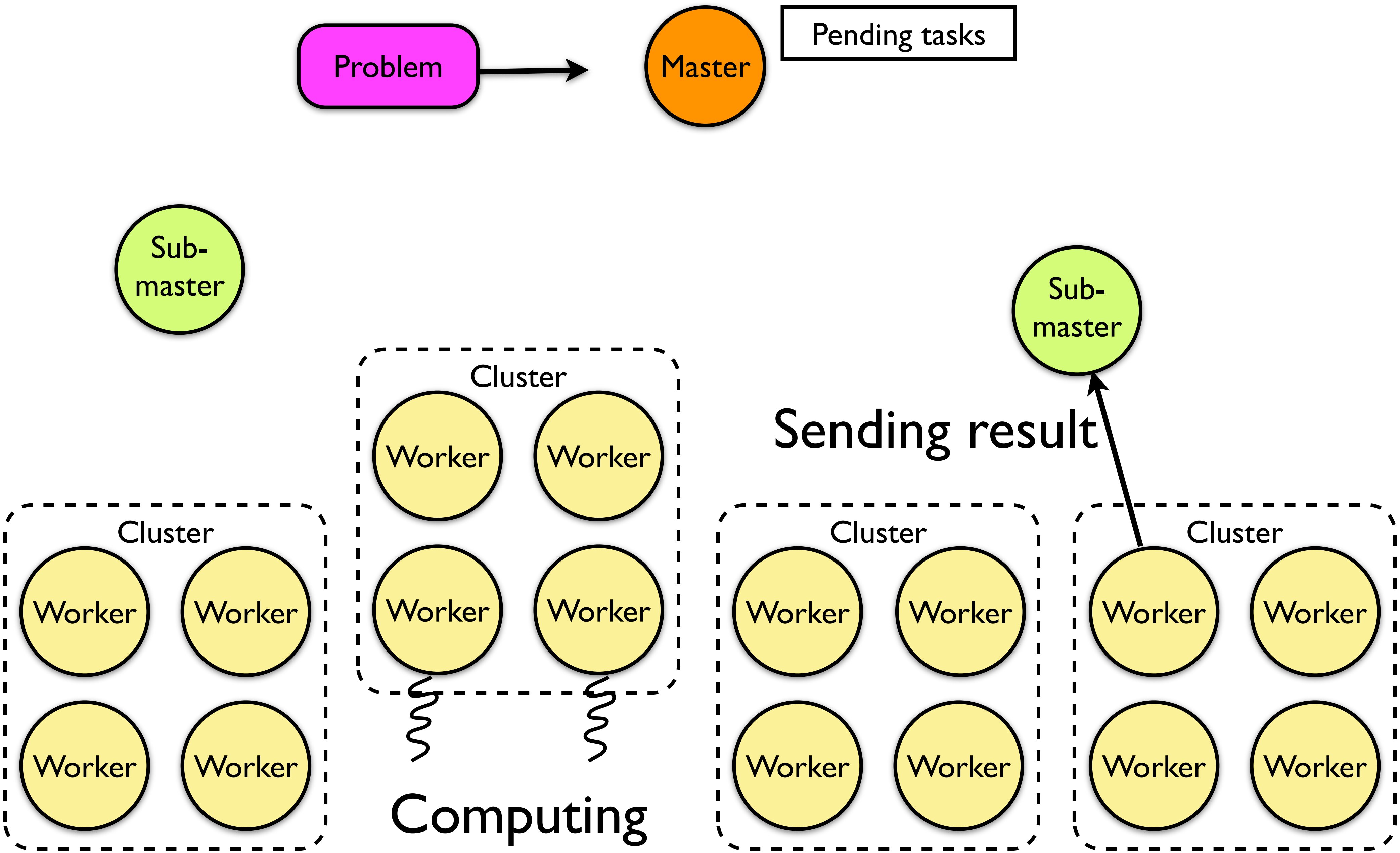

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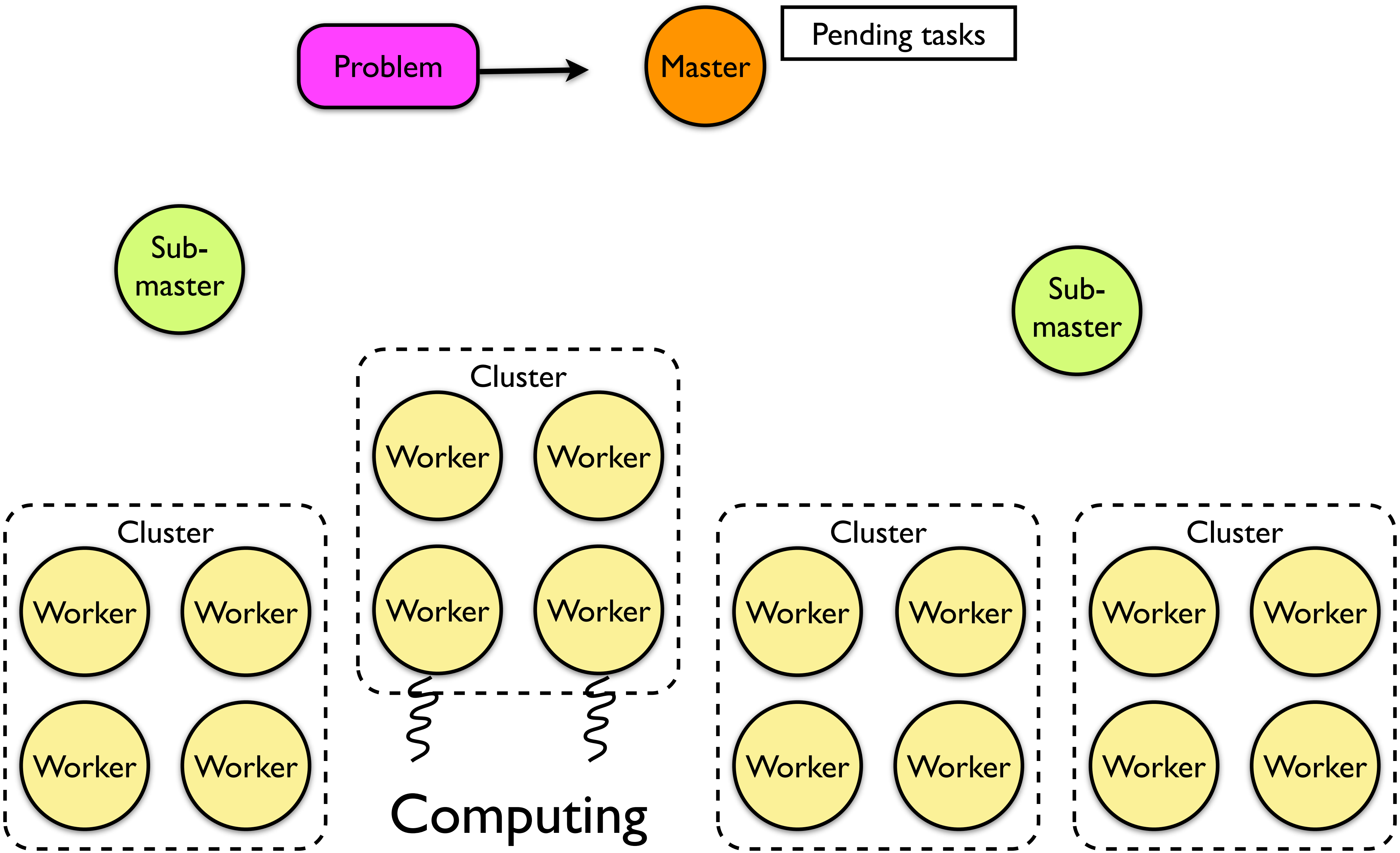

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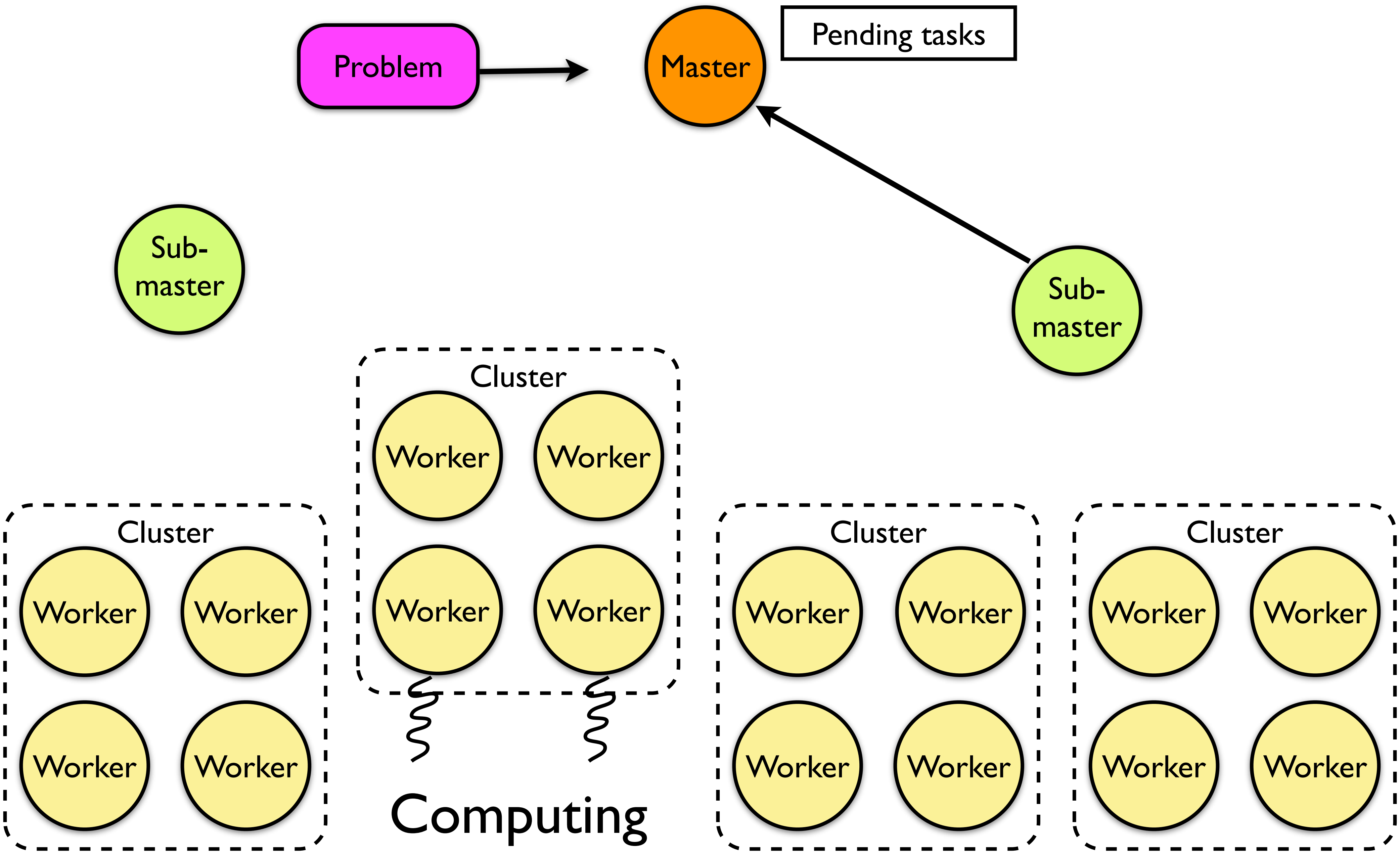

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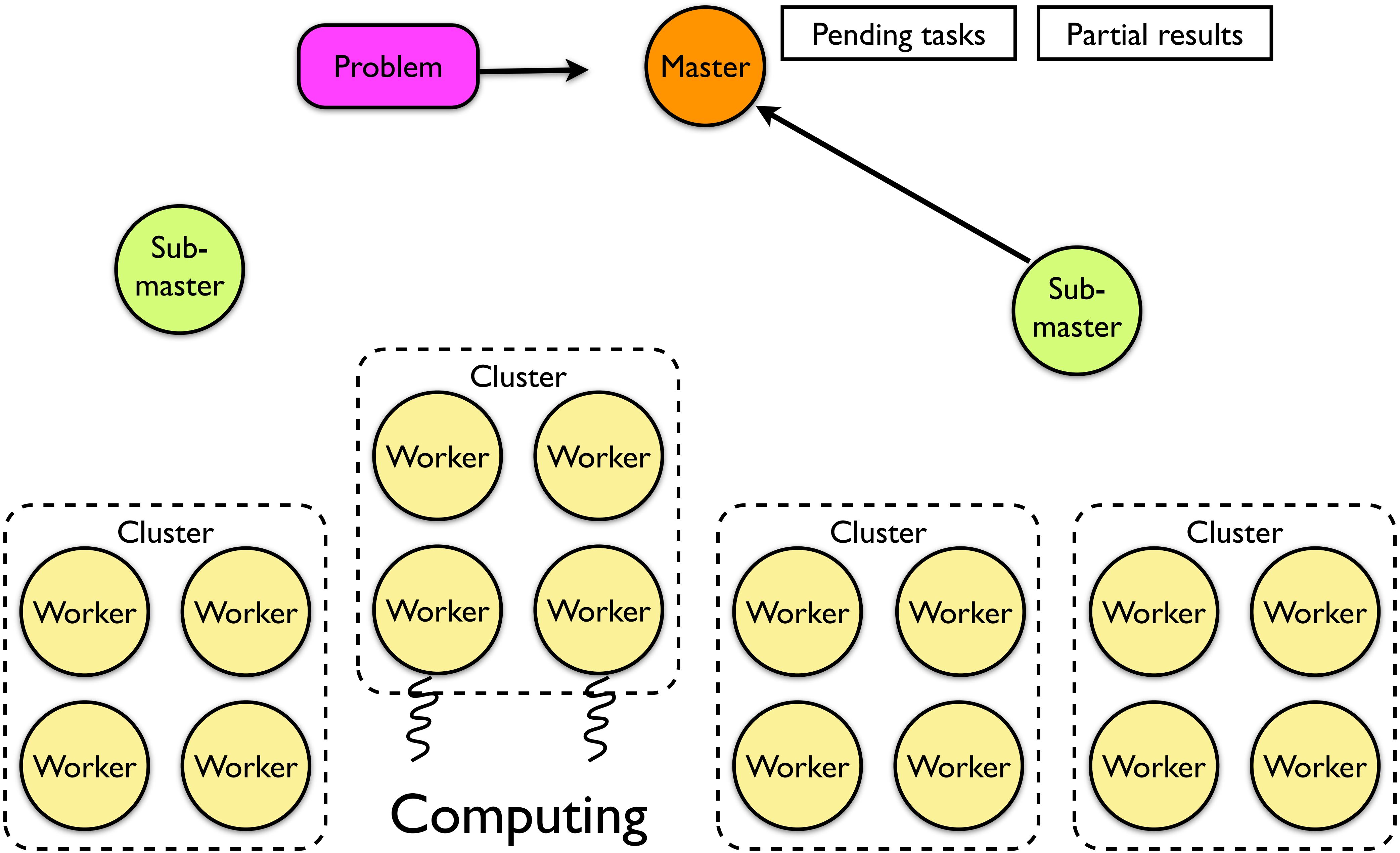

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    - ✓ hierarchical broadcasting scale [Baduel 05]

Organizing Communications for Broadcasting

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- clusters are high-performance communication environments

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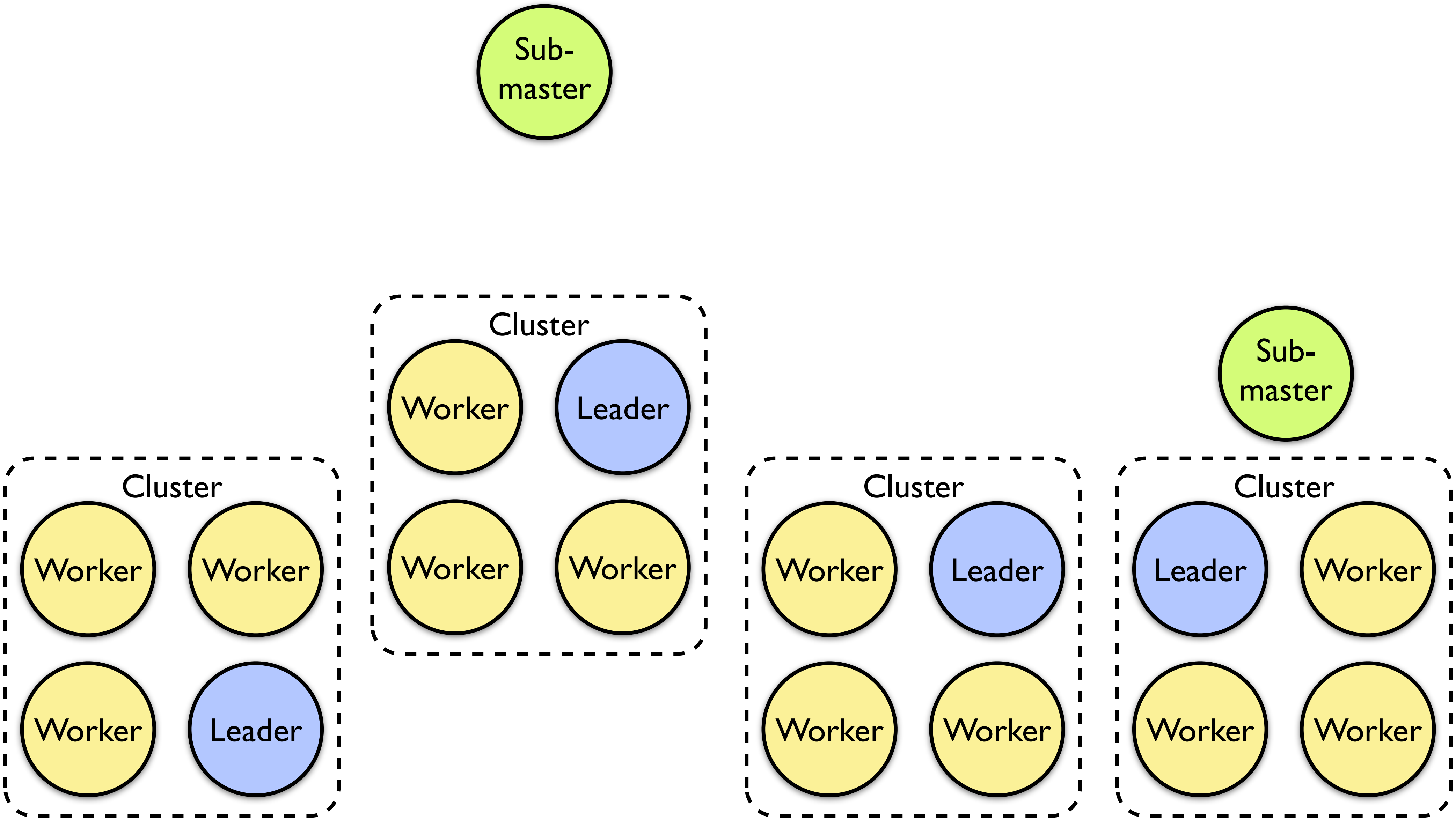
- Process to update Bounds:
  1. the Worker broadcasts the new Bound inside its group
  2. the group Leader broadcasts the new Bound to all Leaders
  3. each Leader broadcasts the new value inside their groups

BnB framework - Communications for Sharing Bound



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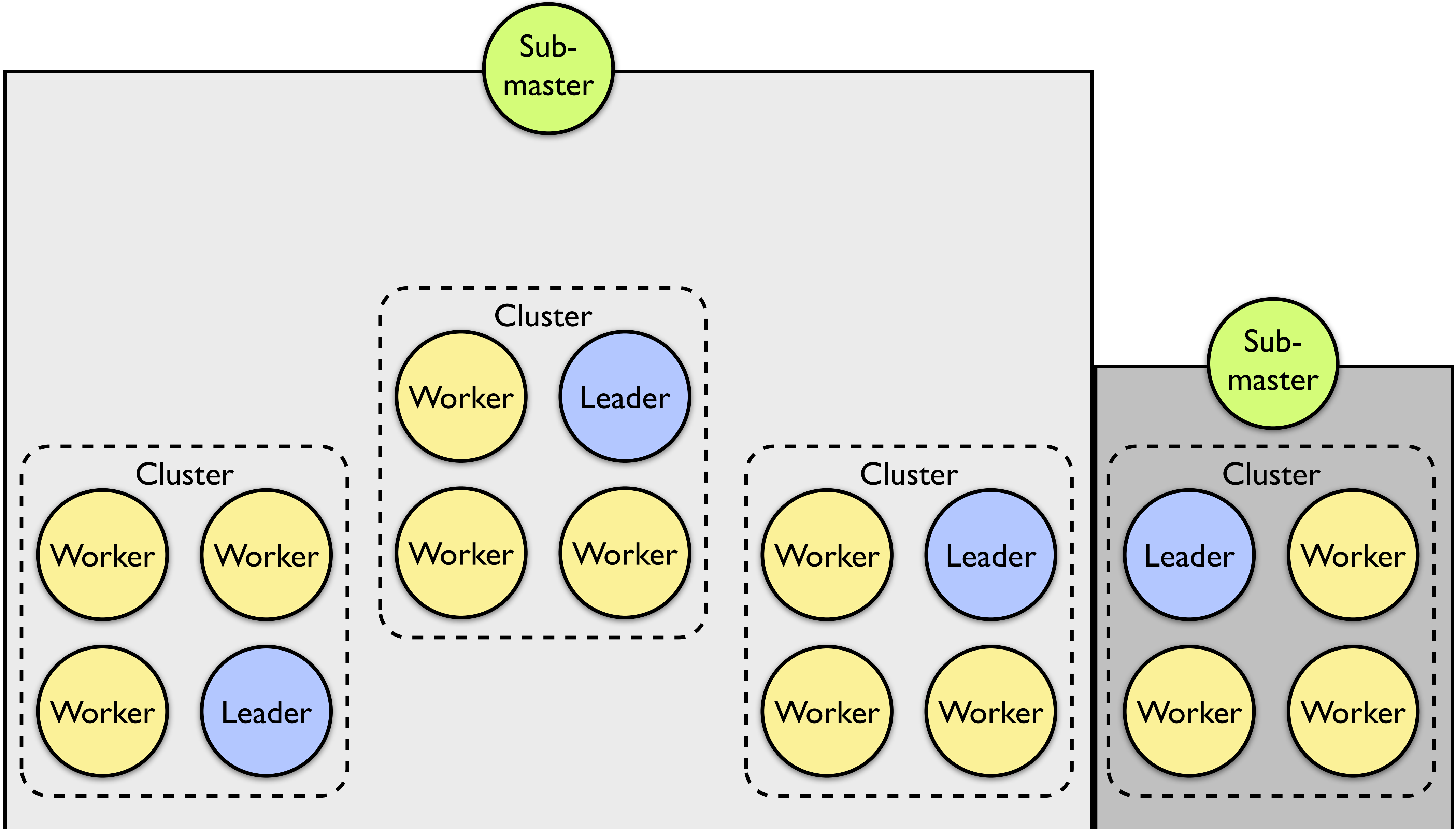

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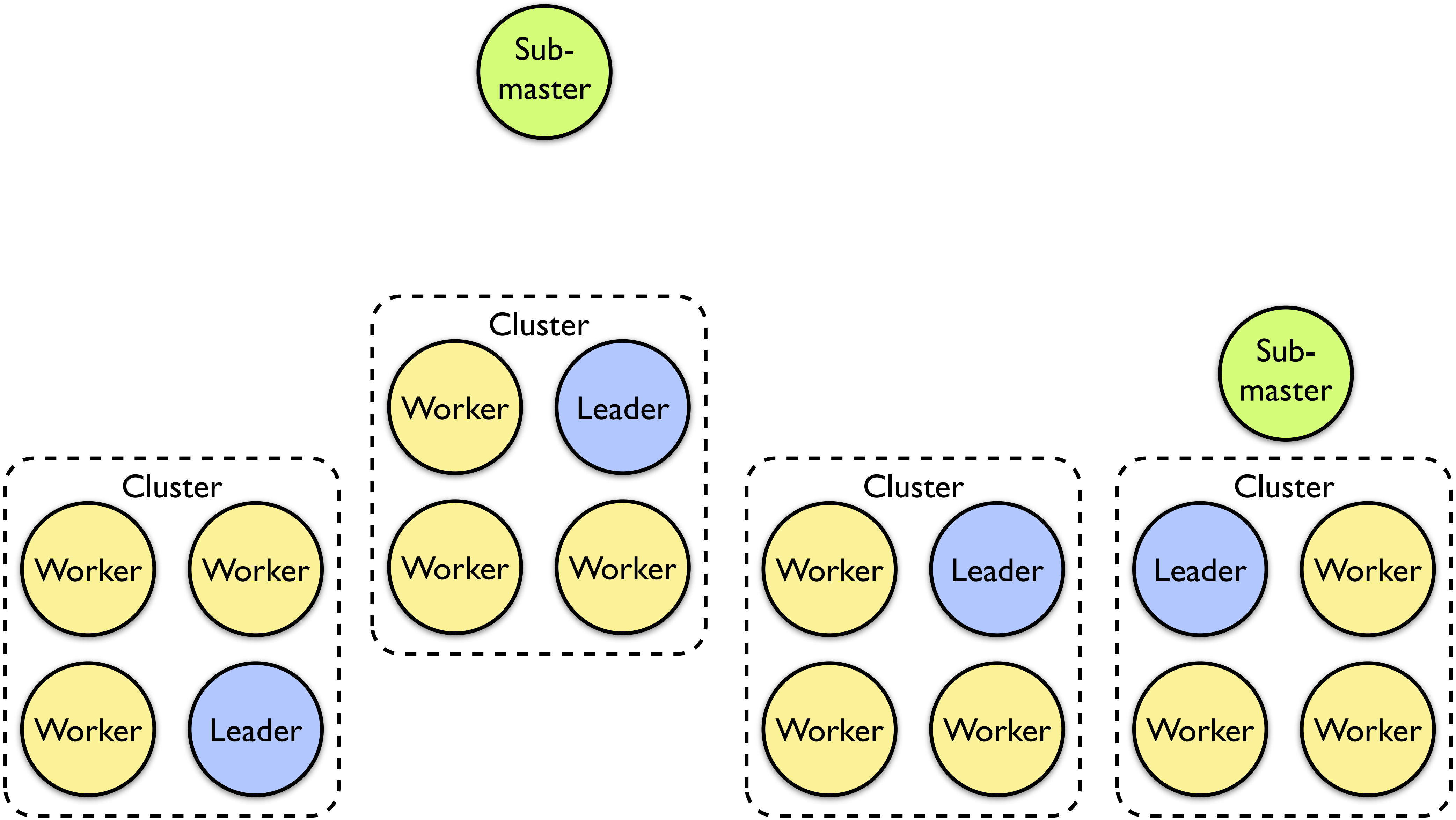

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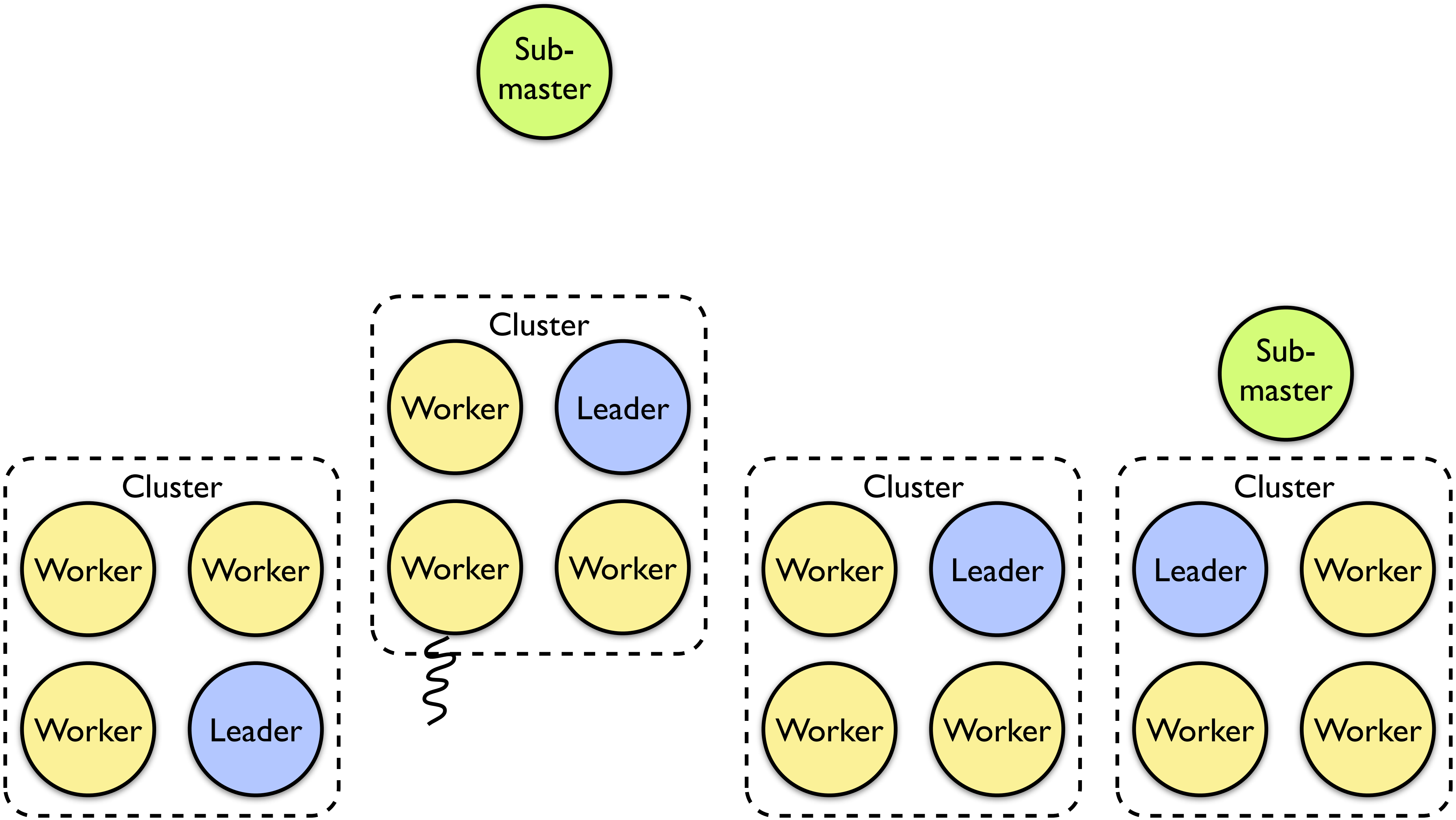

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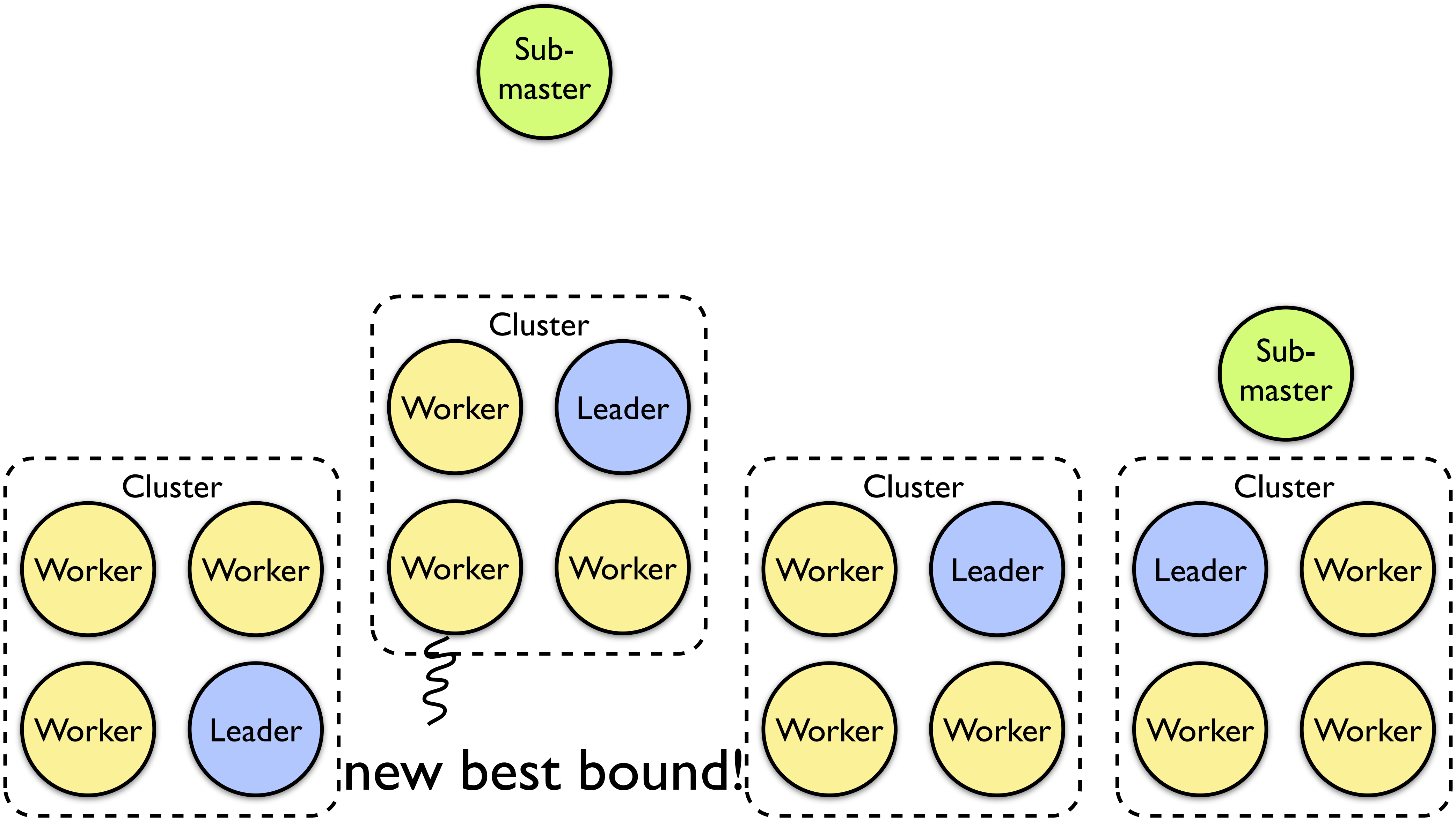

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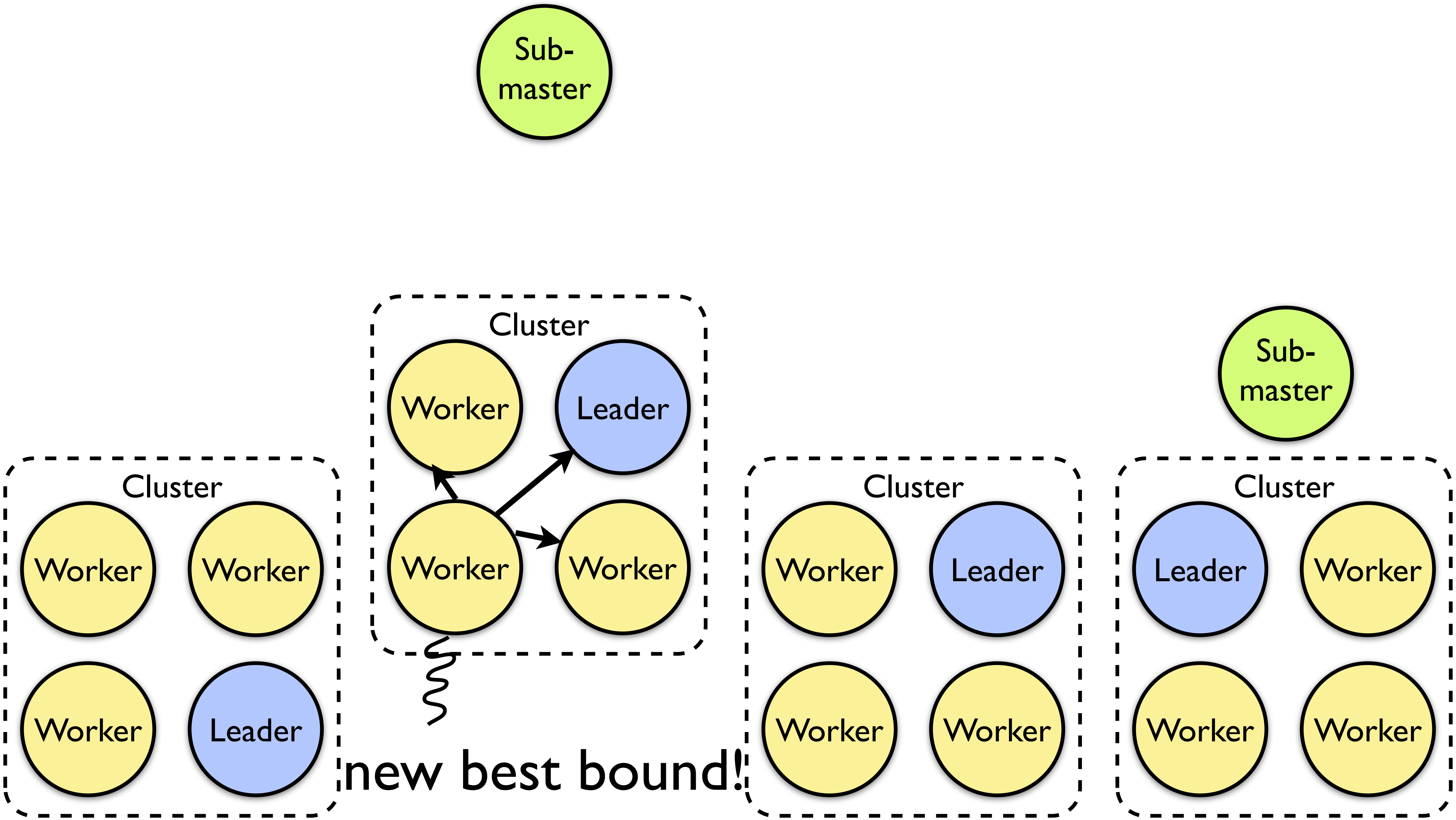

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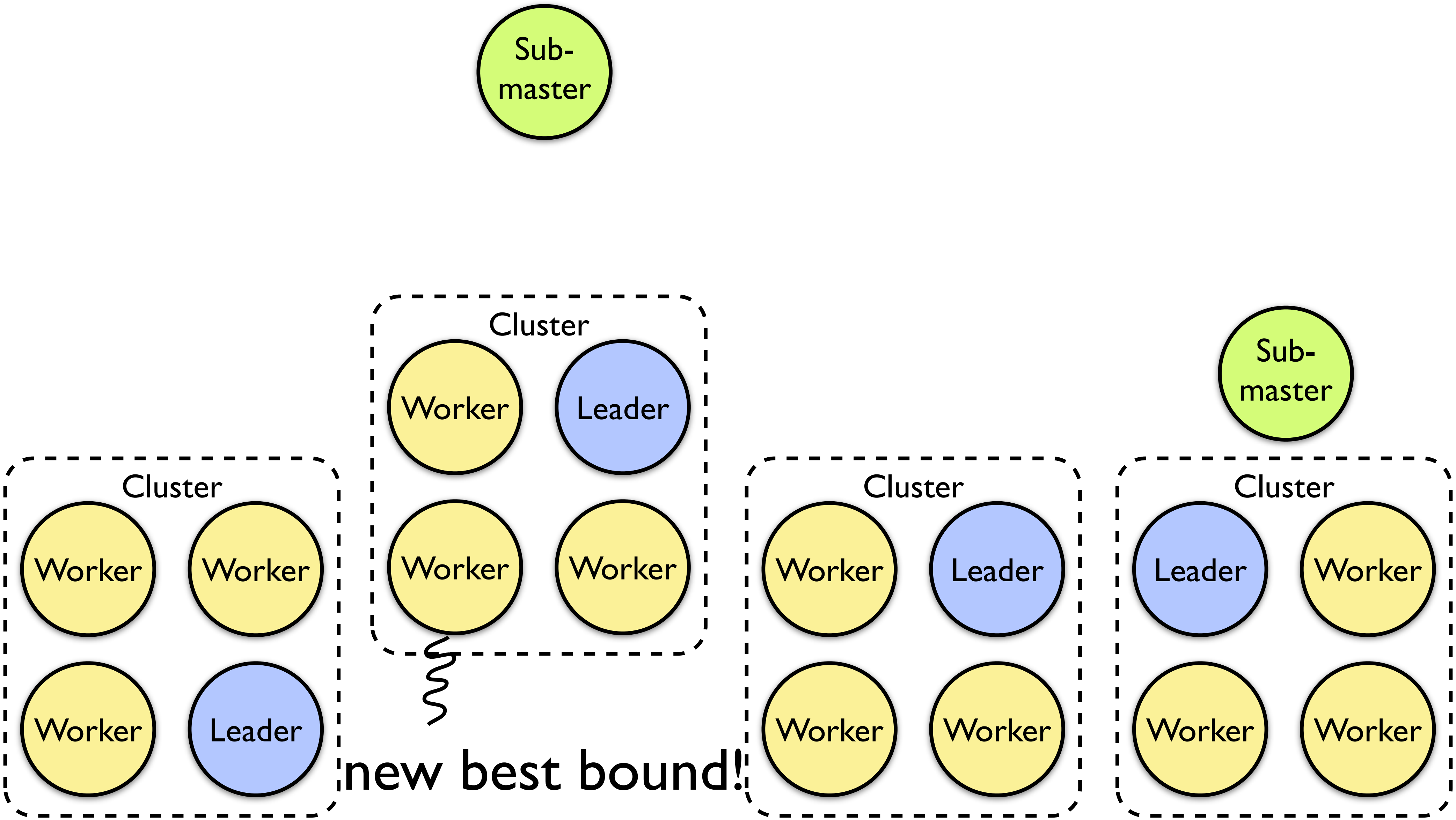

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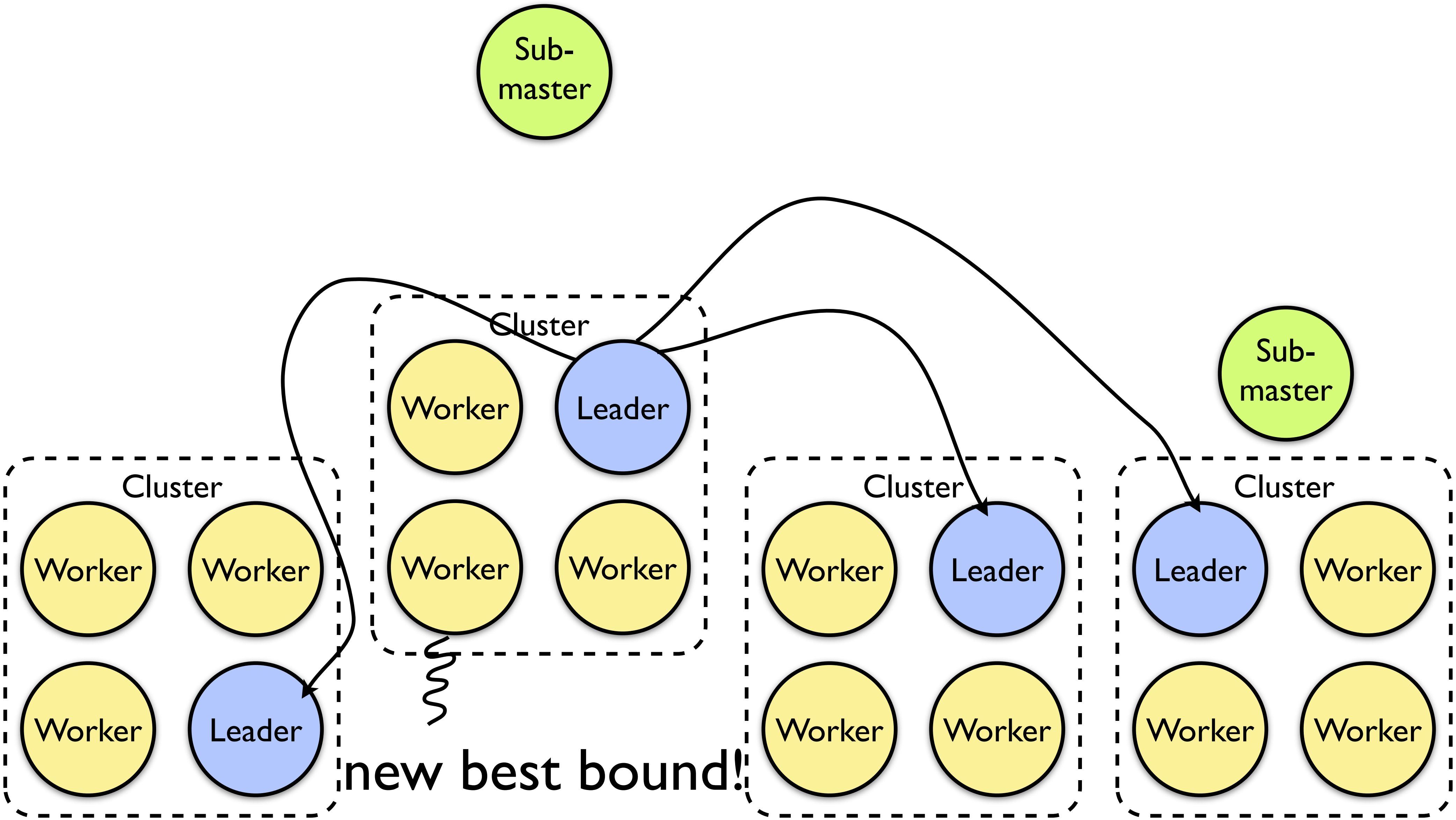

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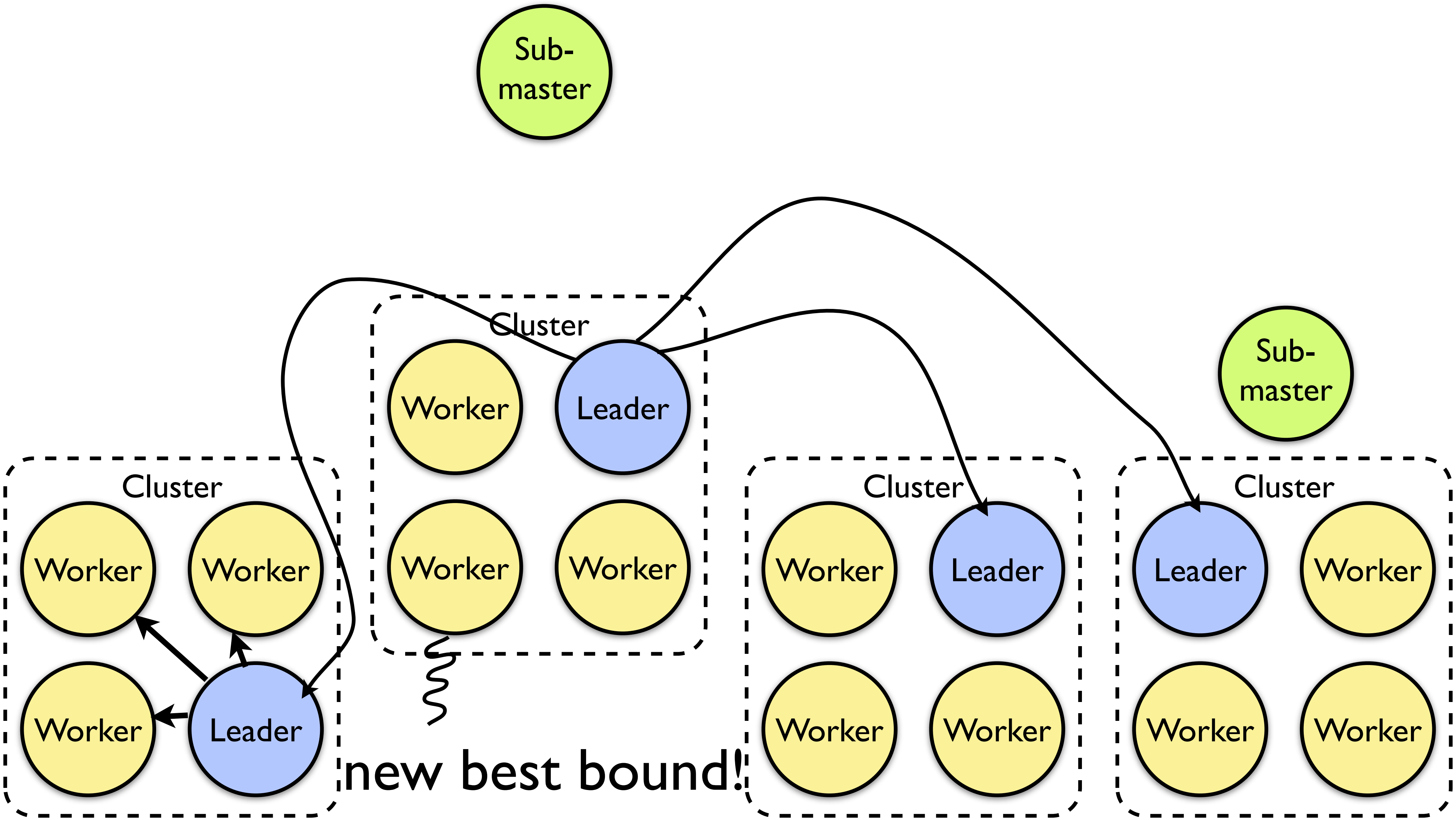
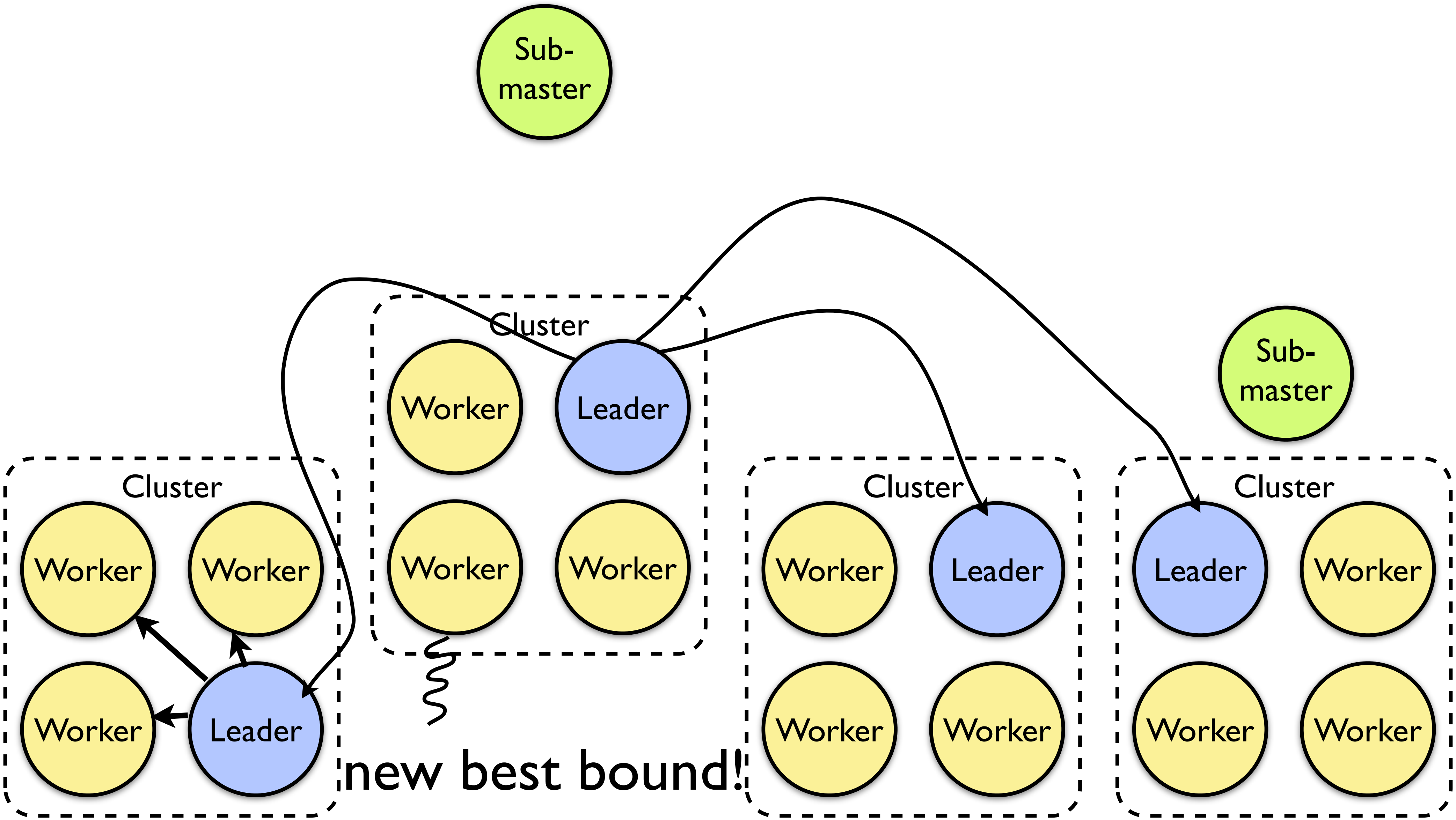


BnB framework - Communications for Sharing Bound

Grid middleware provides communications



BnB Search Strategies

- The improvement of the Bound
  1. depends of how it is shared (communication)
  2. depends of how the search-tree is generated:
     - Classical
       - Depth-First Search
       - Breadth-First Search
     - Contribution
       - First-In-First-Out (FIFO)
       - Priority
       - open API ...

BnB Framework: Fault-Tolerance

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- Manage user exception ➟ computation stopped

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- Load-Balancing is natural with master-worker

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- Load-Balancing is natural with master-worker
  - the framework provides a function to get the number of free Workers ➟ users use it to decide branching

Grid'BnB [HiPC07] Features

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Design

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- Asynchronous communications
- Hierarchical master-worker with com.
- Dynamic task splitting
- Efficient communications with groups
- Fault-tolerance

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- Hidden parallelism and Grid difficulties
- API for COPs
- Ease of deployment
- Principally tree-based
- Implementing and testing search strategies
- Focus on objective function

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- Asynchronous communications
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Design

Validate and Test Grid'BnB by experiments

- Hidden parallelism and Grid difficulties
- API for COPs
- Ease of deployment
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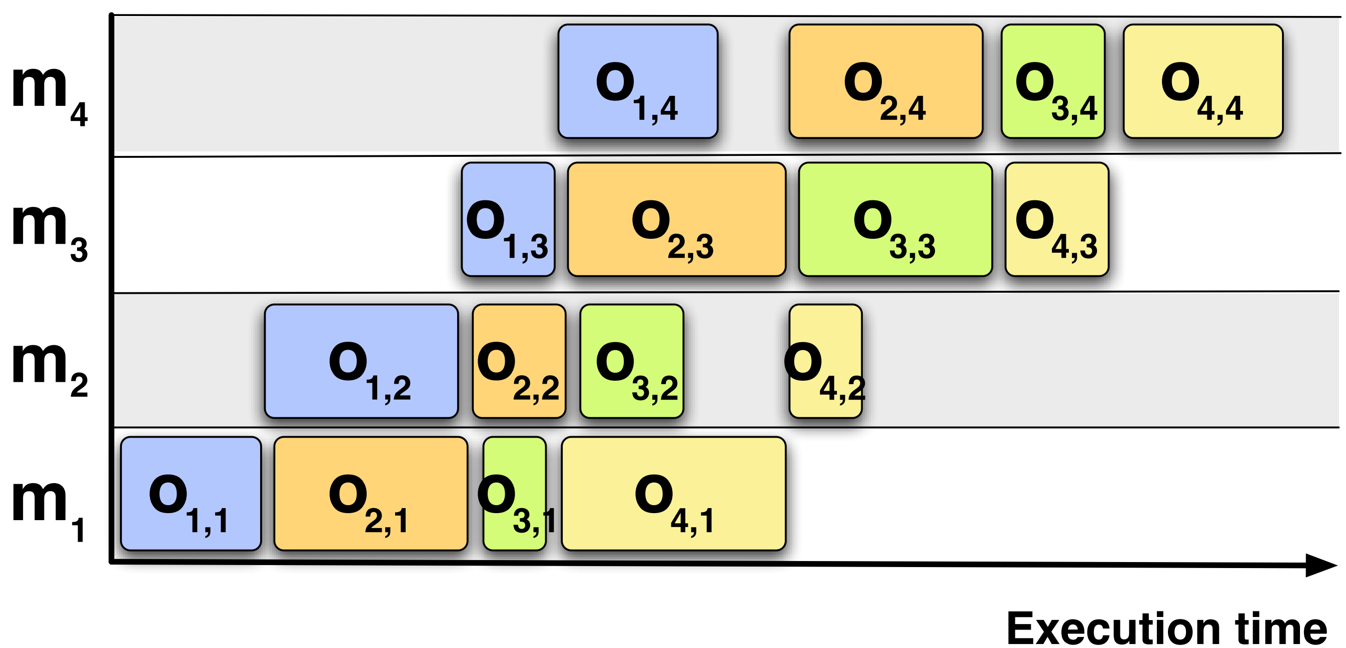
Users

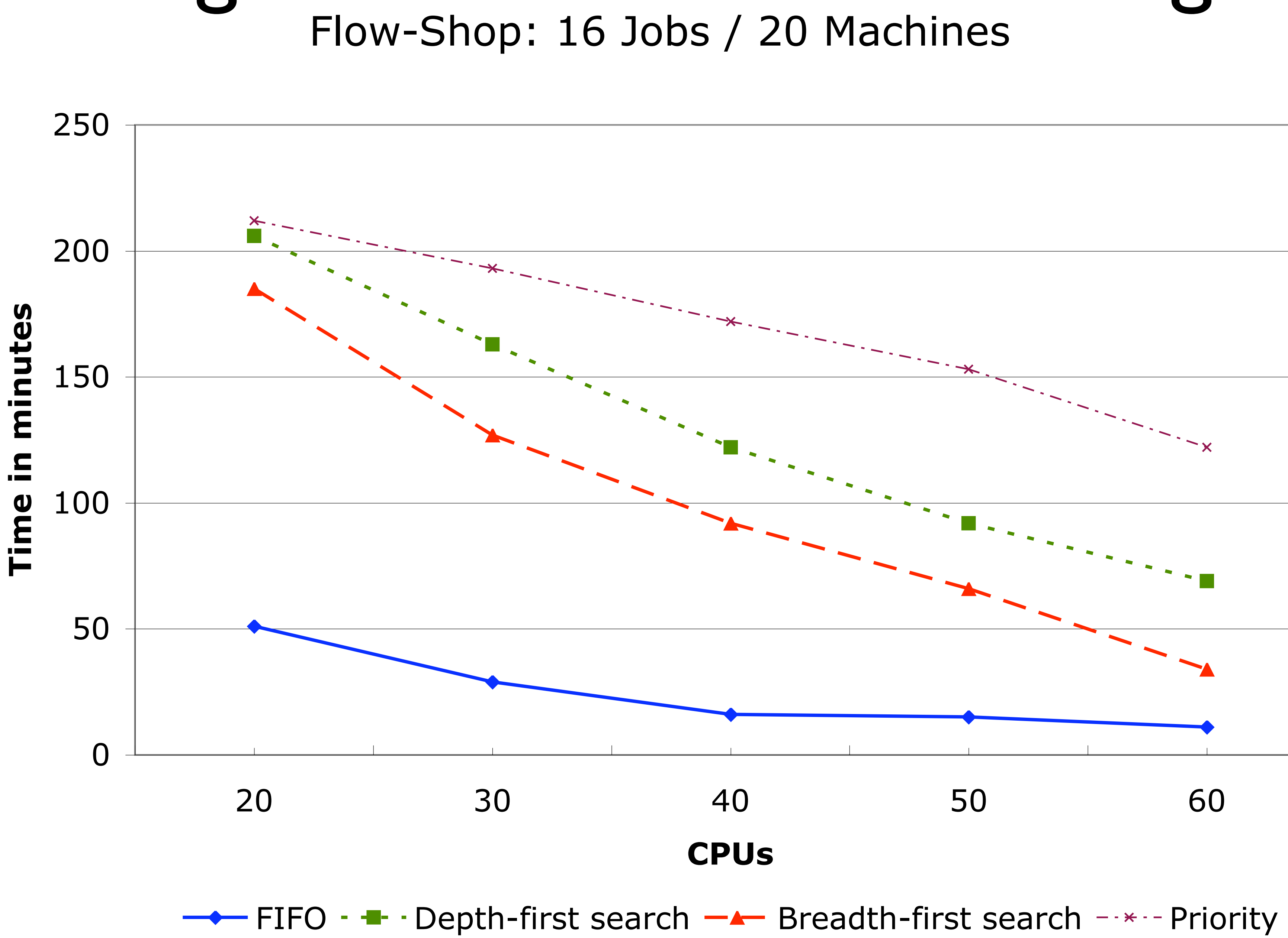
Flow-Shop Experiments

- NP-hard permutation optimization problem

$$J = \{j1, j2, . . . jn\}$$
$$ji = \{ oi1, oi2, . . . oim \}$$
$$M = \{m1, m2, . . . mm\}$$



Single Cluster: Search Strategies



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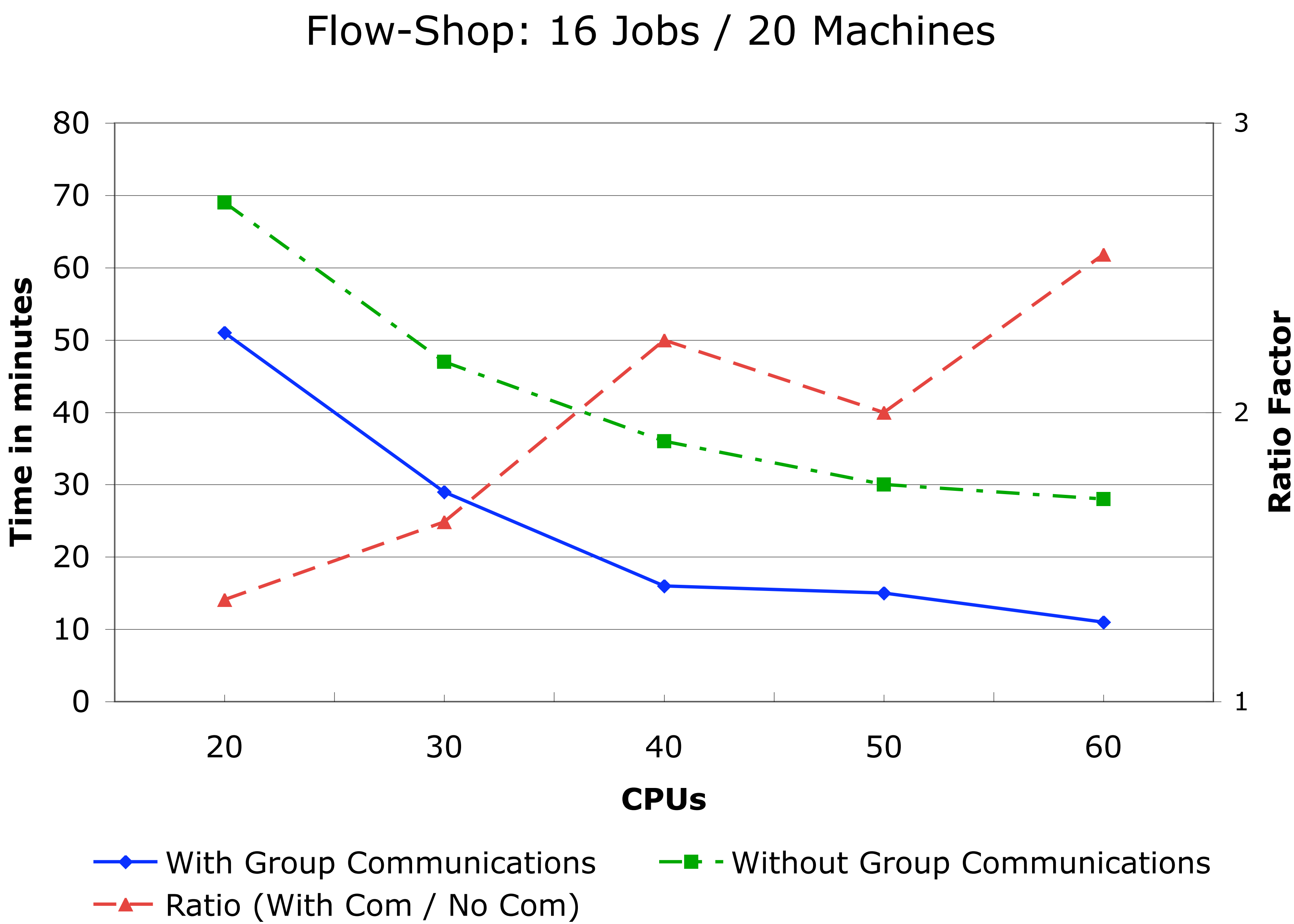
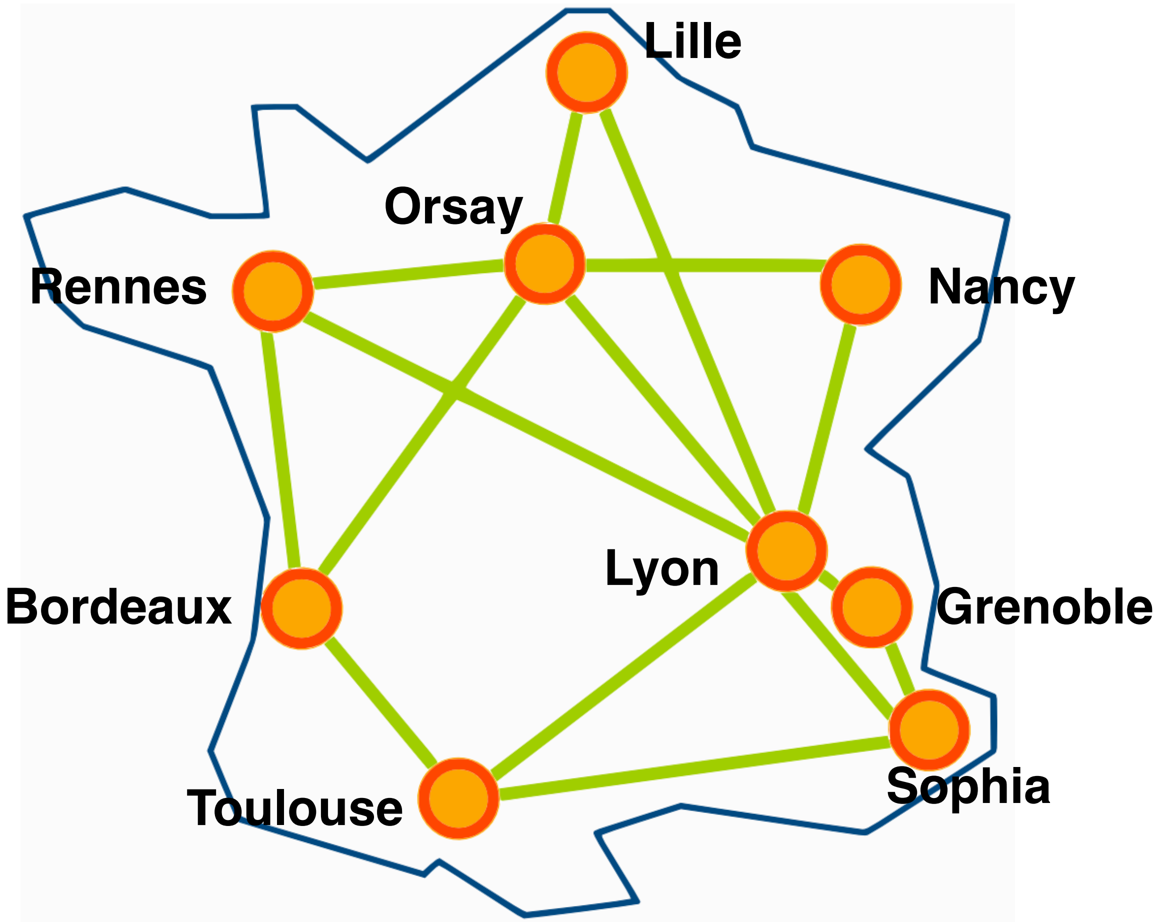


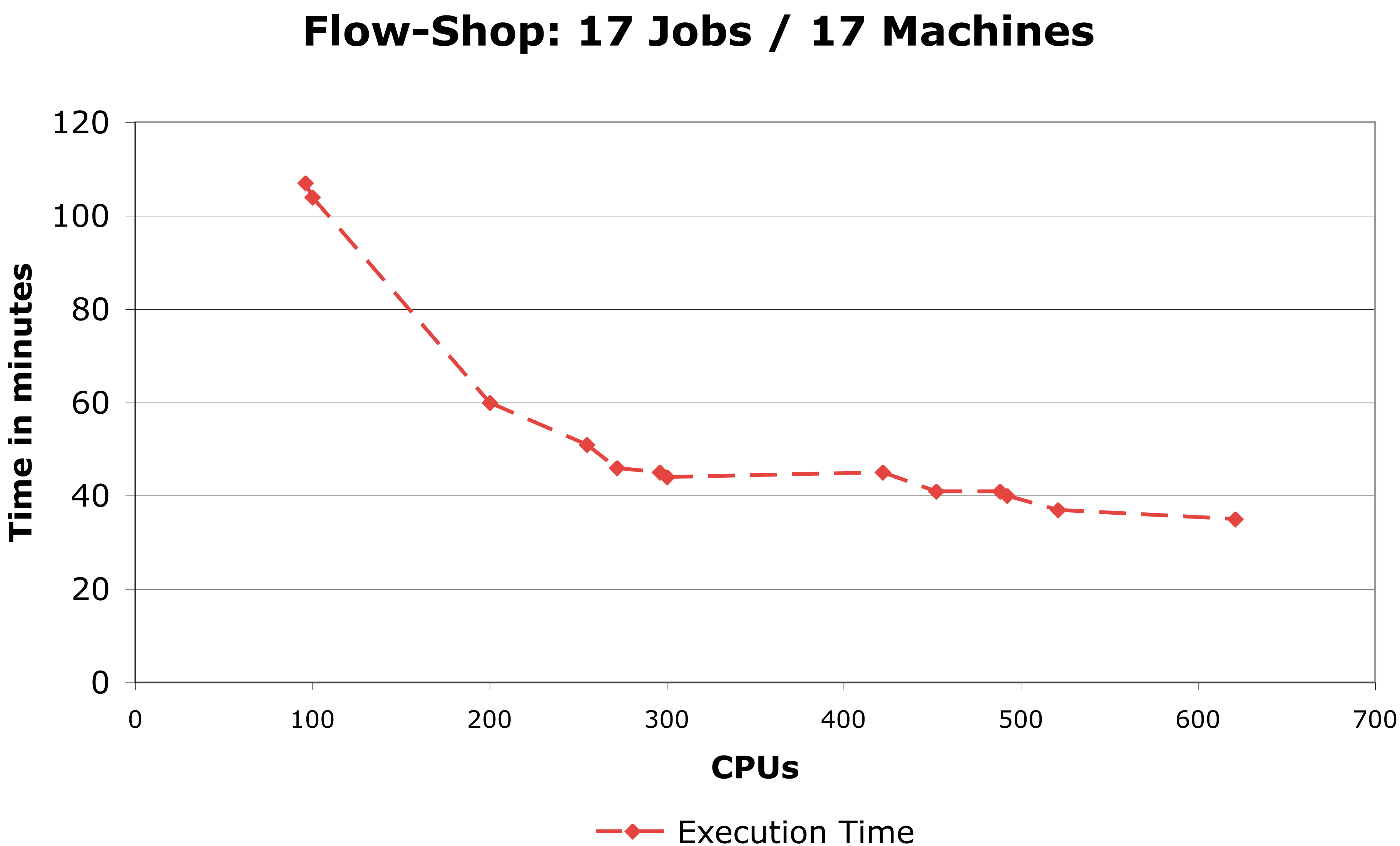
Grid'5000: the French Grid



9 sites - 14 clusters - 3586 CPUs

Grid Experimentations

up to 621 CPUs on 5 sites



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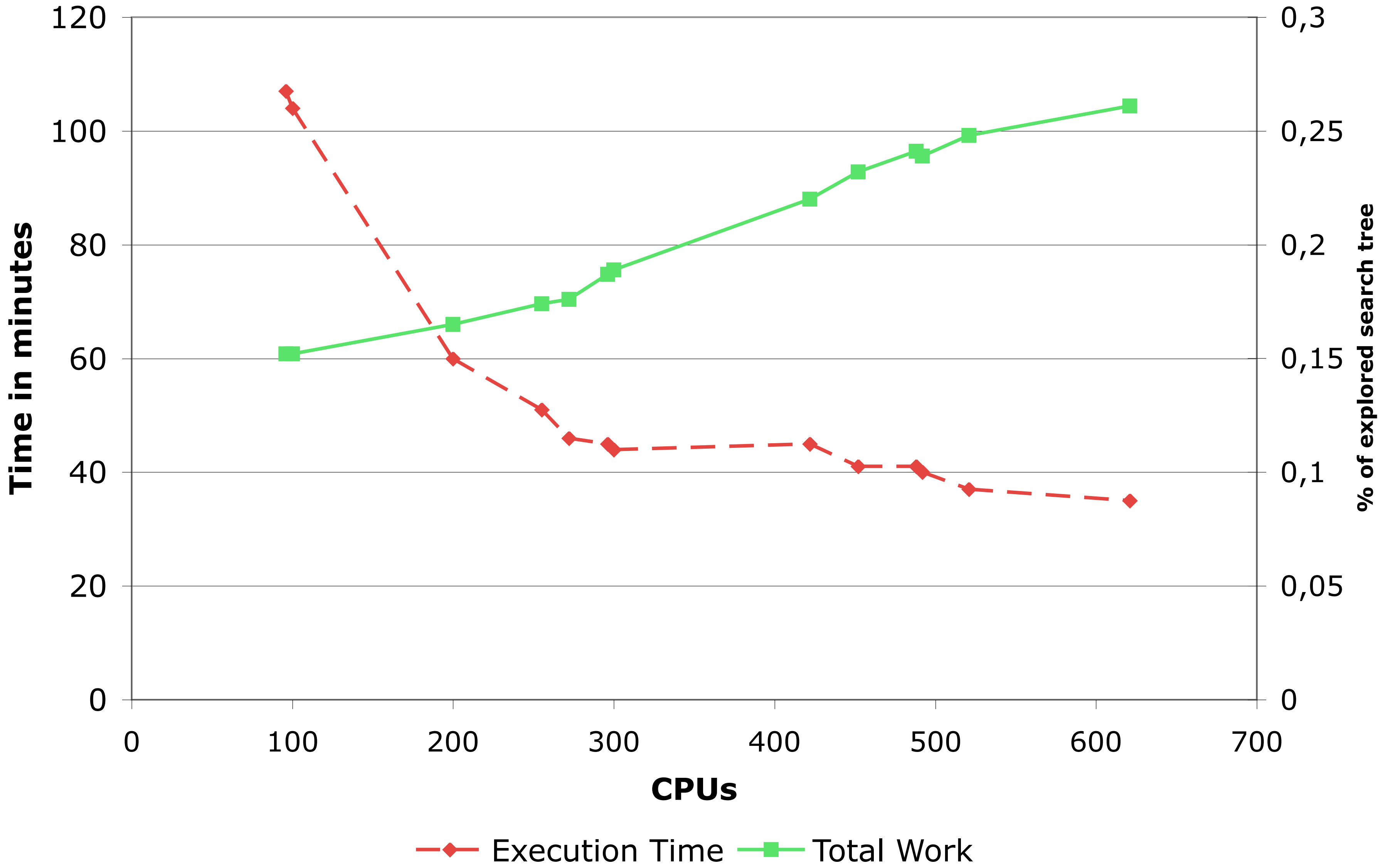
Flow-Shop: 17 Jobs / 17 Machines



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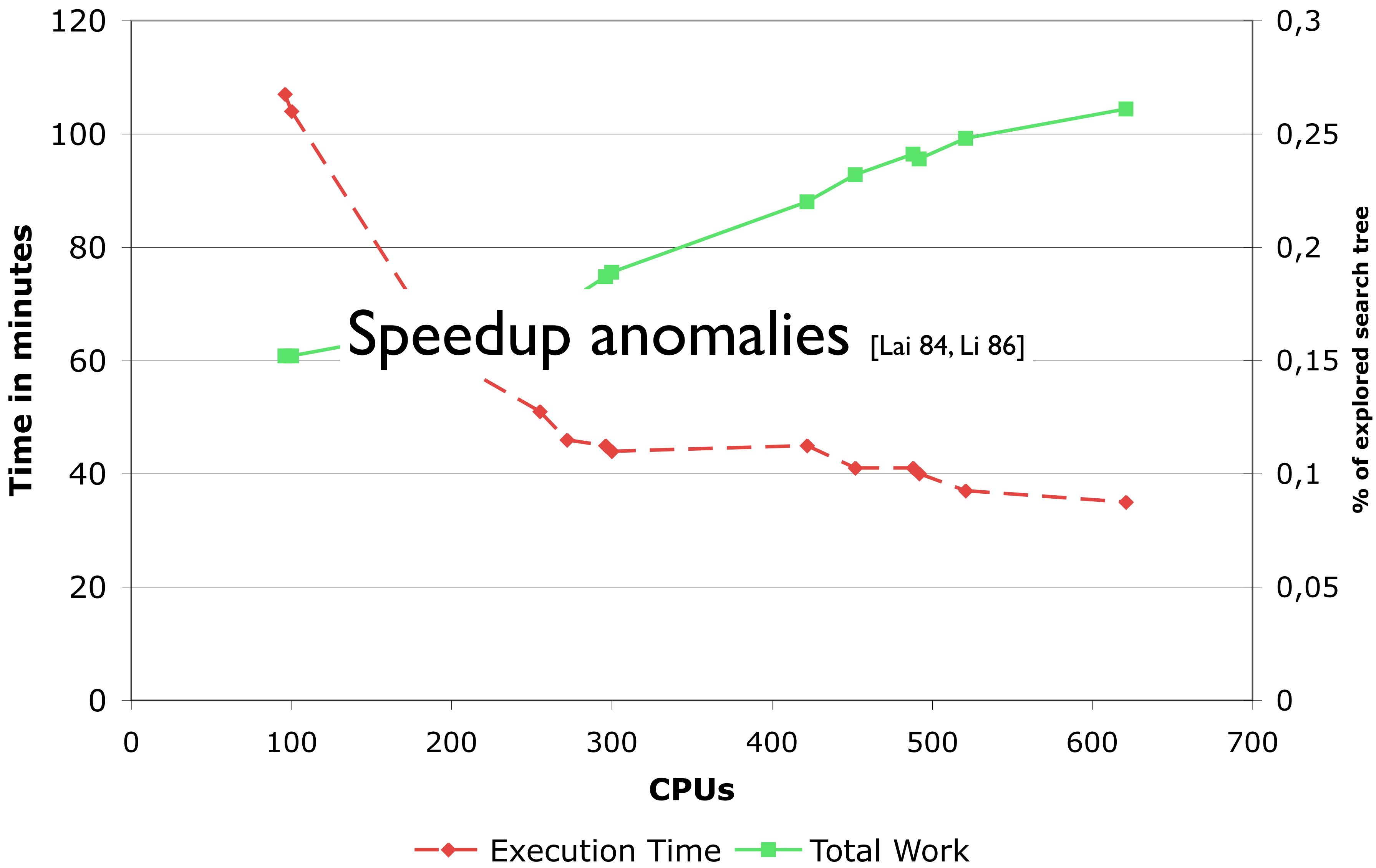
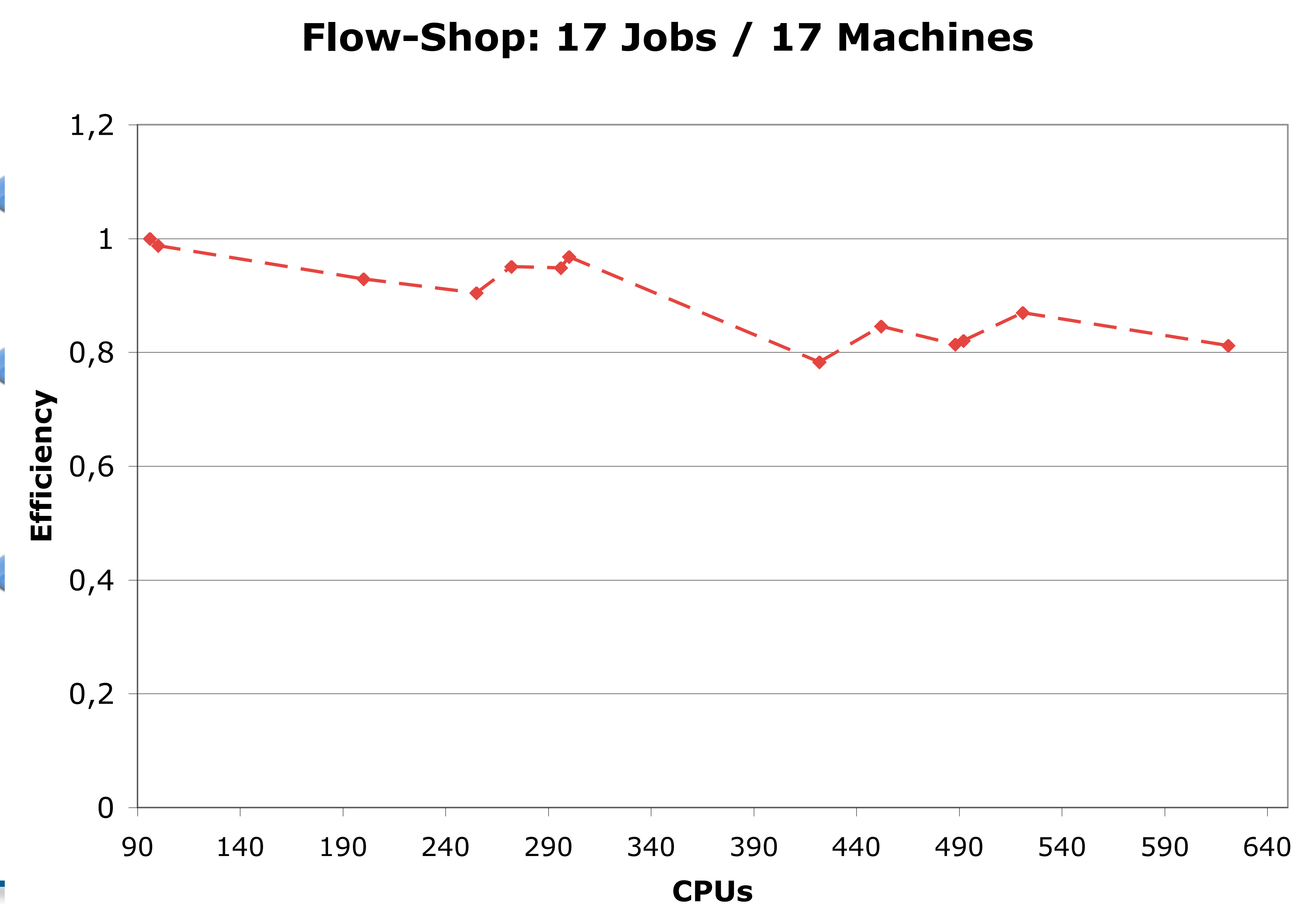


Speedup Anomalies & Efficiency

- Parallel tree-based speedup may sometimes quite spectacular (> or < linear) [Mans 95]
- Speedup Anomalies in BnB [Roucairol 87, Lai 84, Li 86]
  - speedup depends of how the tree is dynamically built
- Efficiency: is a related measure computed as the speedup divided by the number of processors.

Speedup Anomalies & Efficiency



Grid'BnB: Results

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- Experimentally validate our BnB framework for Grids
  - validity of organizing communications
  - scalability on Grid (up to 621 CPUs on 5 sites)

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- Problems:
  - deployment on Grids is difficult
  - dynamically acquiring new resources is difficult
  - popularity of Grid'5000
  - cannot mix Grid'5000 and under-utilized lab desktops

Grid'BnB: Results

- Experimentally validate our BnB framework for Grids
  - validity of organizing communications
  - scalability on Grid (up to 621 CPUs on 5 sites)

Grid middleware needs a better supporting of dynamic infrastructure

  - deployment on Grids is difficult
  - dynamically acquiring new resources is difficult
  - popularity of Grid'5000
  - cannot mix Grid'5000 and under-utilized lab desktops

Agenda

- Context, Problem, and Related Work
- Contributions
  - Branch-and-Bound Framework for Grids
  - Desktop Grid with Peer-to-Peer
  - Mixing Desktops & Clusters
- Perspectives & Conclusion

Peer-to-Peer as Grid Middleware

- Grid Computing and Peer-to-Peer share a common goal:
  - sharing resources [Foster 03, Goux 00]
- Grid related work: [Globus]
  - ✓ providing computational resources
  - \- installing/deploying Grid middleware is difficult
- P2P related work: [Gnutella, Freenet, DHT]
  - \- focusing on sharing data & mono-application
  - ✓ dynamic & easy to deploy

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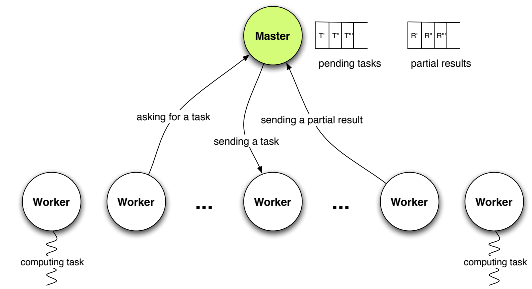
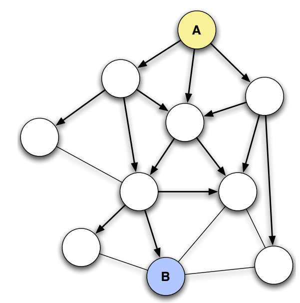
Objective: provide a P2P infrastructure for Grids and sharing computational resources

Which P2P Architecture?

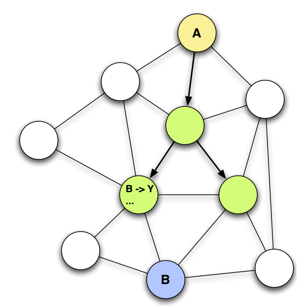
- Master-Worker (SETI@home)
  - centralized
  - targets only desktops
  - good for embarrassingly parallel



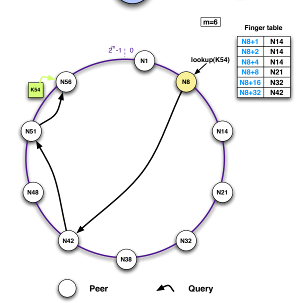
- Pure/Unstructured Peer-to-Peer (Gnutella)
  - flooding problems
  - ✓ supports high-churn (good for Desktop Grids)
  - ✓ supports many kind of application (data, computational)



- Hybrid Peer-to-Peer (JXTA)
  - uses central servers
  - ✓ limits the flooding
  - has to manage churn



- Structured Peer-to-Peer (Chord)
  - high cost for managing churn
  - efficient for data sharing (Distributed Hash Table)



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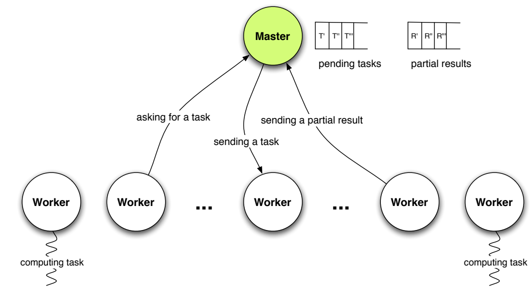

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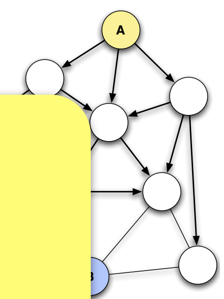

Pure Peer-to-Peer is the most adapted
Needs to avoid the flooding problem

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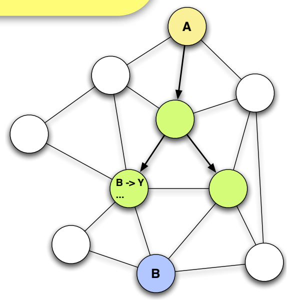

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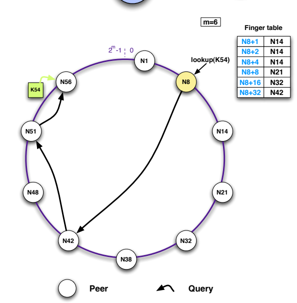
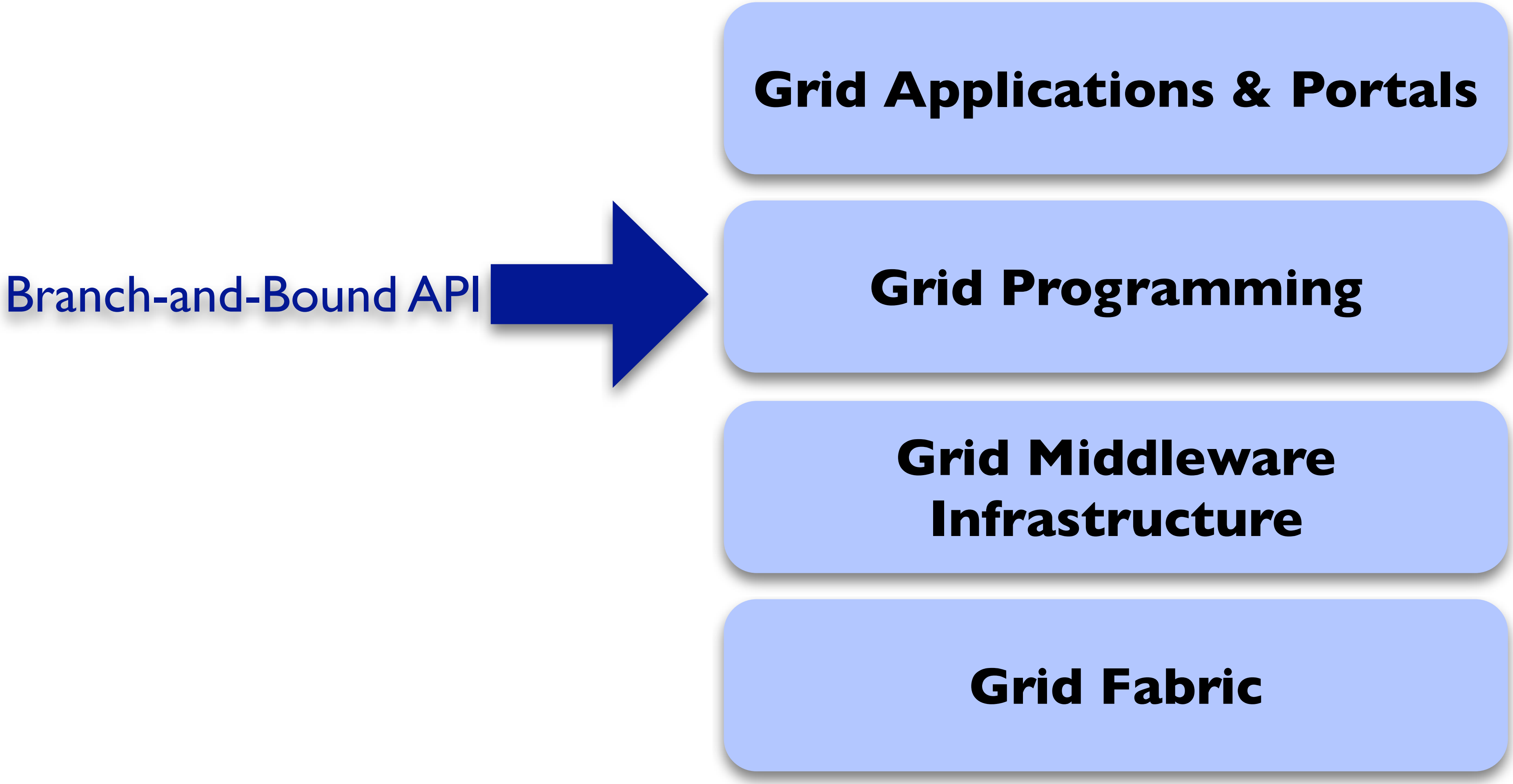


Contribution & Positioning



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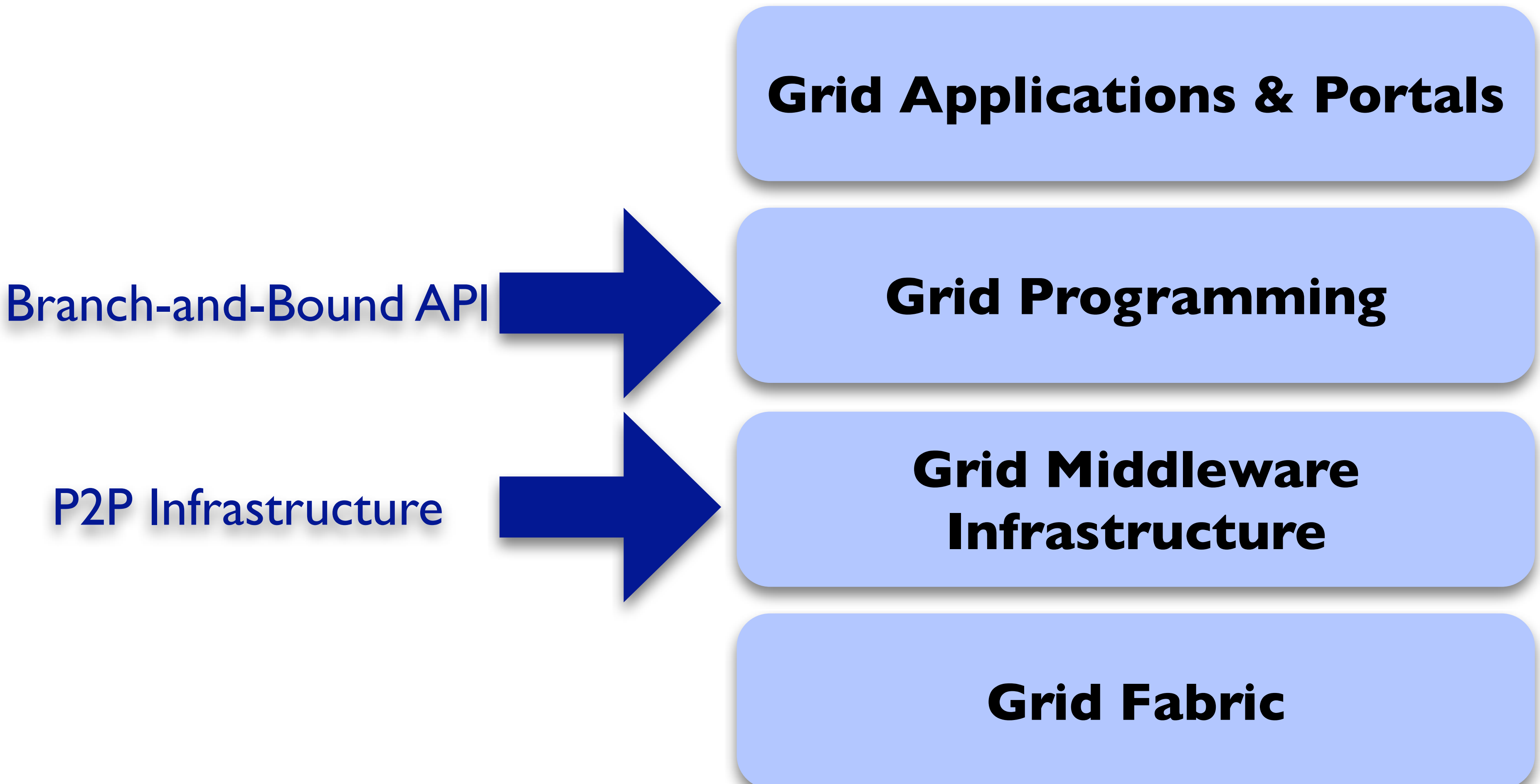

The Peer-to-Peer Infrastructure [CMST06]

The Peer-to-Peer Infrastructure [CMST06]

- Pure Peer-to-Peer overlay network
- Using it as Grid middleware infrastructure

- The proposed solution to avoid the flooding problem:
  - 3 node-request protocols:
    - 1 node: Random walk algorithm
    - n nodes: Breadth-First-Search (BFS) algorithm with acknowledgement
    - max nodes: BFS without acknowledgement

- Best-effort

INRIA Sophia P2P Desktop Grid

- Need to validate the infrastructure with desktops
- 260 desktops at INRIA Sophia lab
- No disturbing normal users:
  - running in low priority
  - working schedules:
    - 24/24 ≈ 50 machines (INRIA-2424)
    - night/weekend ≈ 260 machines (INRIA-ALL)

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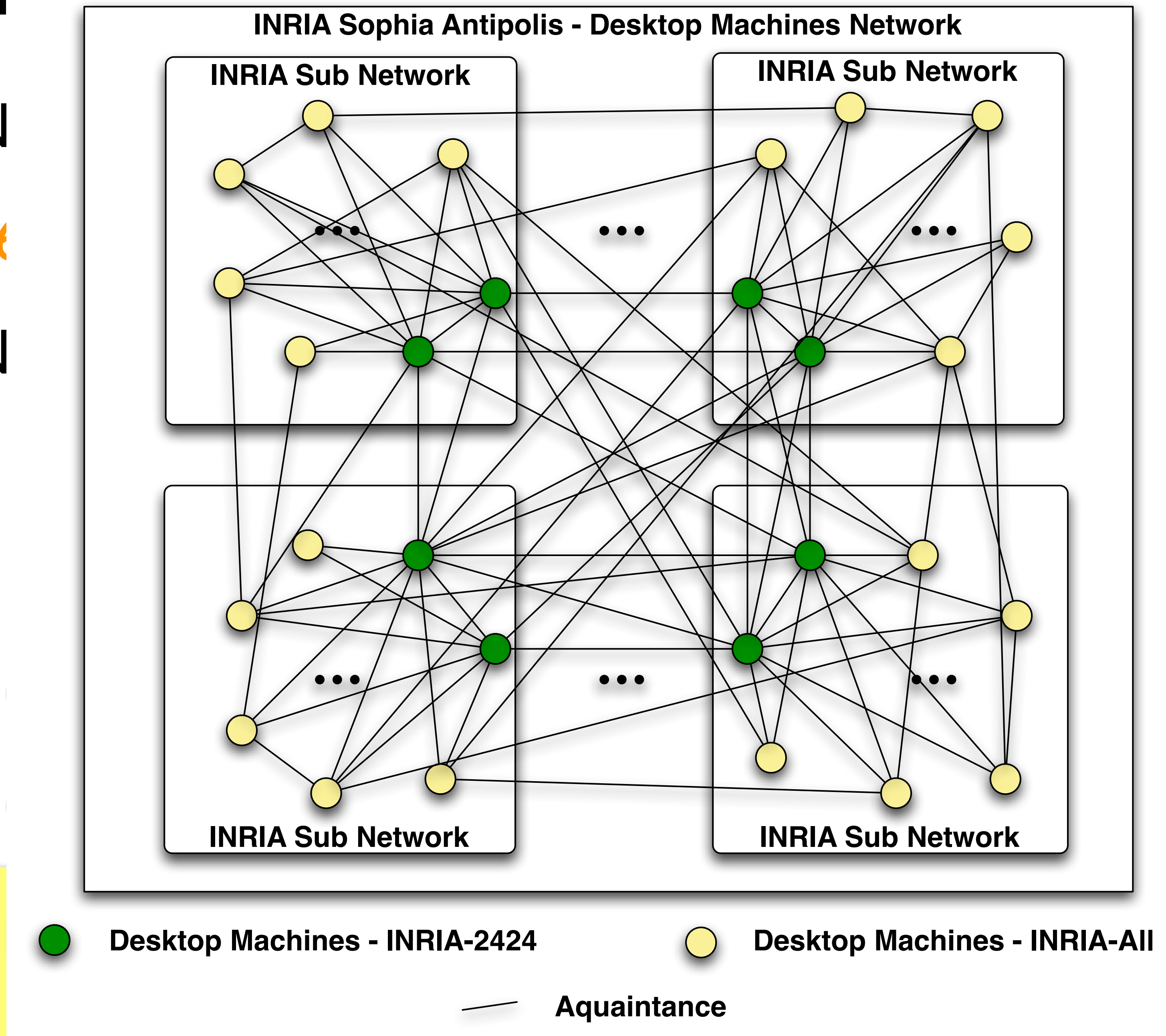
Deployed our P2P infrastructure as permanent Desktop Grid at INRIA Sophia

INRIA Sophia P2P Desktop Grid



Long Running Experiments with the P2P Desktop Grid

- Context: ETSI Grid Plugtests contest ➟ n-queens
- n-queens:
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How many solution for 25 queens ?

n-queens Experiment Results

Total # of Tasks	**12,125,199**
Task Computation	**≈ 138"**
Computation Time	**≈ 185 days**
Cumulated Time	**≈ 53 years**
# of Desktop Machines	**260**
Total of Solution Found	2,207,893,435,808,352 **≈ 2 quadrillions**

- World Record [Sloane Integers Sequence A000170]
- What we learn from this experiments:
  - validate the workability of the infrastructure
  - validate the robustness of the infrastructure
  - hard to forecast machine's performances

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Mixing Desktops & Clusters [PARCO07]

Grid'BnB
Parallel BnB Framework for Grid

P2P Infrastructure
as Grid Midlleware

Mixing Desktops & Clusters [PARCO07]

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Parallel BnB Framework for Grid

+

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API for solving COPs &
Dynamic Grid Infrastructure

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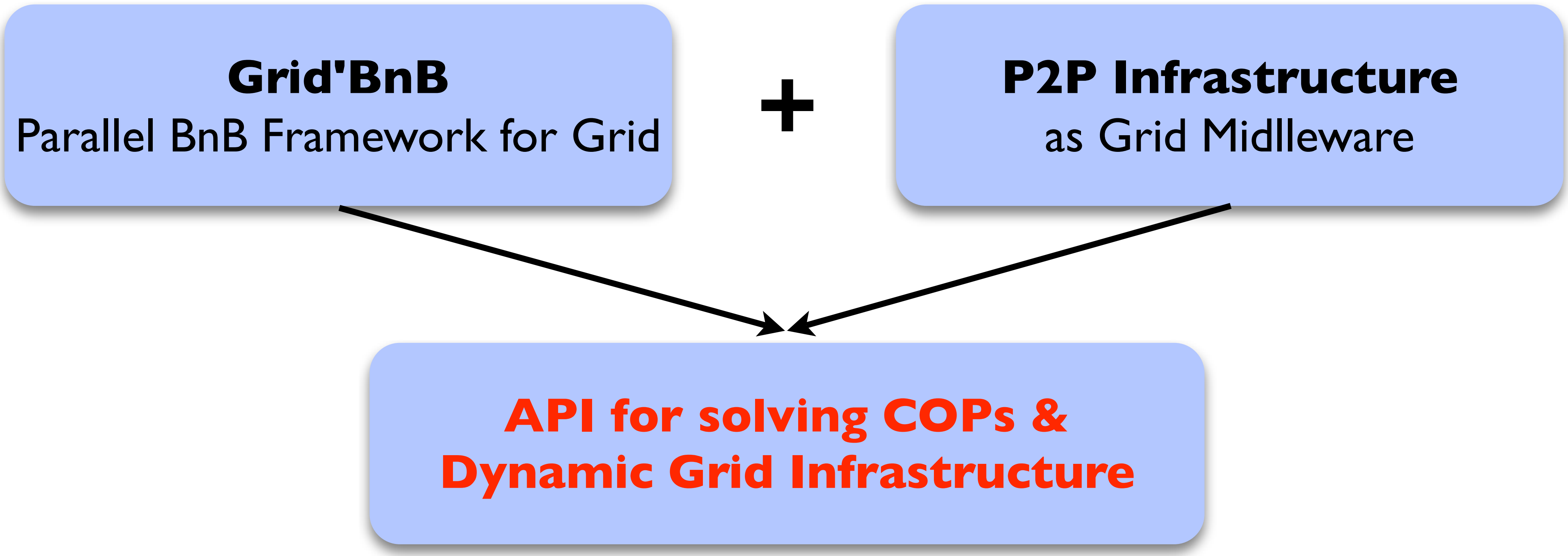
Mixing Desktops & Clusters [PARCO07]



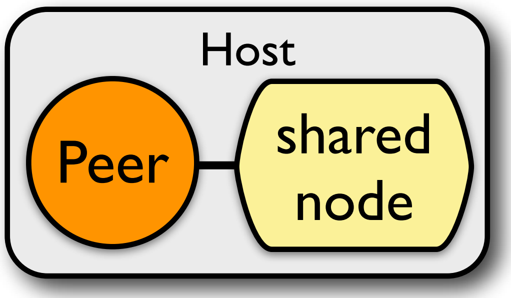
Validate by experiments on a Grid of Desktops & Clusters

New Problems:

firewalls ➟ forwarder

sharing clusters with the P2P infrastructure

Sharing Cluster's Nodes with P2P



Peer sharing local node

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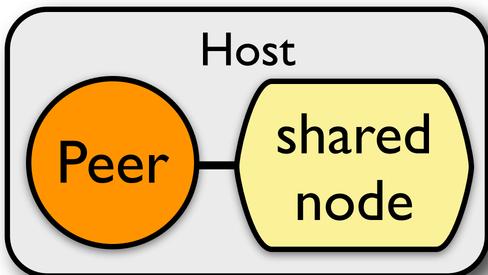

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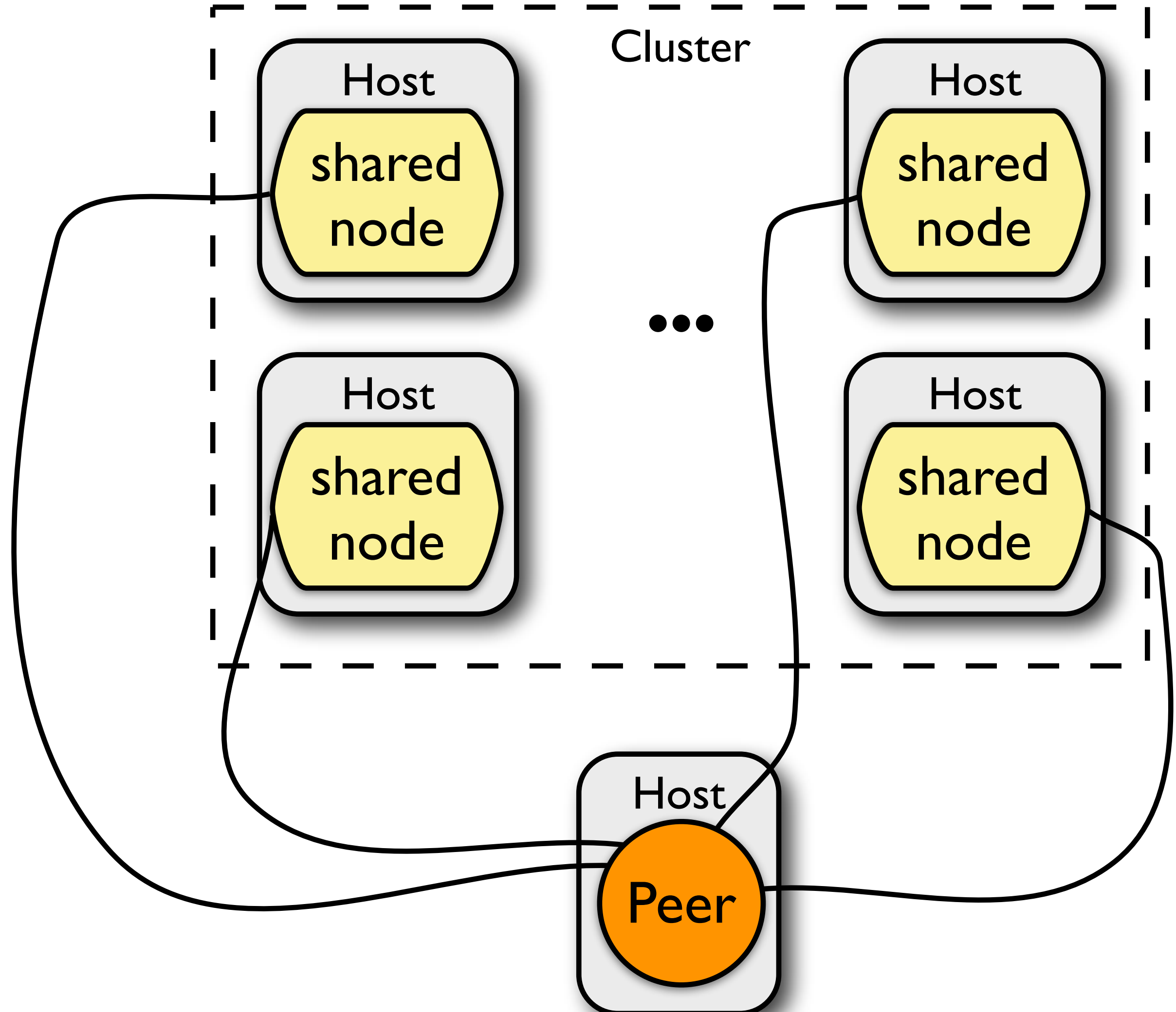
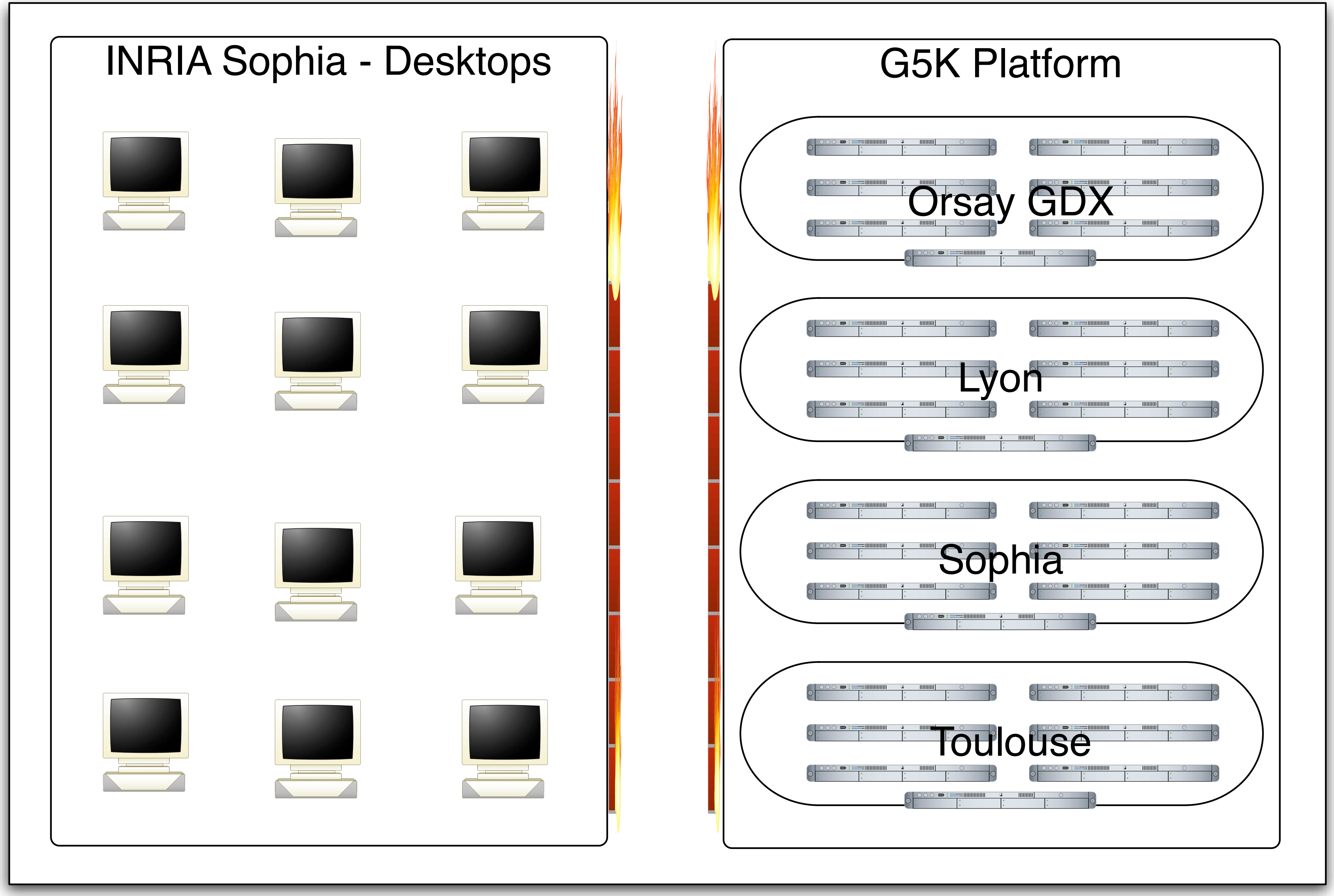


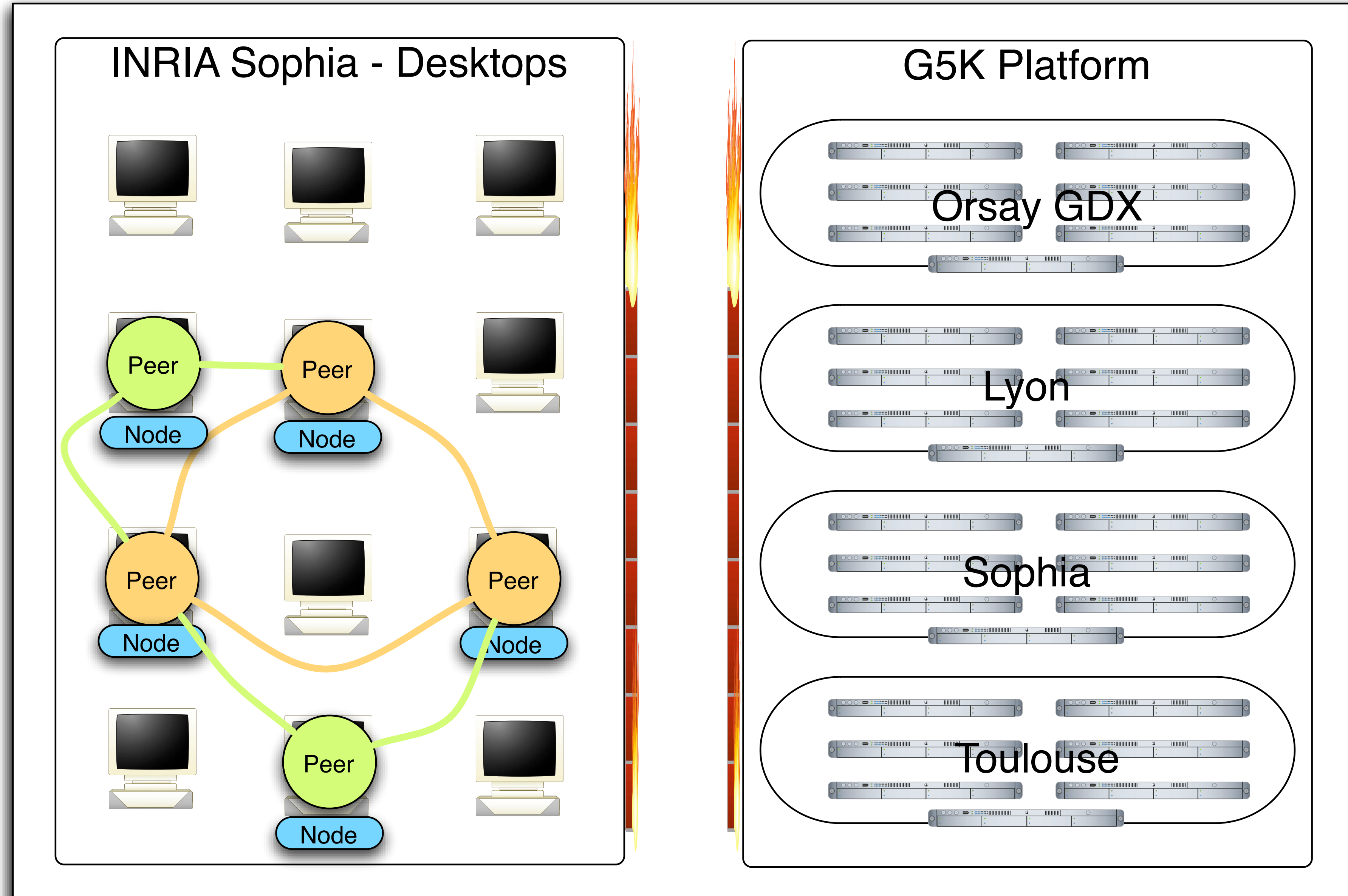
Peer sharing remote nodes

Testbed



INRIA Sophia - Desktops
G5K Platform
Orsay GDX
Lyon
Sophia
Toulouse

Testbed



INRIA Sophia - Desktops
Peer
Node
Peer
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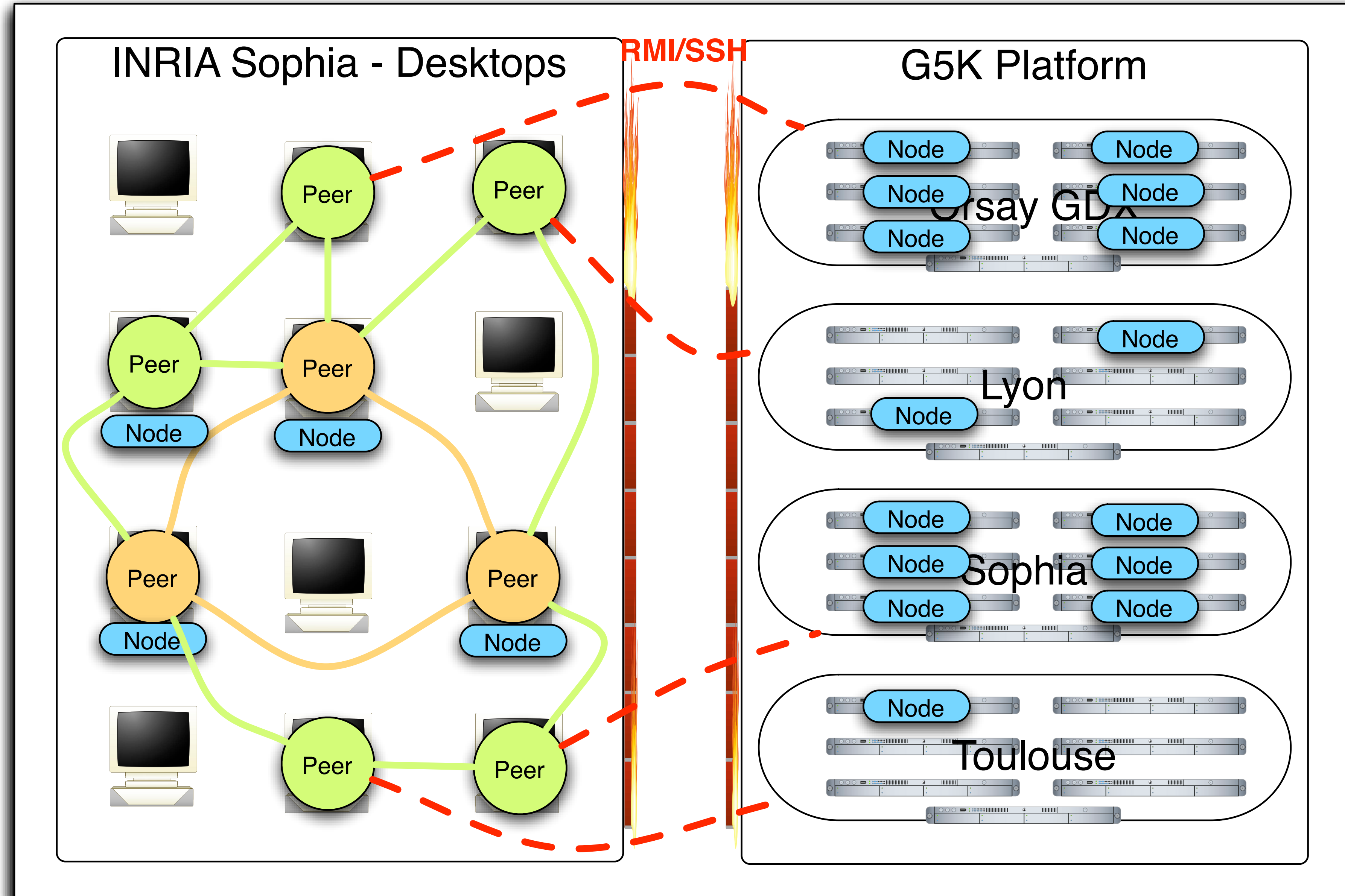

INRIA Sophia - Desktops
RMI/SSH
G5K Platform
Peer
Peer
Peer
Peer
Node
Peer
Node
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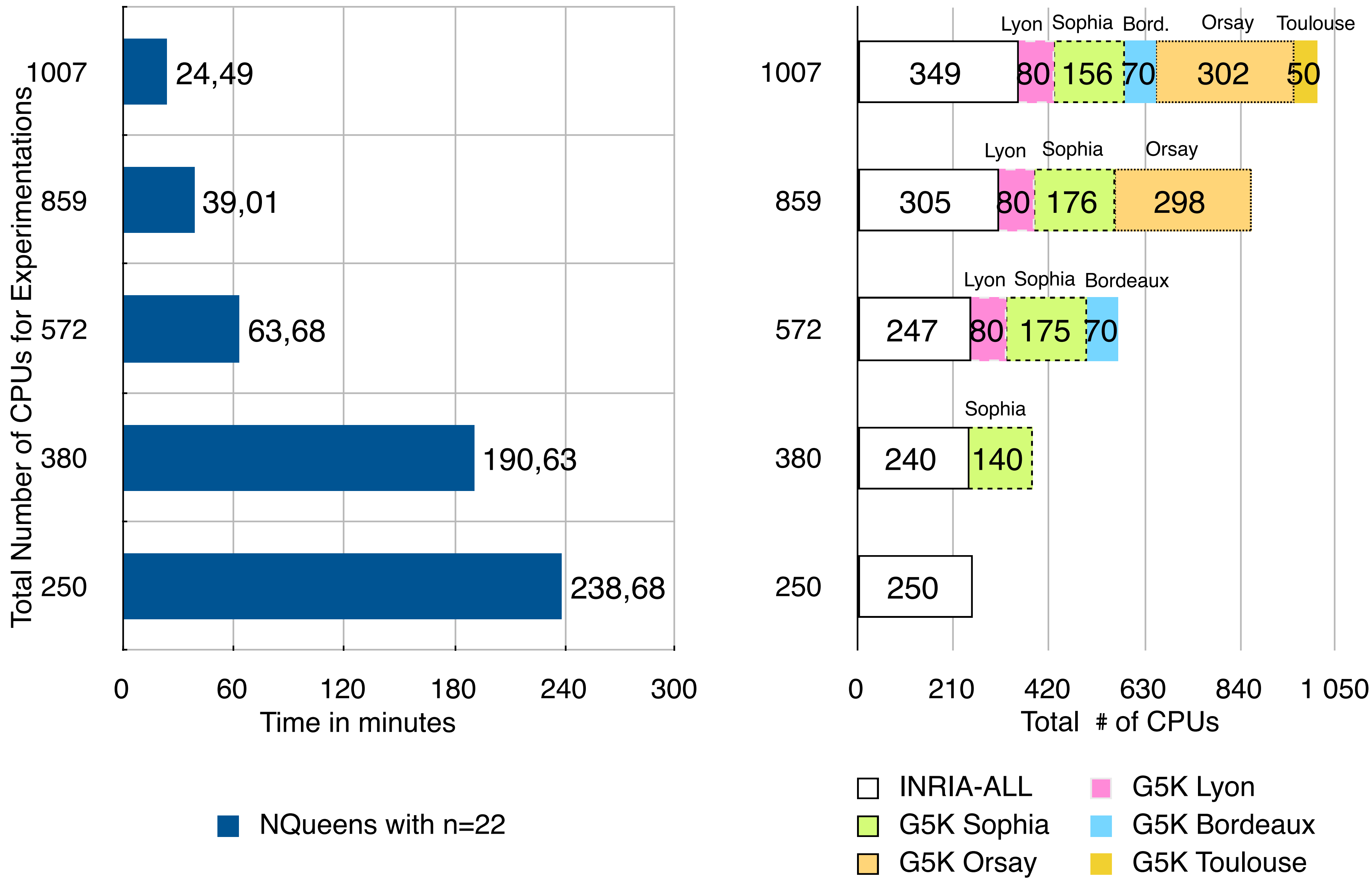
Large-Scale Experiments

- **Goal**: validate the infrastructure by experiments
- With **n-queens**:
  - no communication between workers
  - test the workability of the infrastructure
- With **flow-shop**:
  - communications between workers
  - test solving COPs

N-Queens Results



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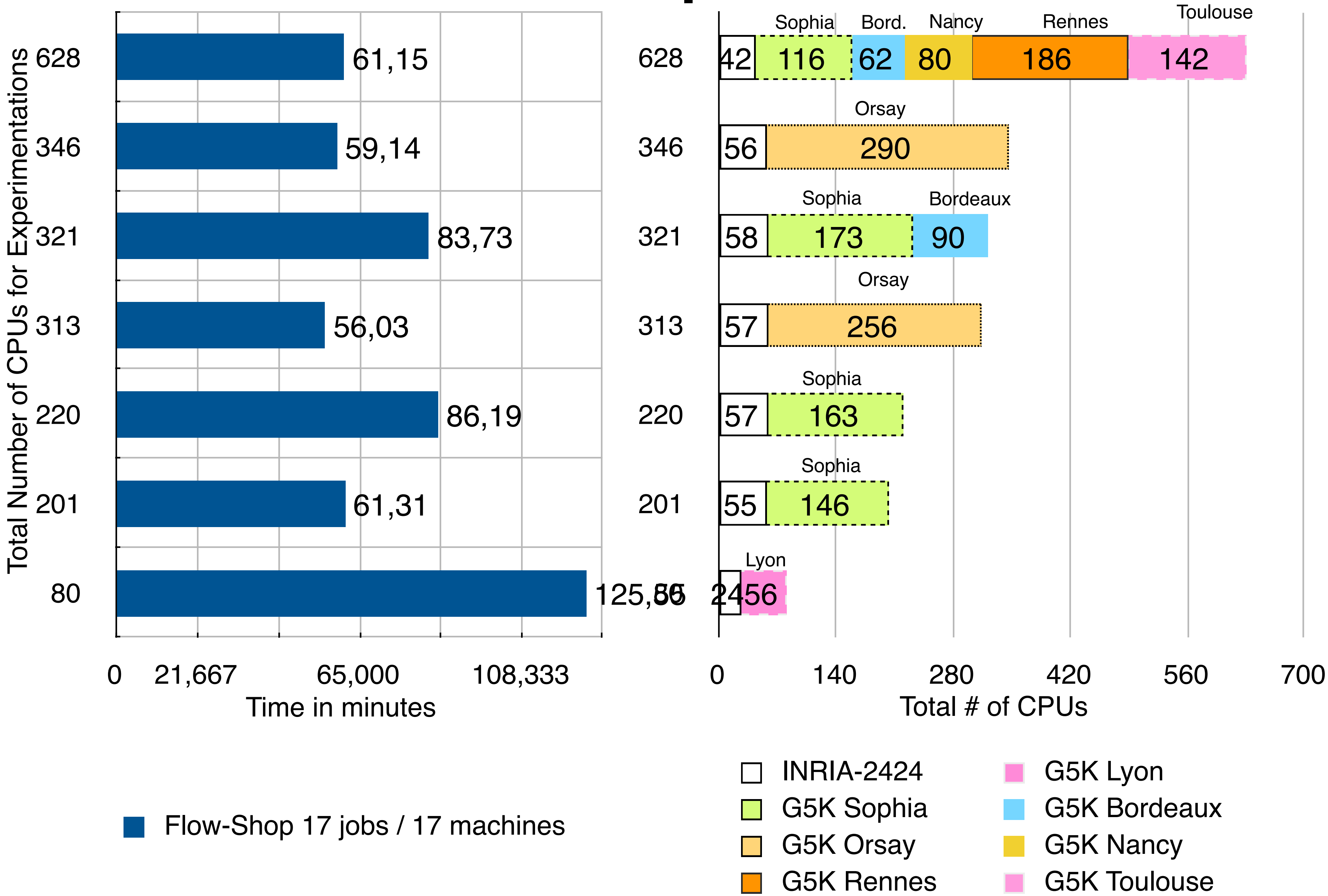

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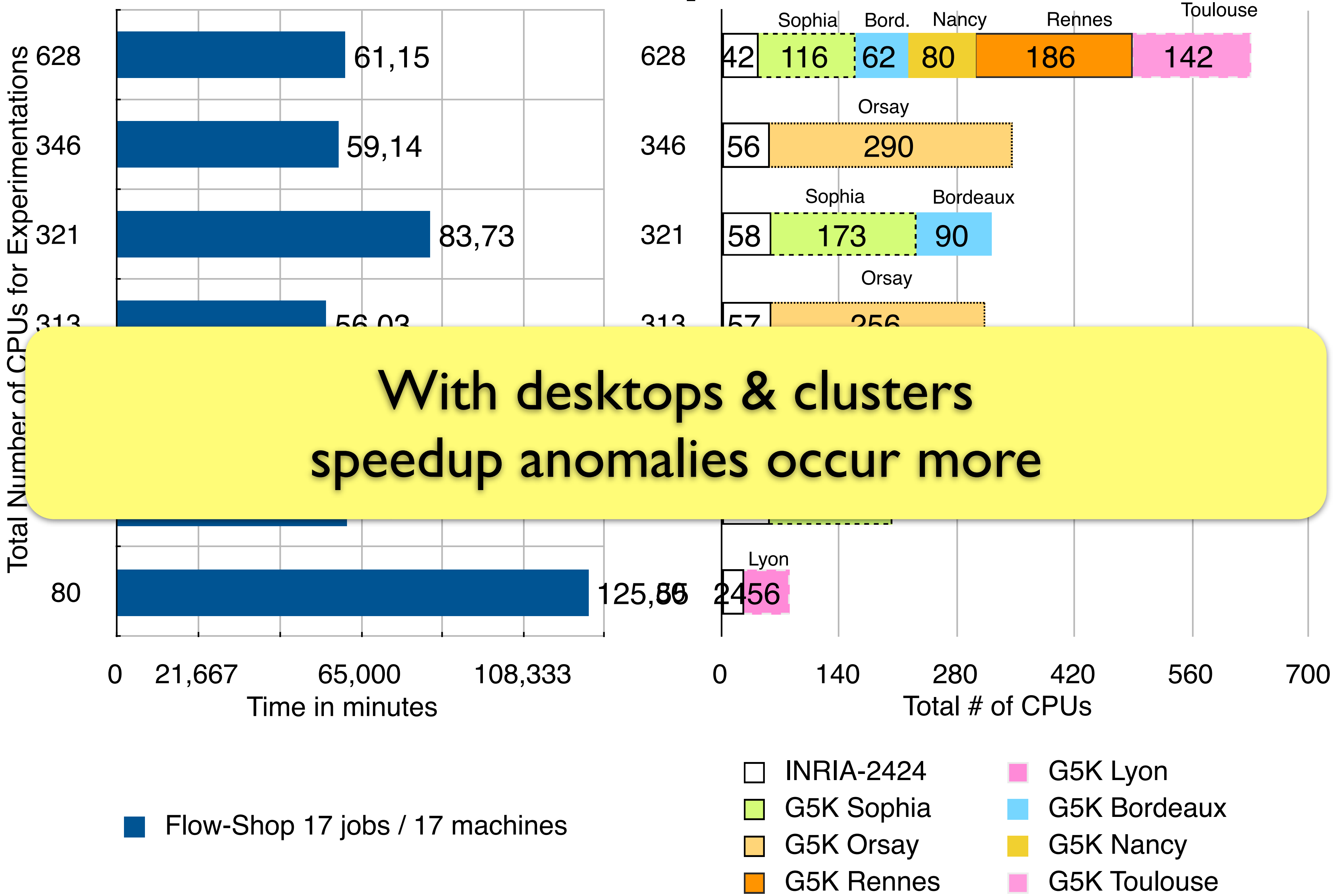

With desktops & clusters speedup anomalies occur more

Mixing - Analysis

- N-Queens problem scales well up to 1007 CPUs
  - 349 Desktops + 5 Clusters
- Flow-Shop up to 628 CPUs
  - 42 Desktops + 5 Clusters
  - worse performances than using only clusters (anomalies are more frequents)
- Experimented in closed environments -- security

- Grid'5000 platform's success ➟ hard for running long exp.

P2P as a Meta-Grid infrastructure

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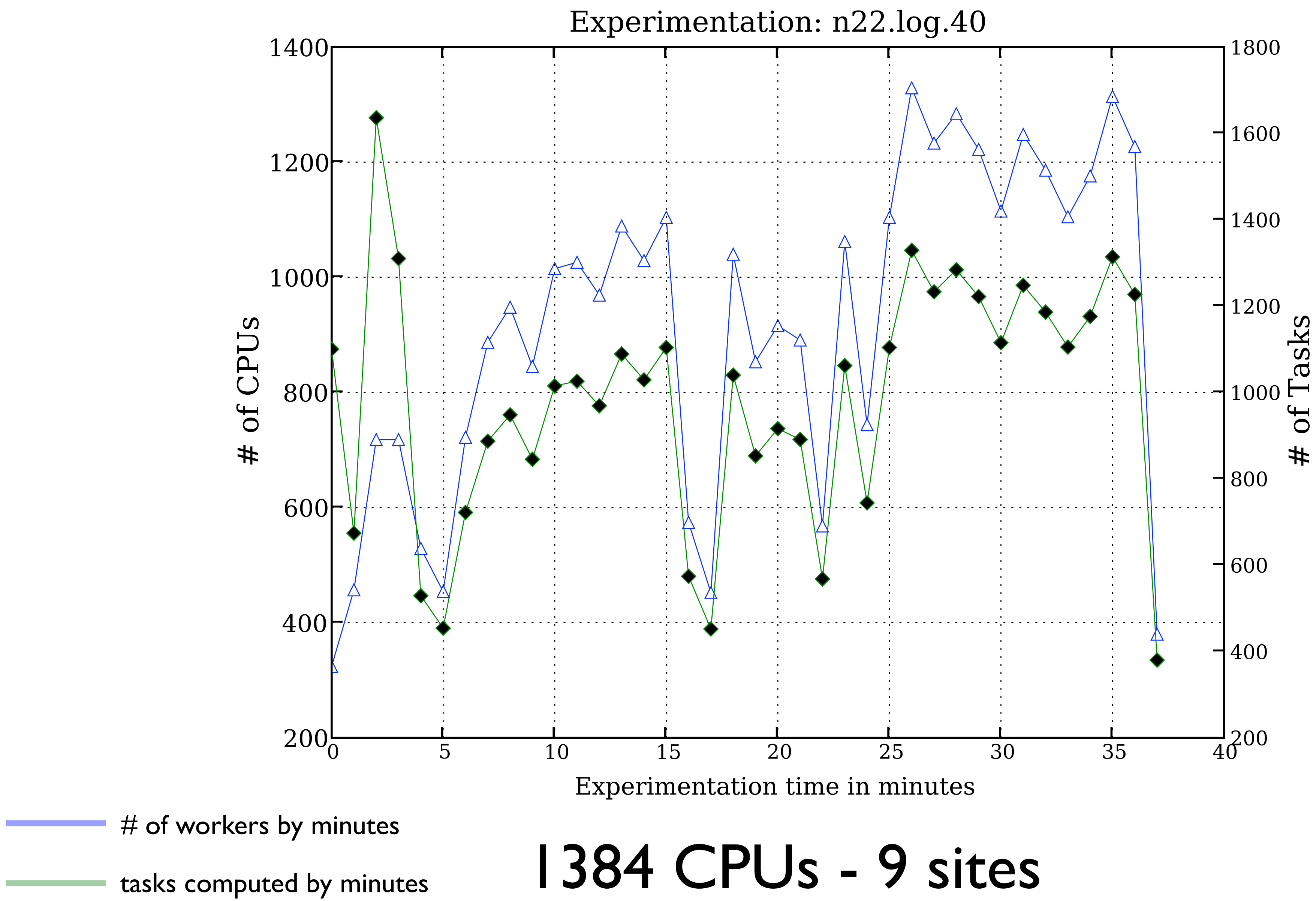
P2P infrastructure as a dynamic Grid middleware

P2P with N-Queens on Grid'5000



1384 CPUs - 9 sites

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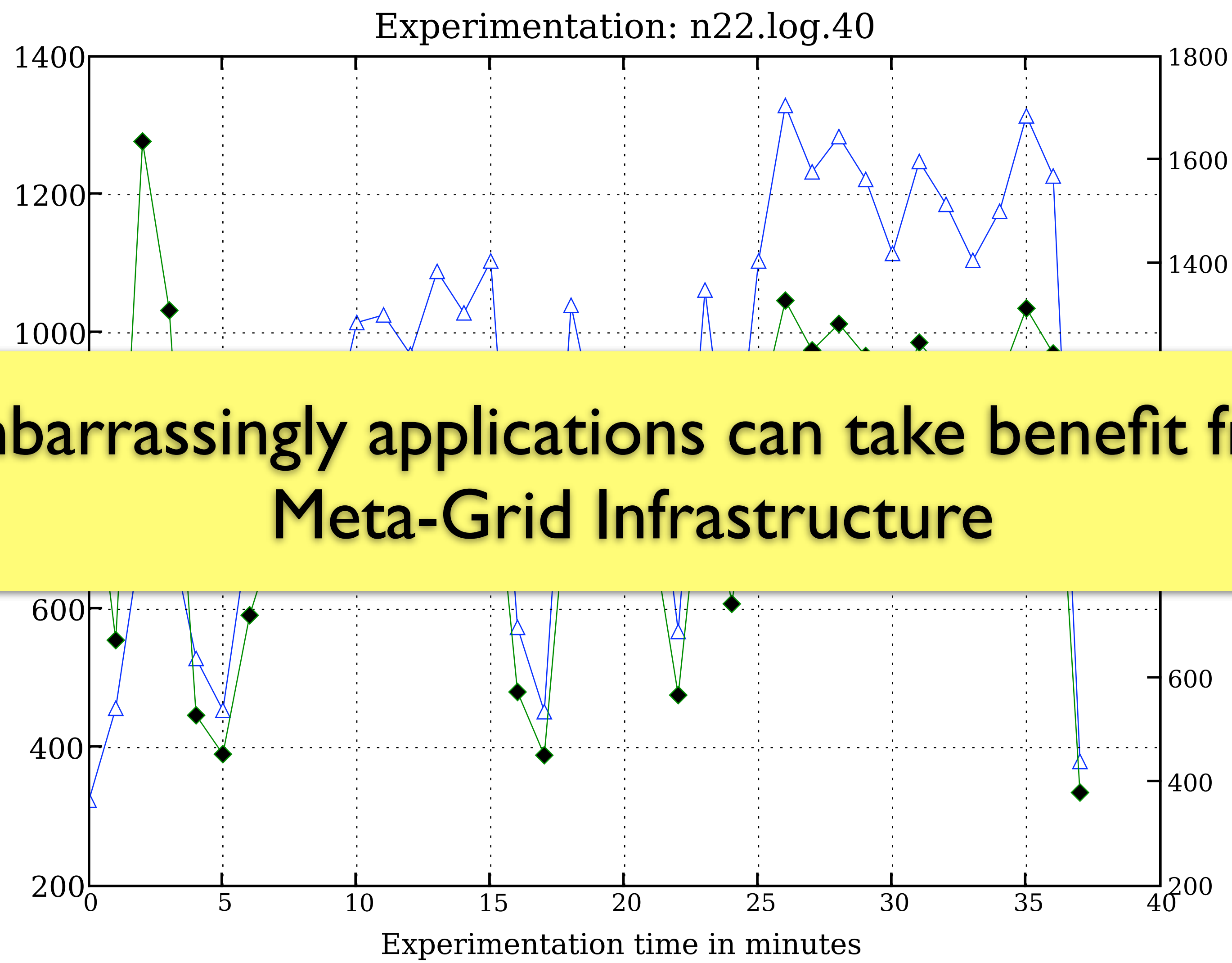

Embarrassingly applications can take benefit from Meta-Grid Infrastructure

# of workers by minutes

tasks computed by minutes

1384 CPUs - 9 sites

Agenda

- Context, Problem, and Related Work
- Contributions
  - Branch-and-Bound Framework for Grids
  - Desktop Grid with Peer-to-Peer
  - Mixing Desktops & Clusters
- Perspectives & Conclusion

Summary

- Grid'BnB: a BnB framework for Grids
  - communication between workers
  - organizing workers in groups
- Grid infrastructure
  - based on P2P architecture
  - mixing desktops and clusters
  - deployed at INRIA Sophia lab

Perspectives

- Peer-to-Peer Infrastructure:
  - Job Scheduler
  - Resource Localization (PhD)
- Large-Scale Experiments:
  - International Grid: France, Japan, and Netherlands
  - Grid Pugtests
- Deployment:
  - Contracts in Grids (GCM Standard)
- Industrialization:
  - P2P ➟ Desktop Resource Virtualization
- CPER - P2P
  - 1M€/4years to professionalize the INRIA Grid

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➟ **Provides framework and infrastructure to hide Grid difficulties**

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