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

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Grid Computing and Distributed Systems (GRIDs) Laboratory
Department of Computer Science and Software Engineering

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Monday 2 June 2008

Agenda

- About Me / Previous Experience
- PhD Main Contributions
  - Branch-and-Bound Framework for Grids
  - Desktop Grid with Peer-to-Peer
  - Mixing Desktops & Clusters
  - Perspectives
- Possible Support & Conclusion

About Me

- June 2004 **Master in Networking and Distributed Systems**
  - INRIA Sophia Antipolis - OASIS research group / University of Nice Sophia Antipolis, France
  - *"P2P Model and Infrastructure for Communicating Applications"*, supervised by Prof. Denis Caromel
- July-September 2004 **Internship at Indiana University, USA**
  - *"Asynchronous Peer-to-Peer Web Services and Firewalls"*, supervised by Prof. Dennis Gannon
- October 2007 **PhD in Computer Science**
  - INRIA Sophia Antipolis - OASIS research group / University of Nice Sophia Antipolis, France
  - *"Branch-and-Bound with Peer-to-Peer on Large-Scale Grids"*, supervised by Denis Caromel

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The Big Picture

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Solving combinatorial optimization problems with Grids

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2. **Peer-to-Peer Infrastructure for Grids**

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  3. **Large-scale experiments**

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- Grid Computing
  - large pool of resources
  - large-scale environment

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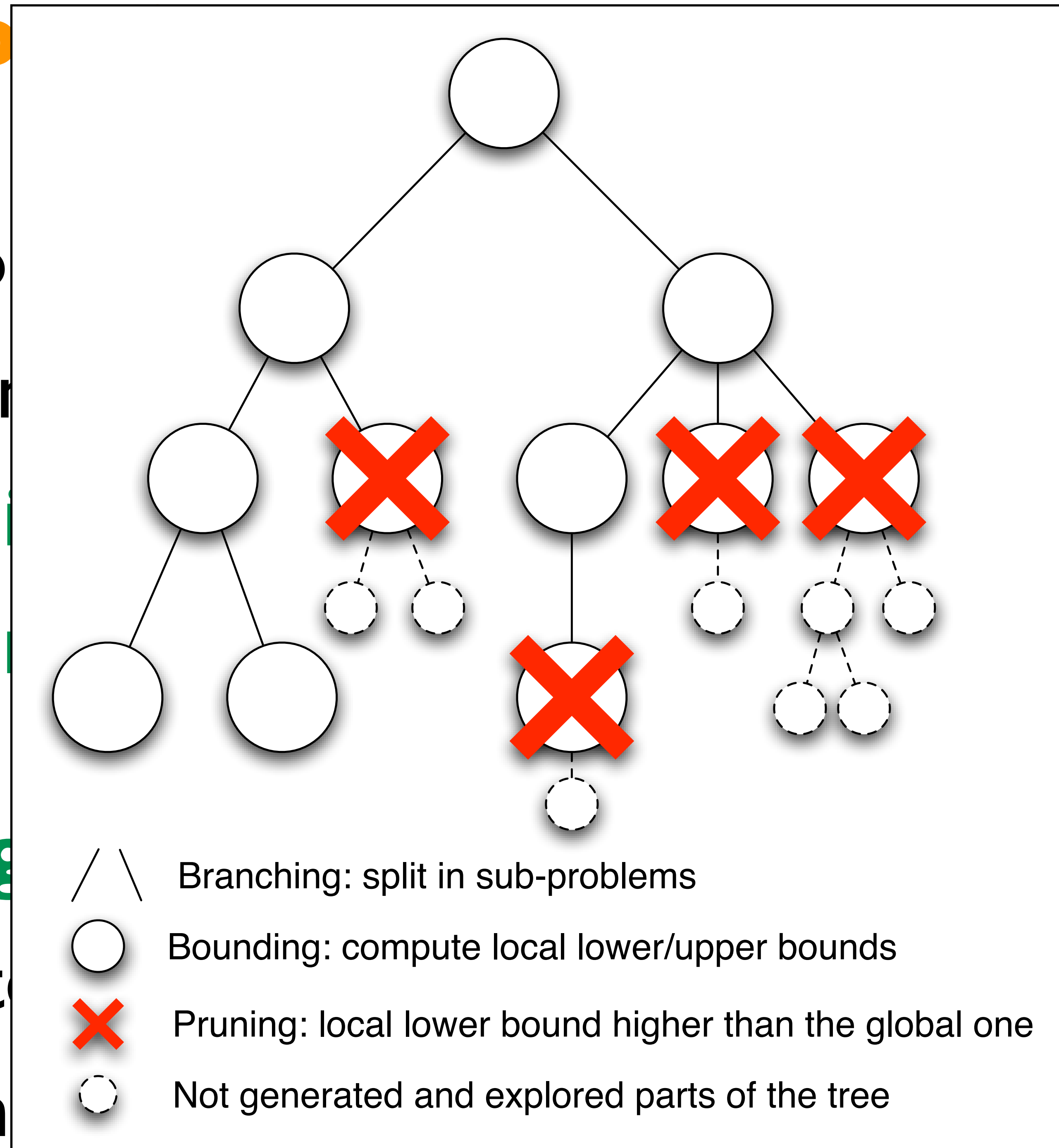

Grid Computing

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Grid Fabric

Schedulers, Networking, OS
Federated Hardware Resources

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Grid Applications & Portals

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Grid Computing
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Use Branch-and-Bound on Grids for solving COPs

Efficient communications with Grids is difficult
Problem with sharing bounds

BnB on Grids: Problems and Solutions

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Latency	

BnB on Grids: Problems and Solutions

Latency	Asynchronous communications

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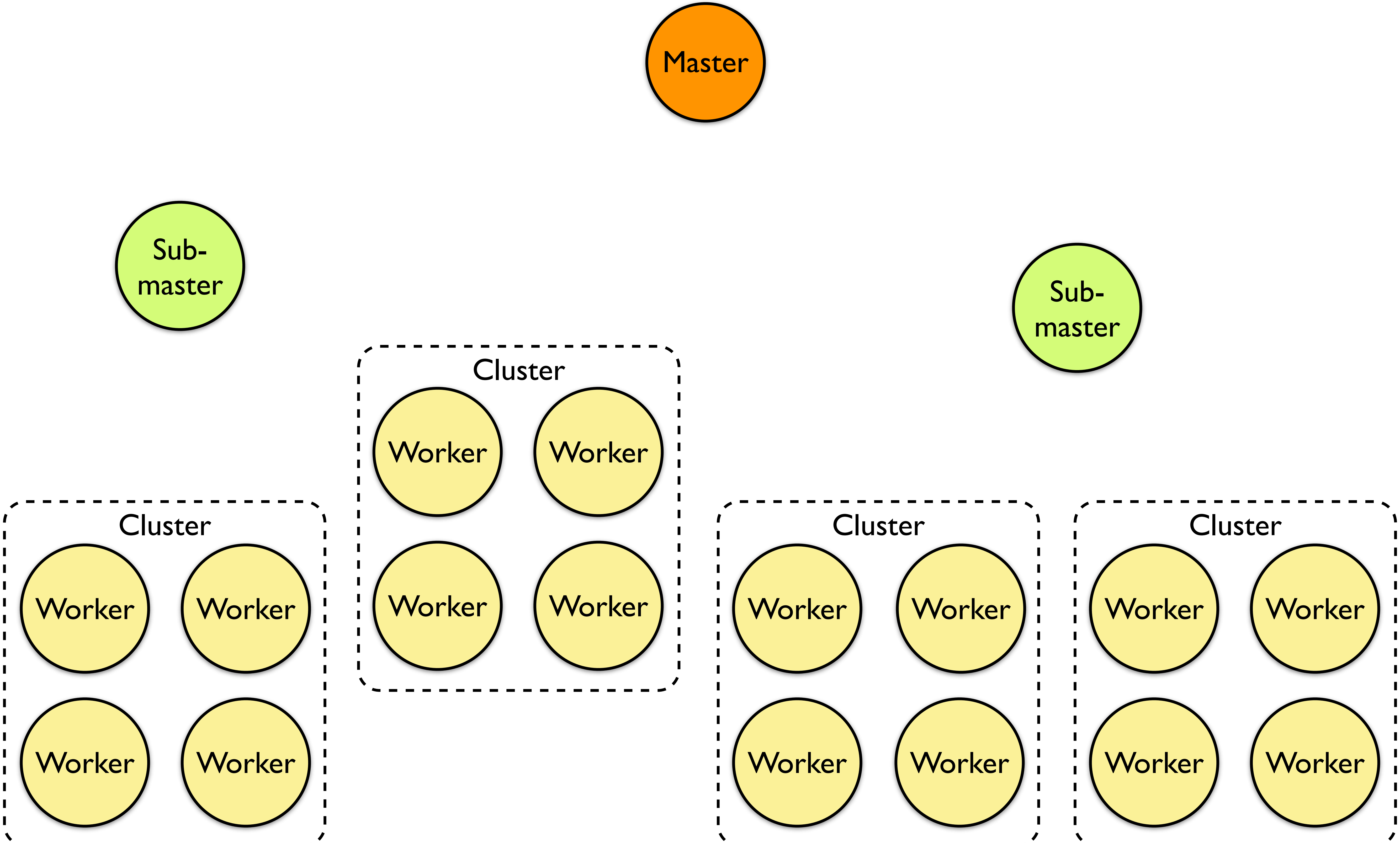
Objective: hide Grid difficulties to users
Especially communication problems

BnB Framework - Architecture



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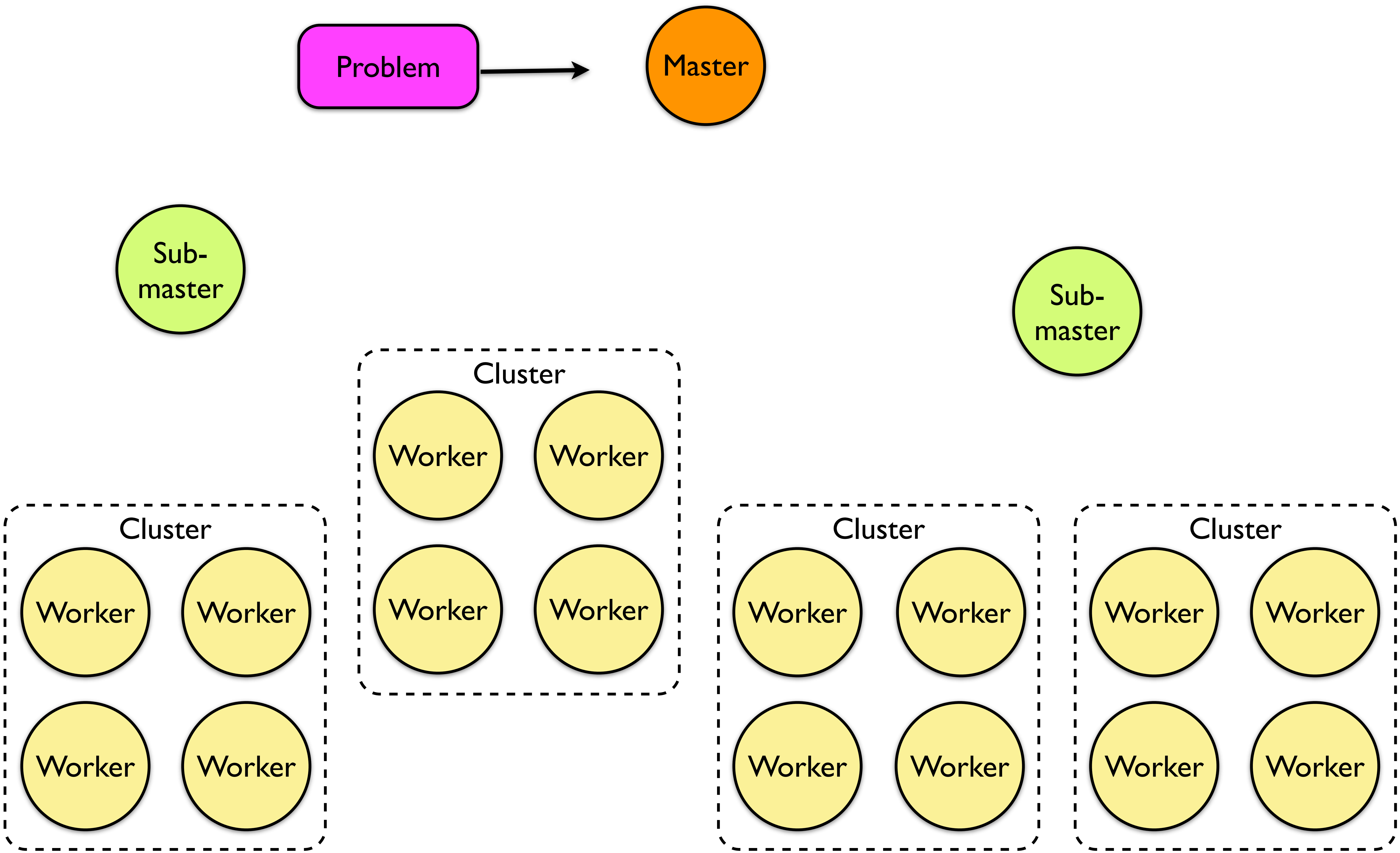

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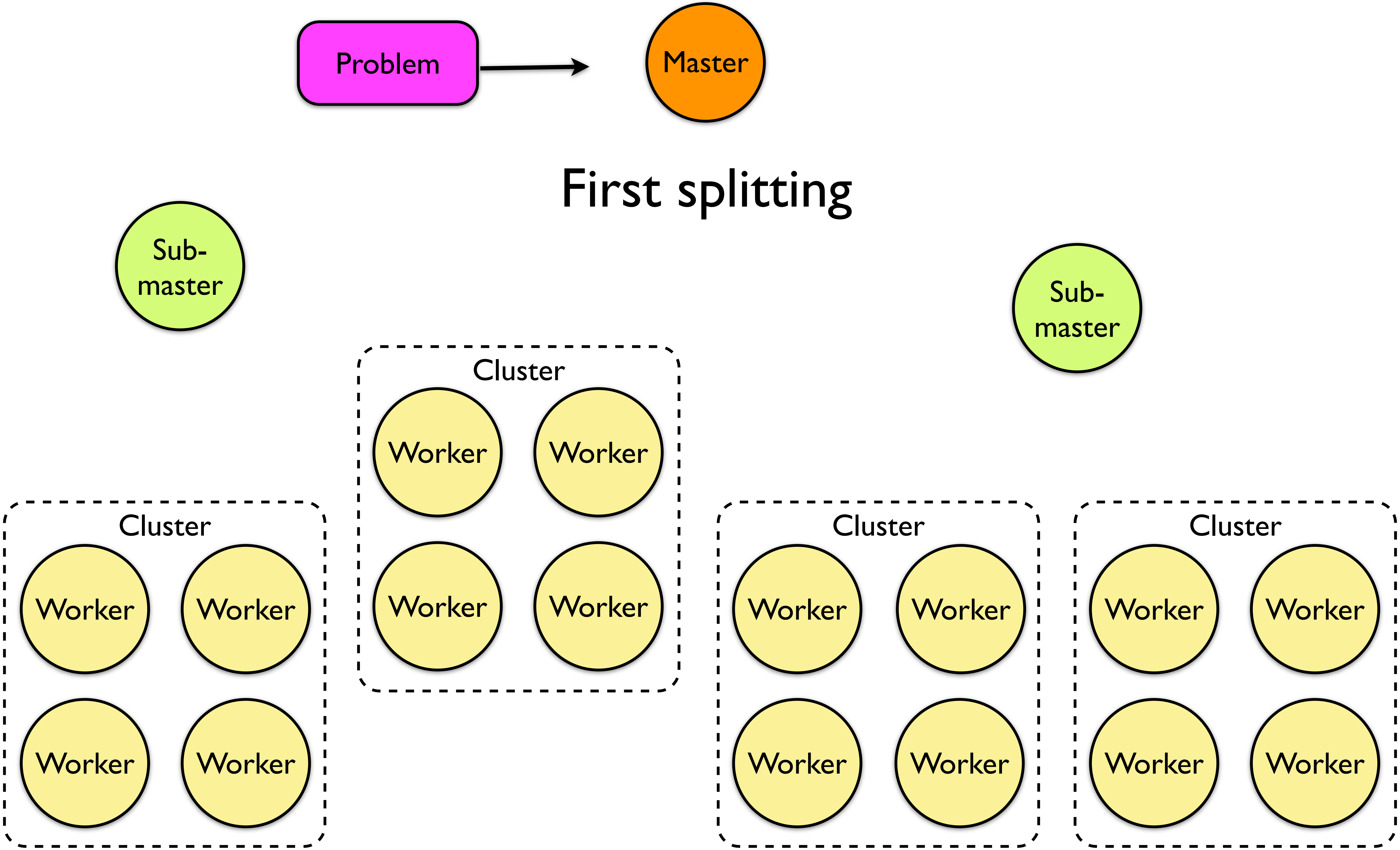

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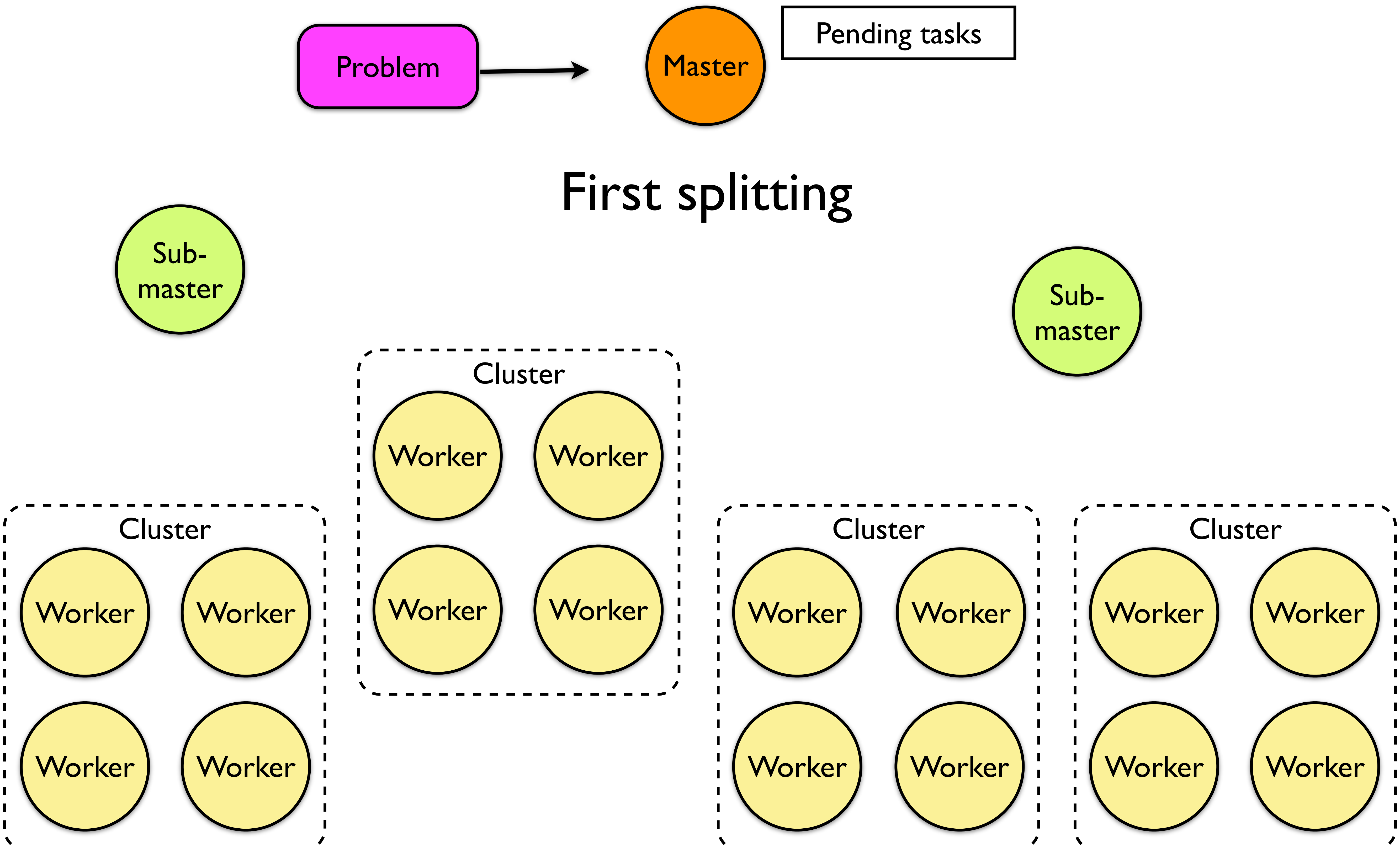

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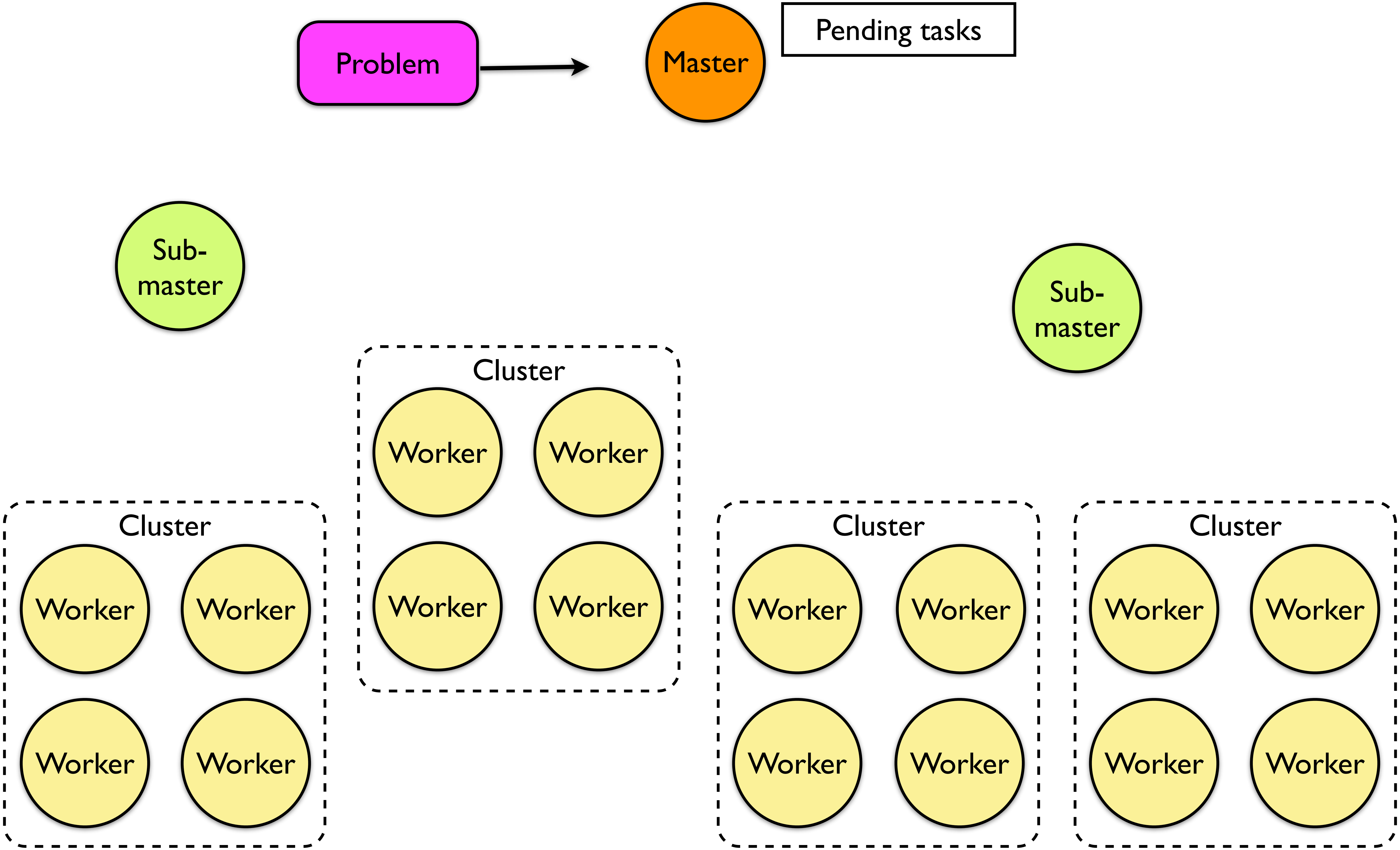

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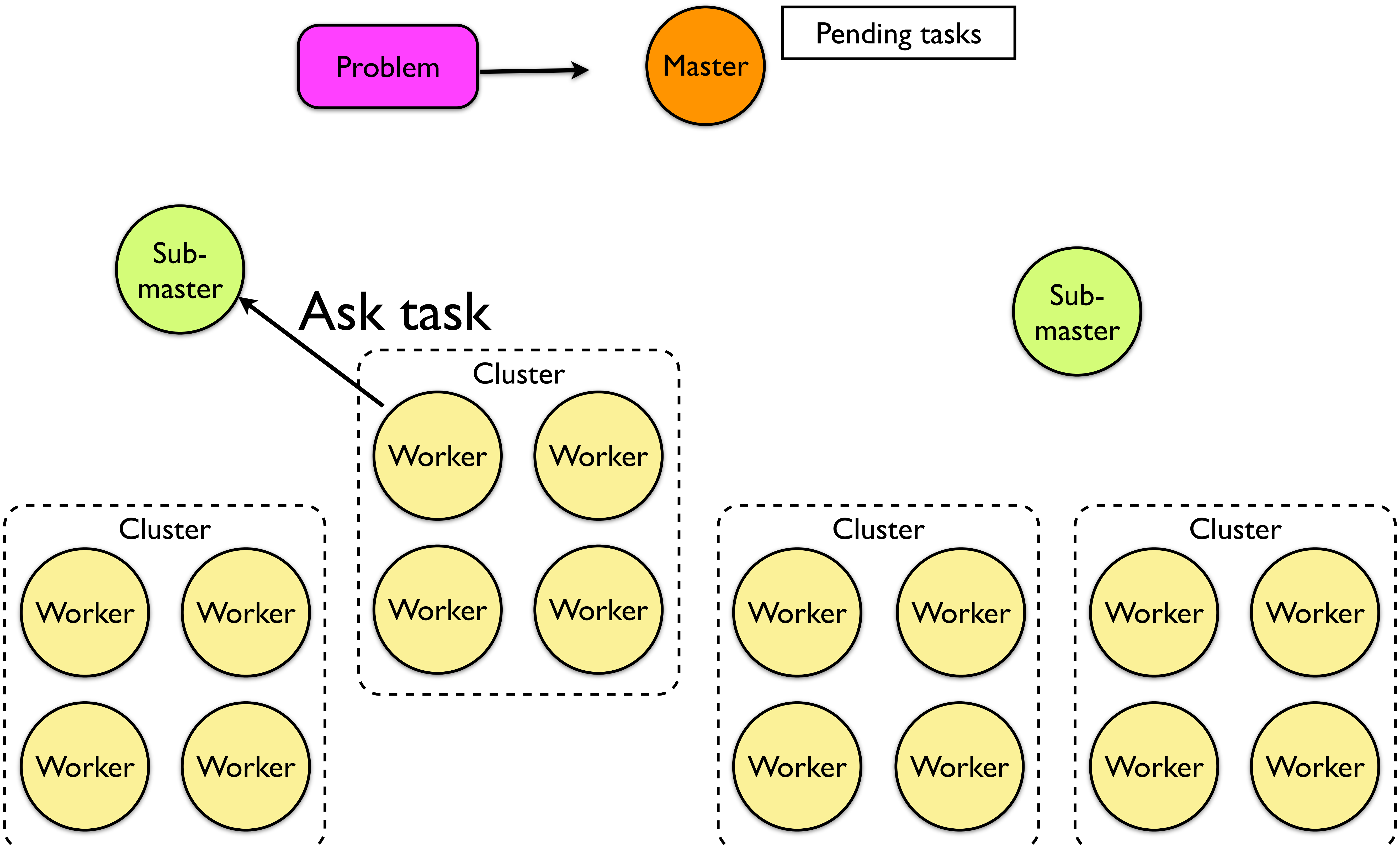

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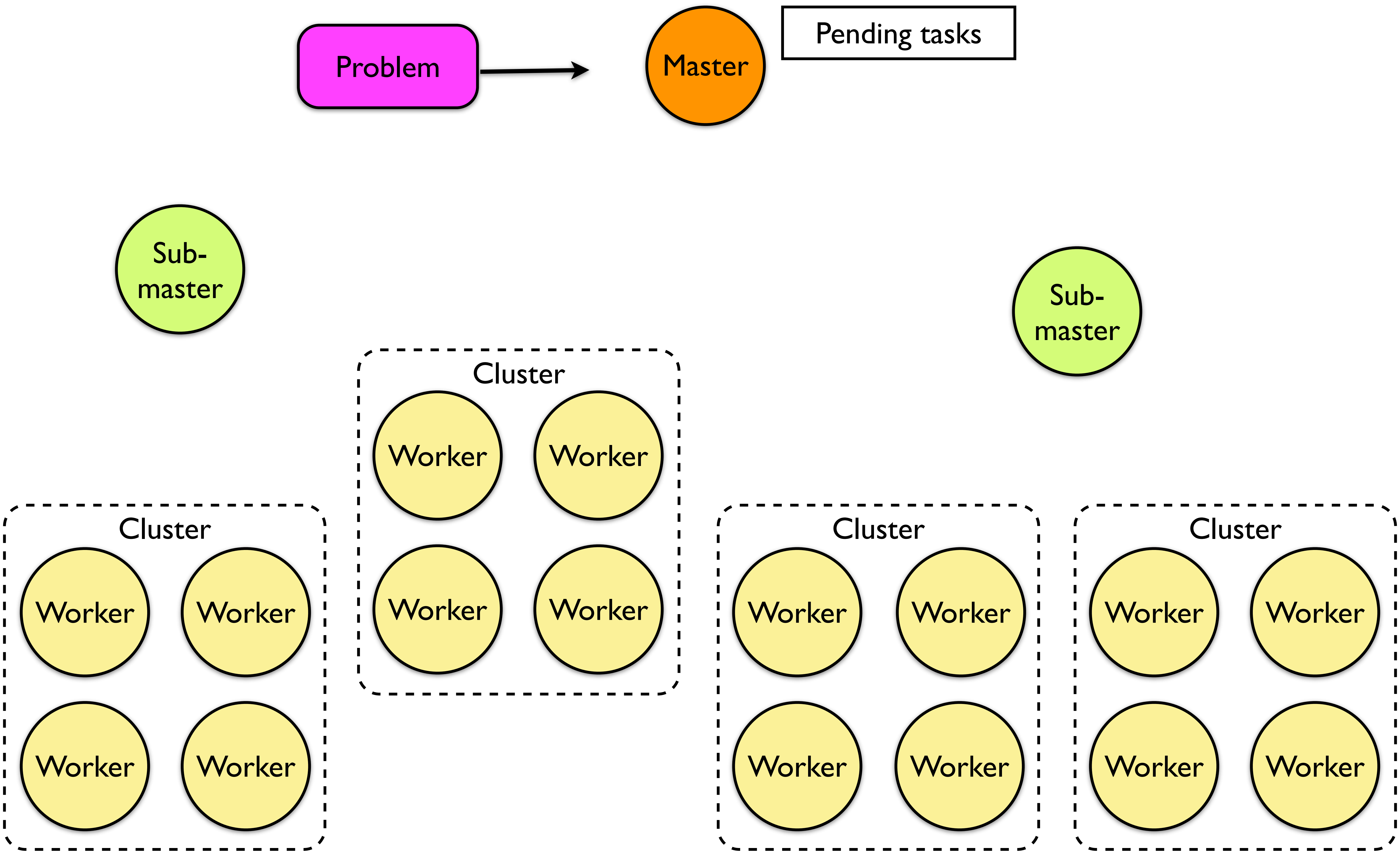

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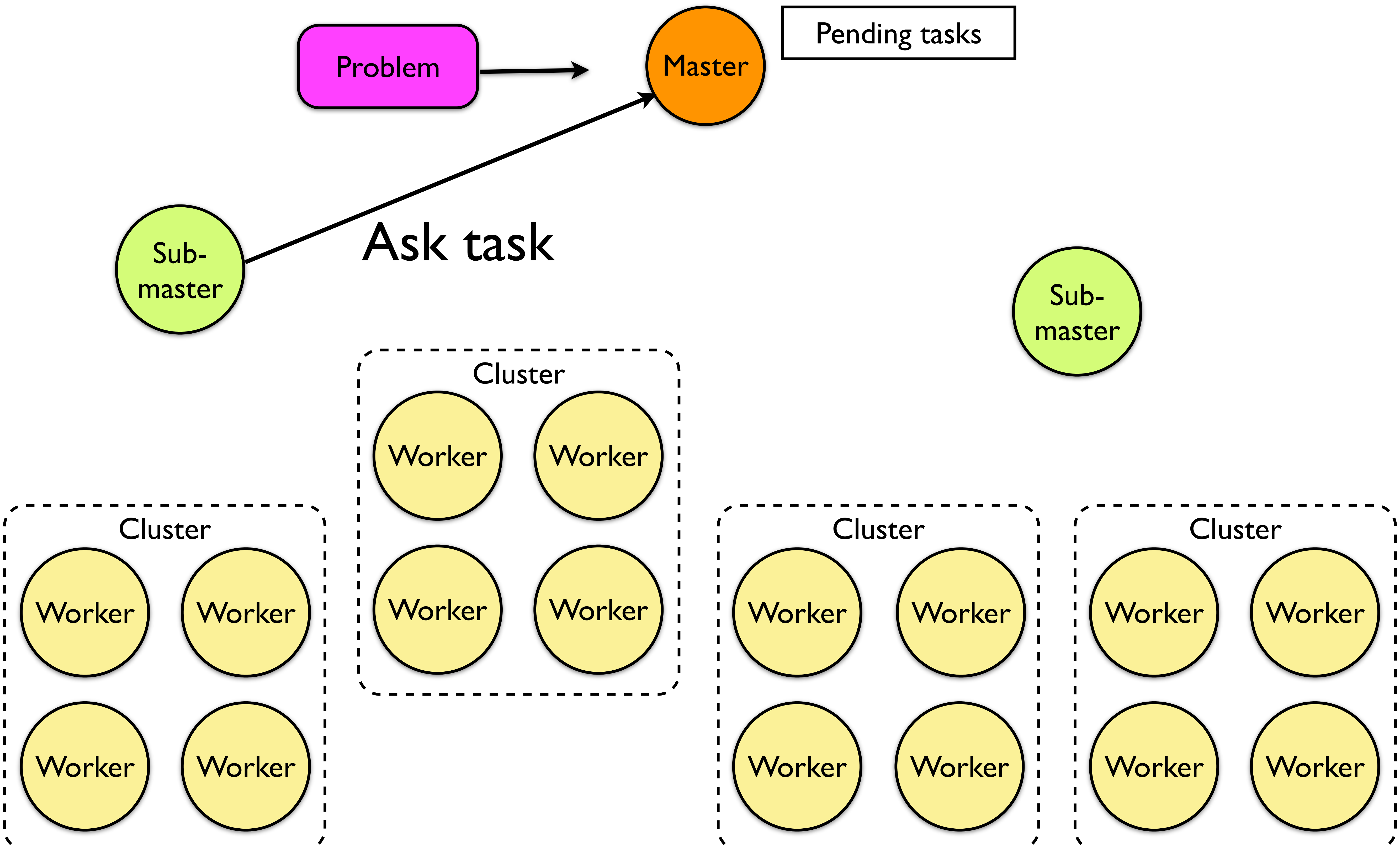

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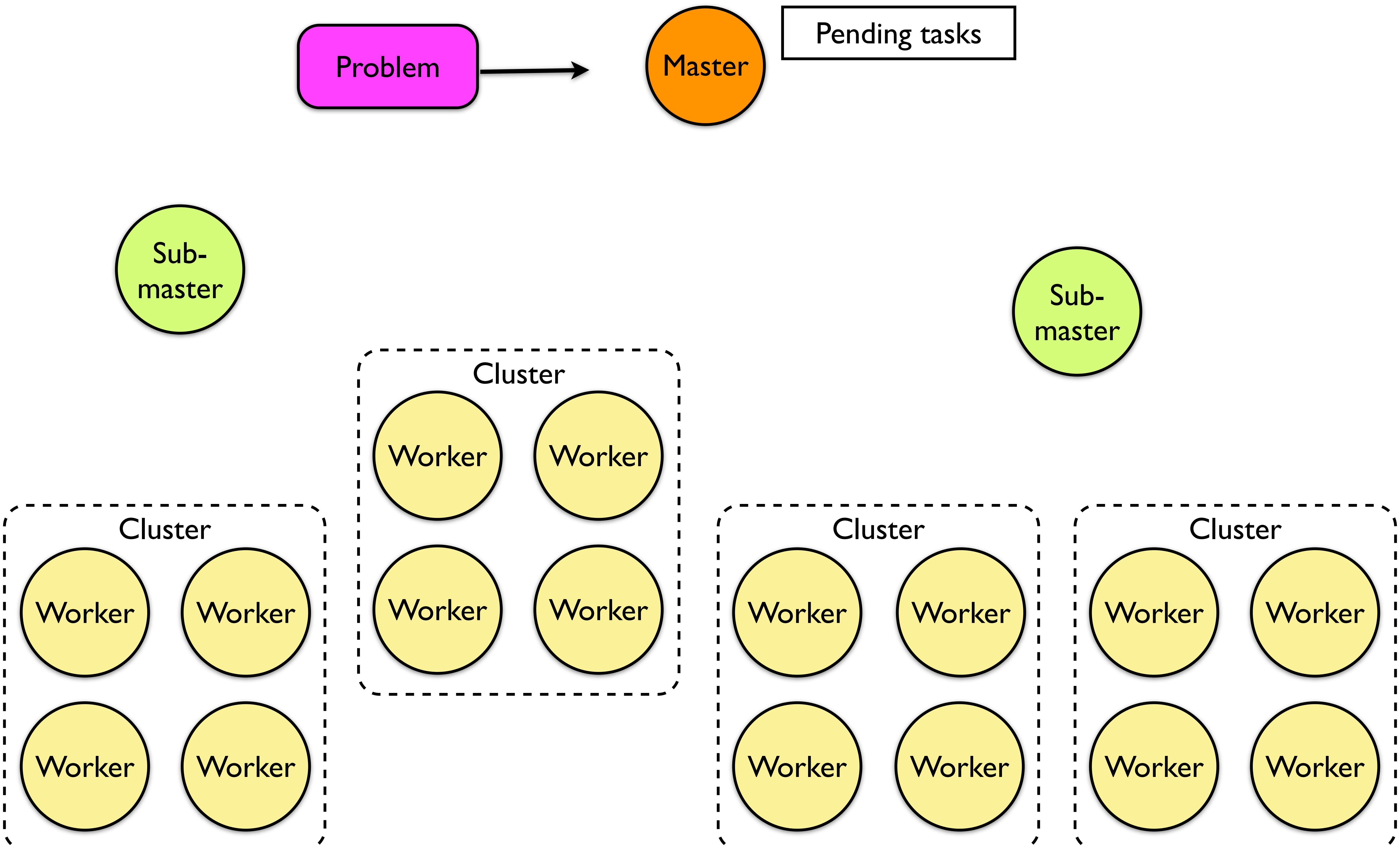

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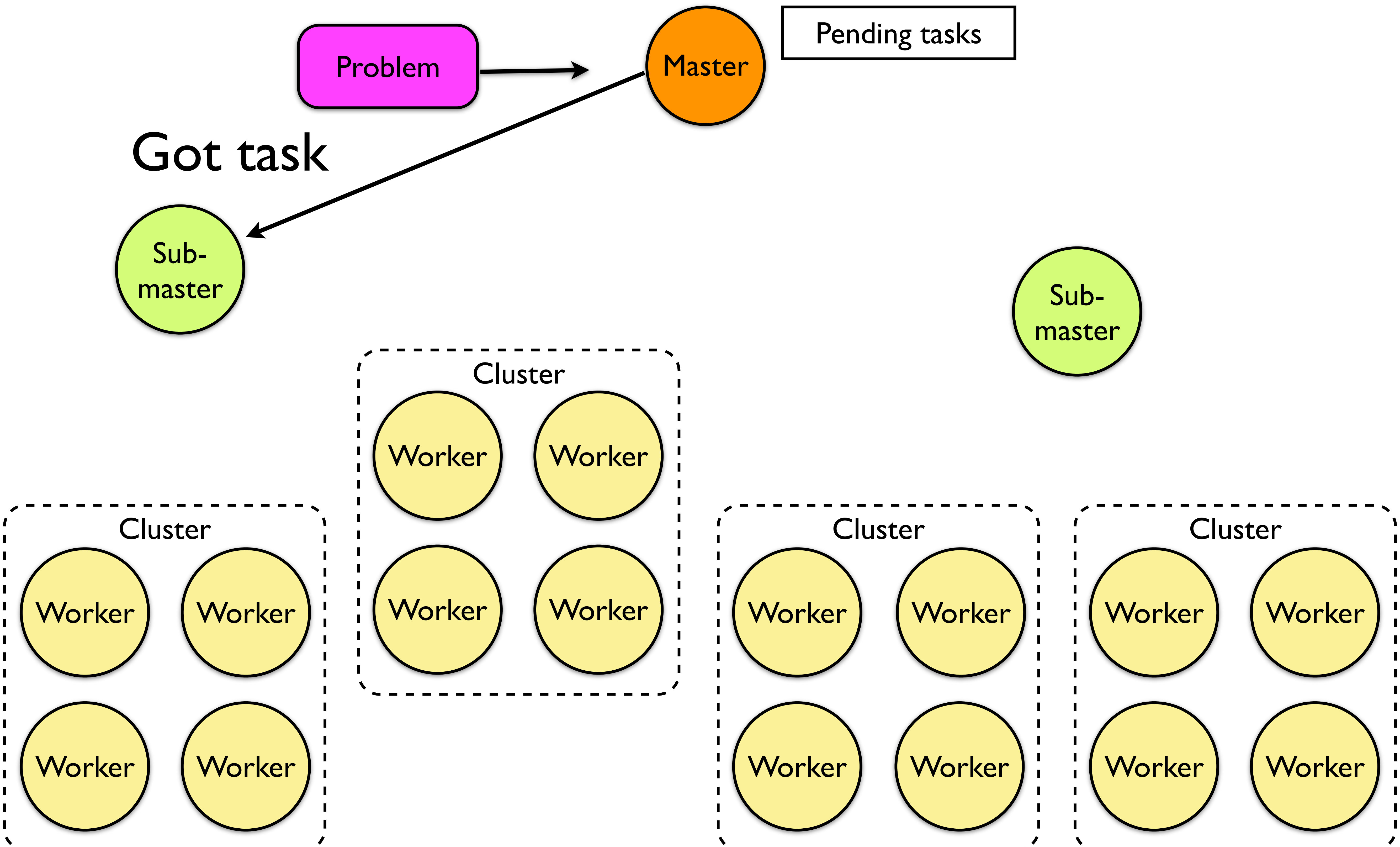

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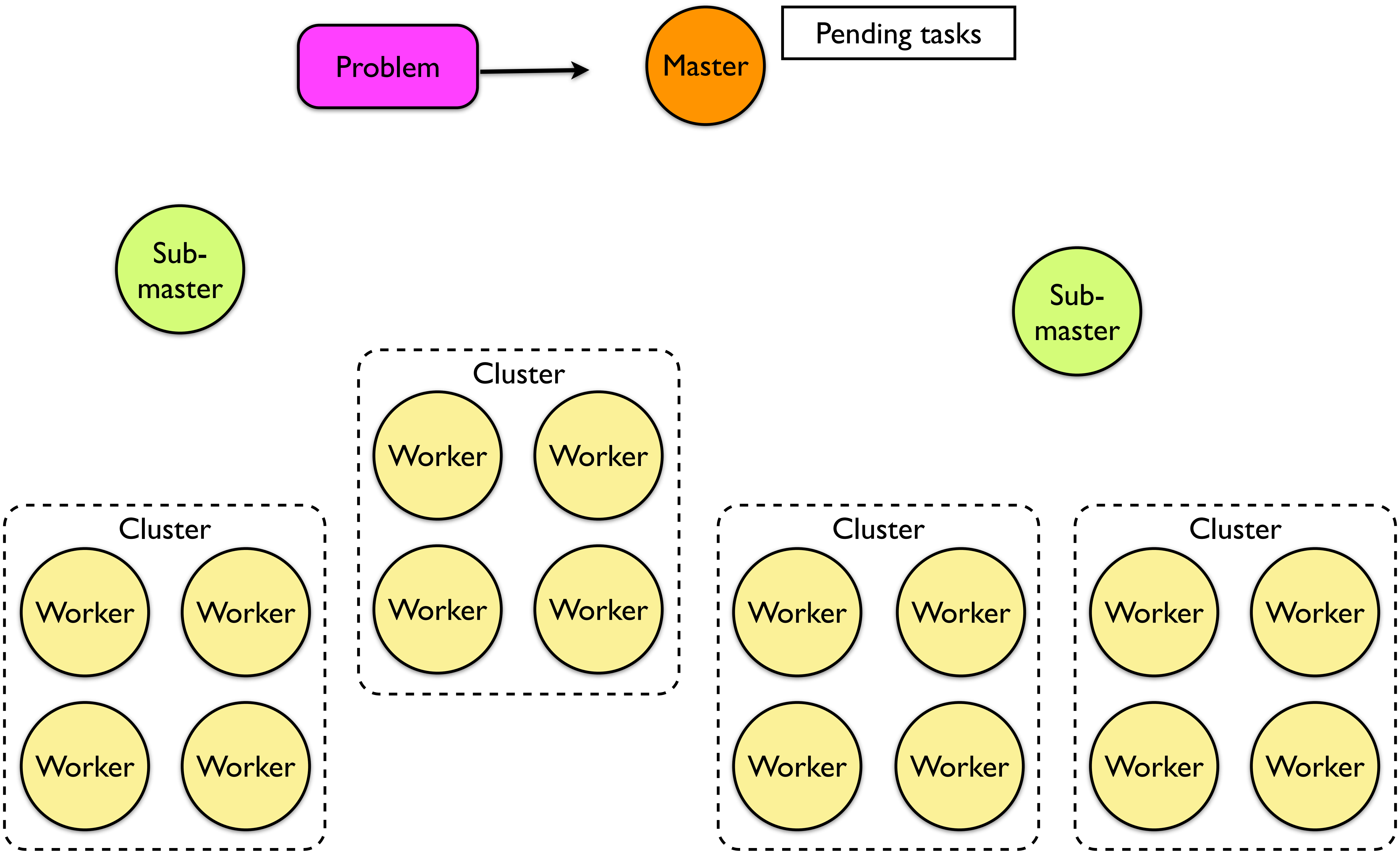

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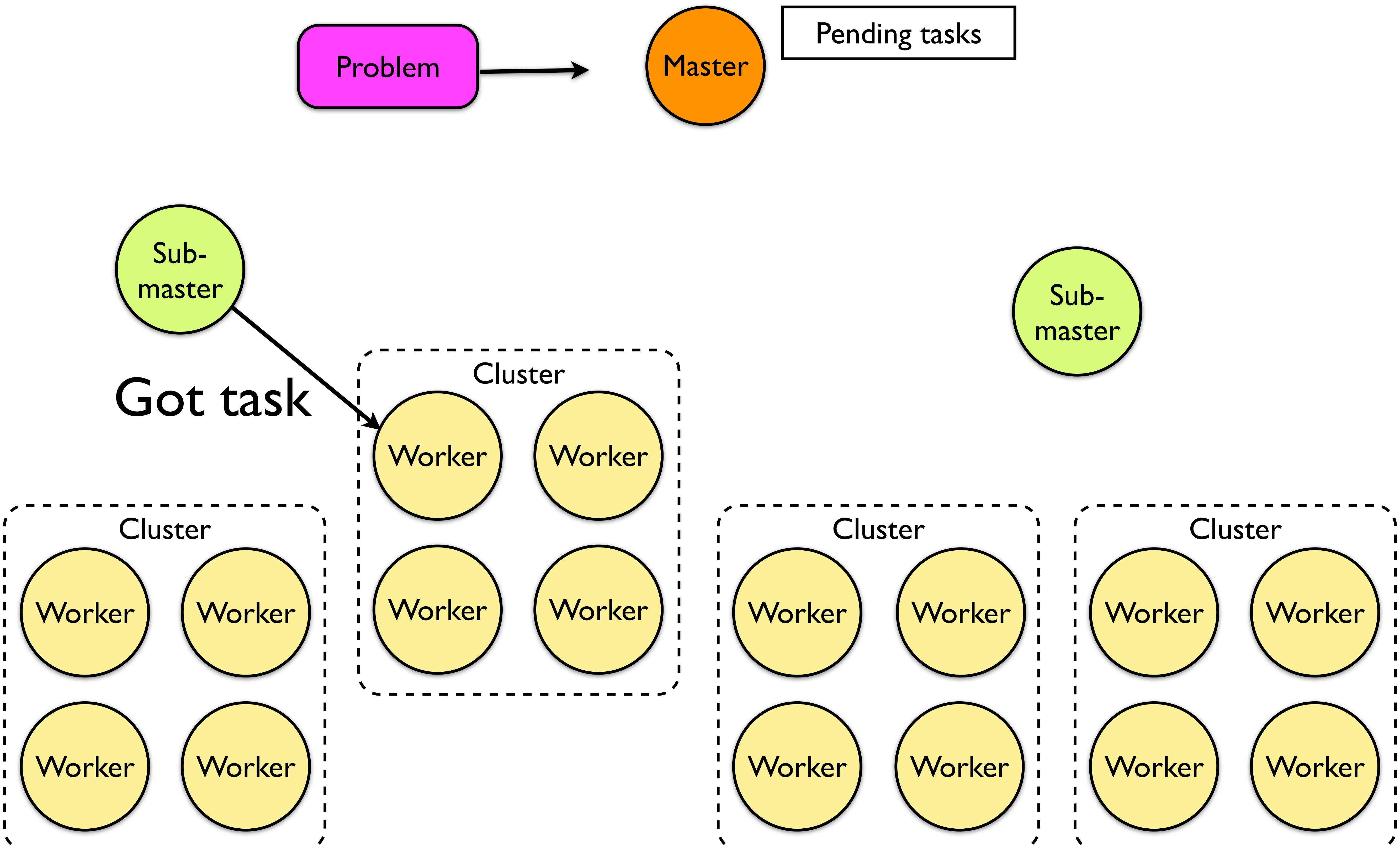

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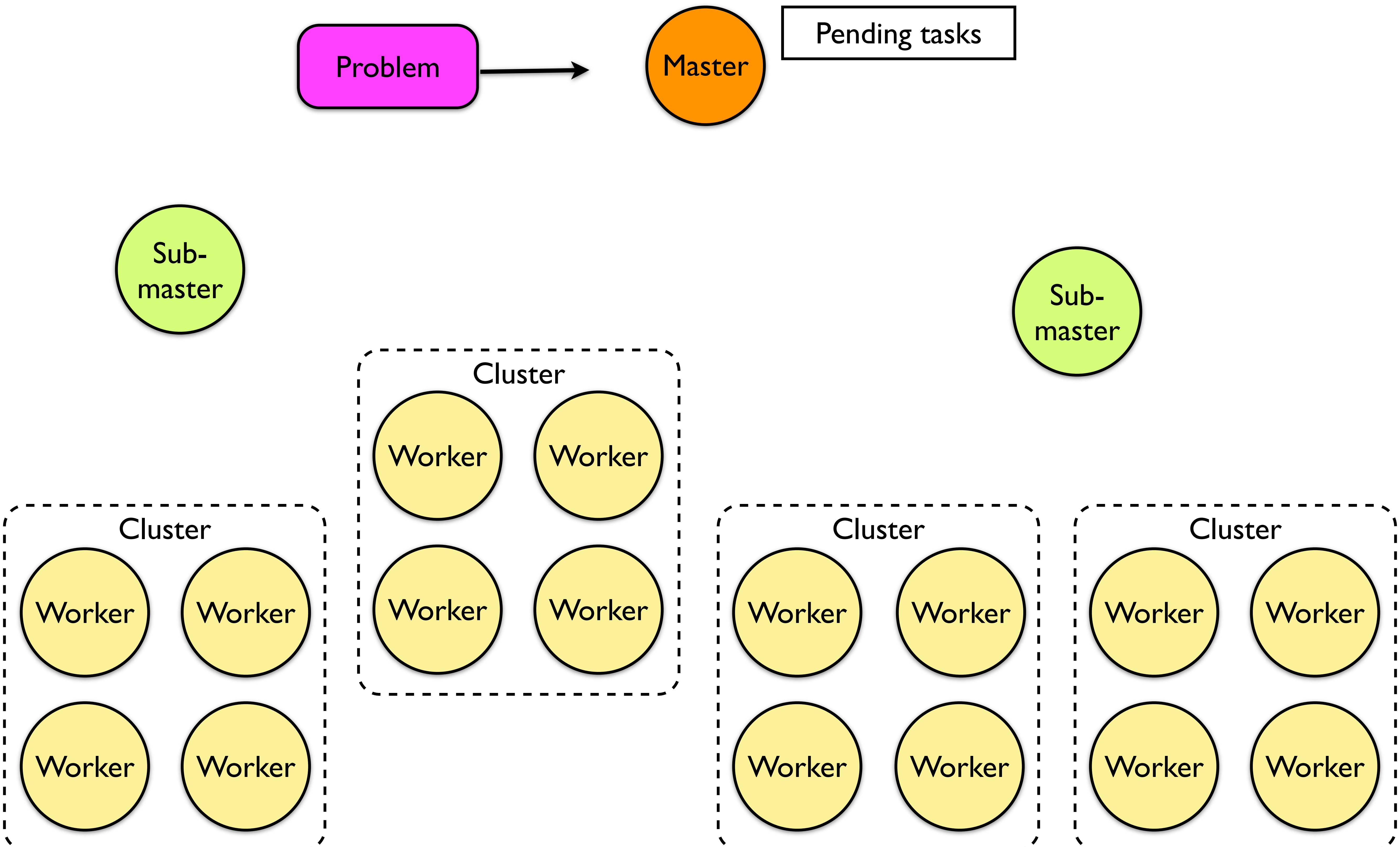

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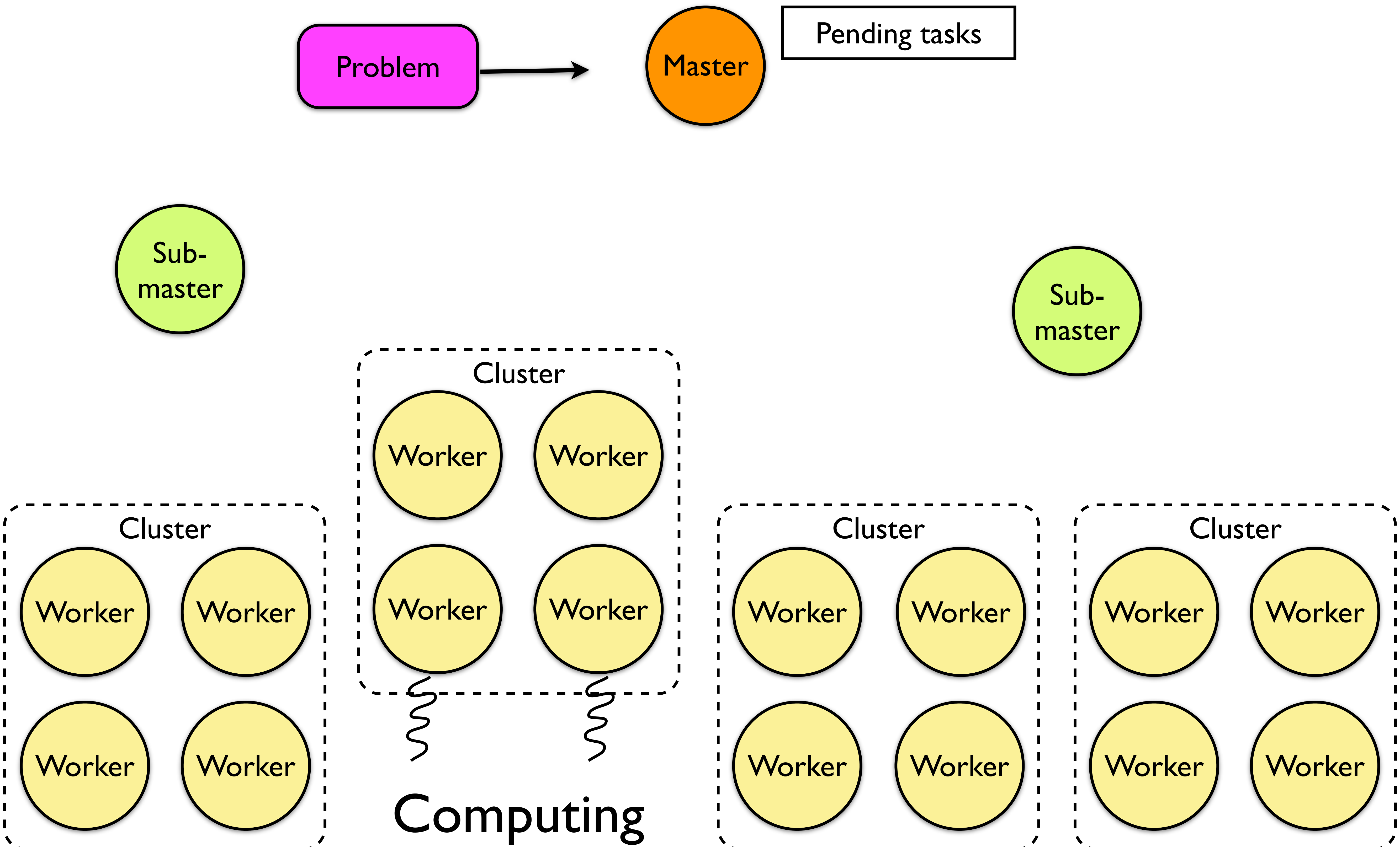

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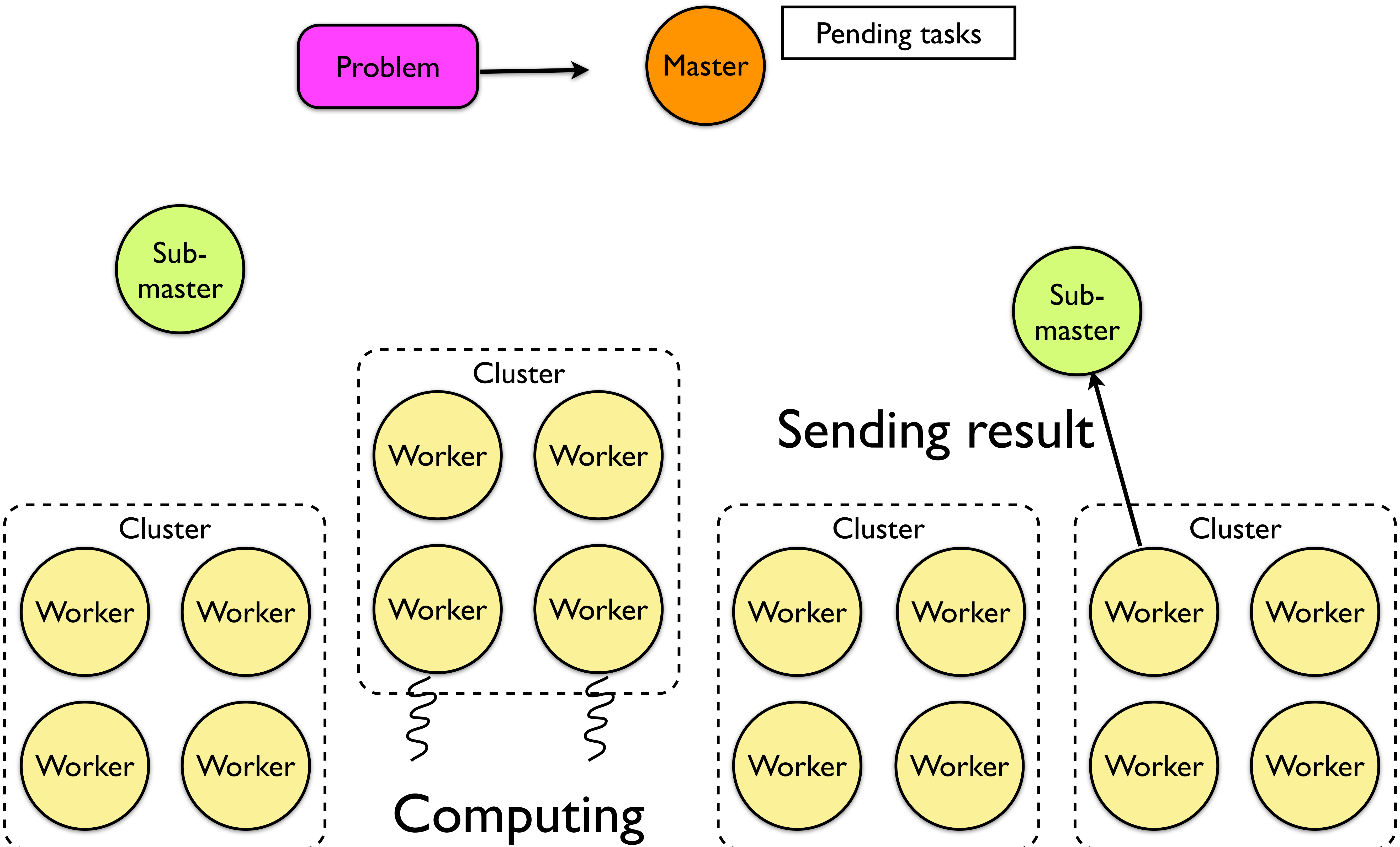

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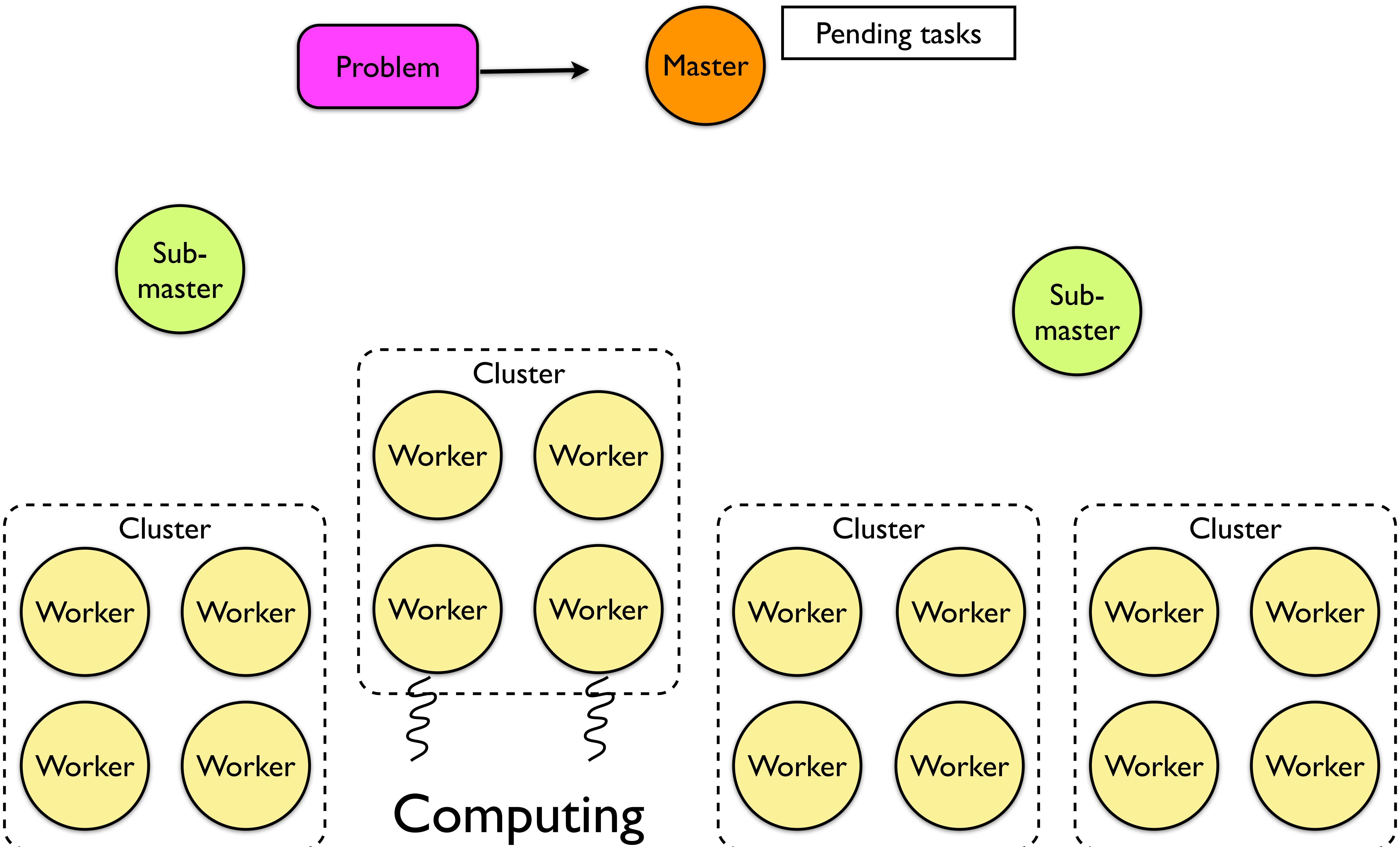

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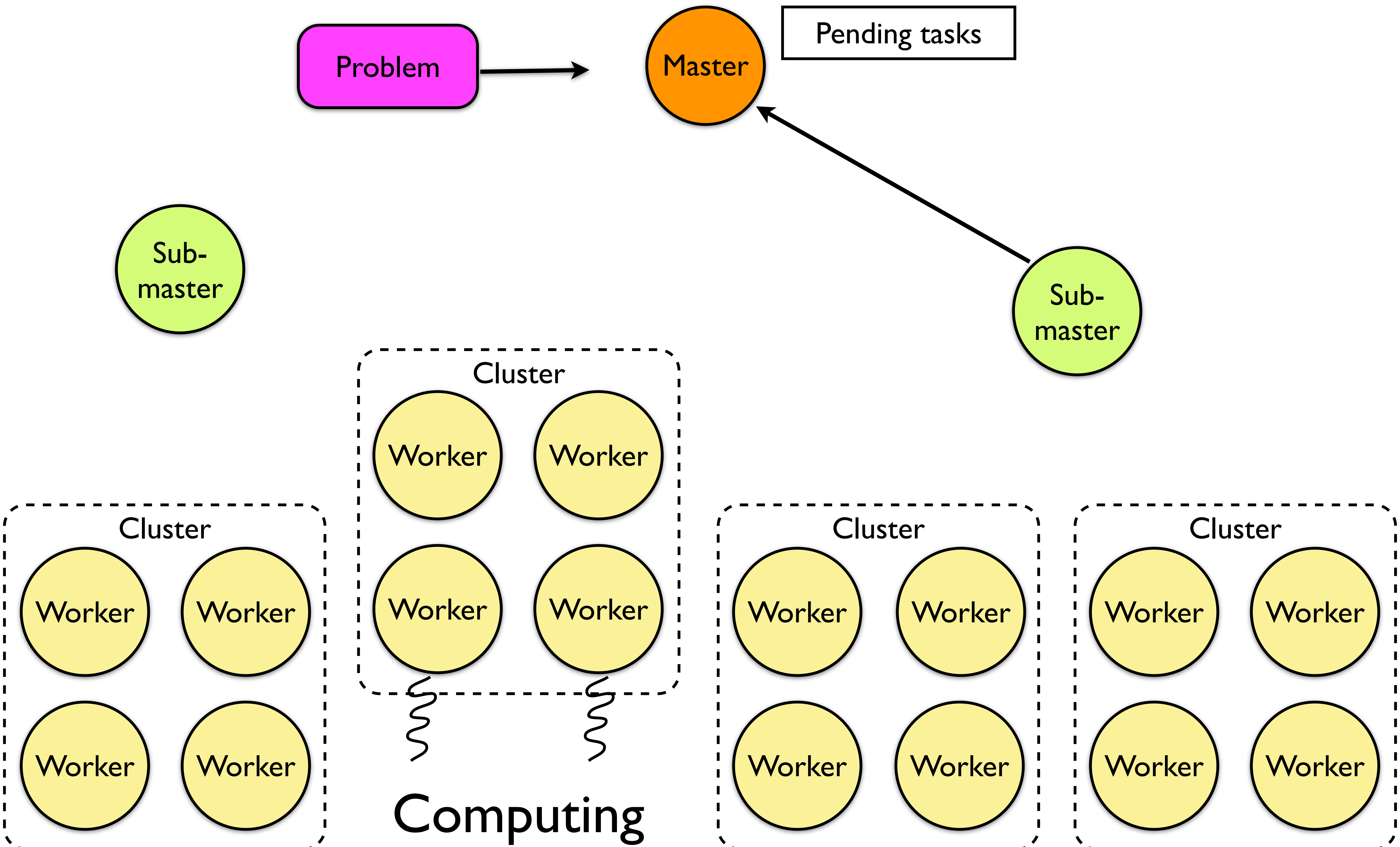

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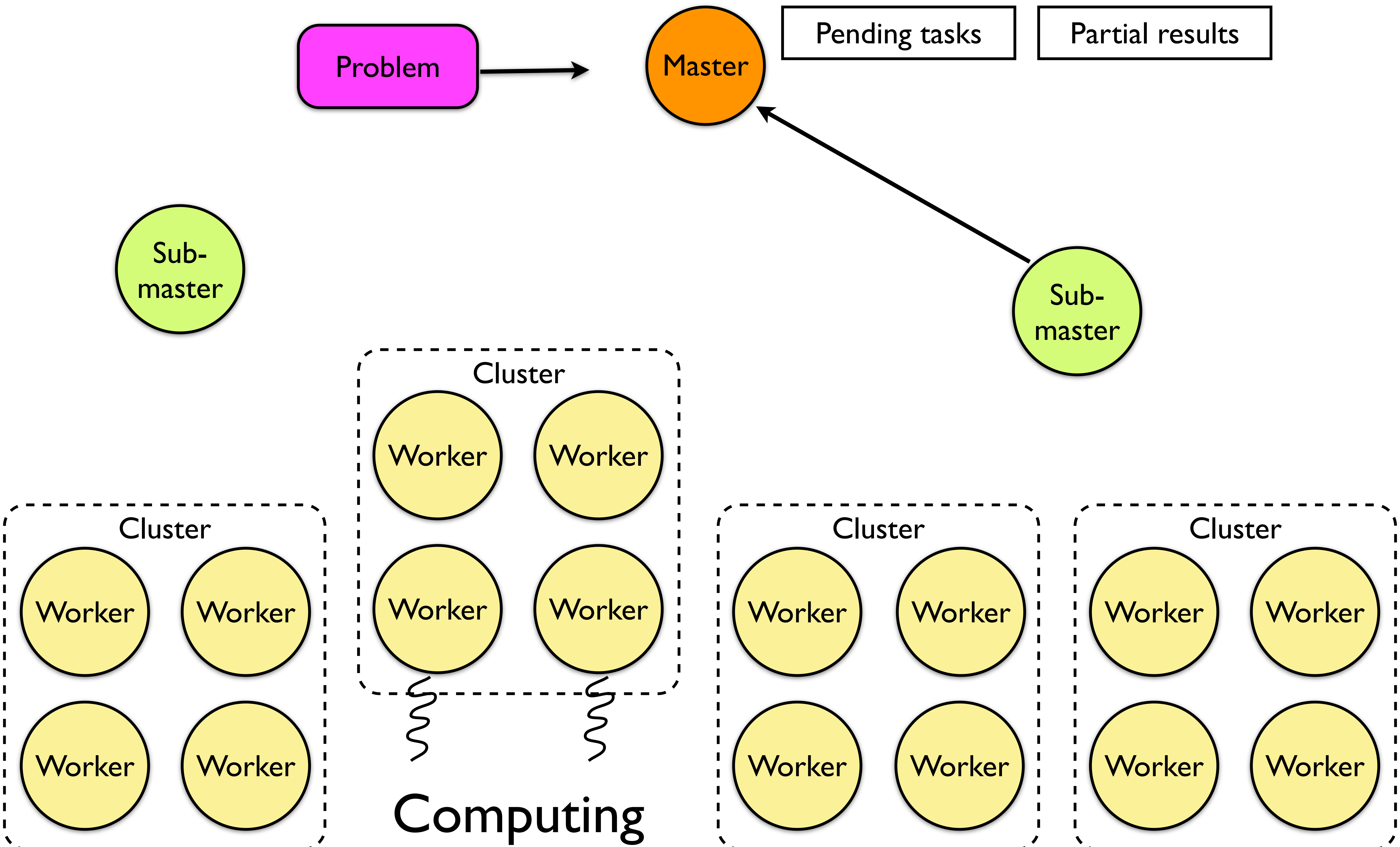

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    - ✓ hierarchical broadcasting scale [Baduel 05]

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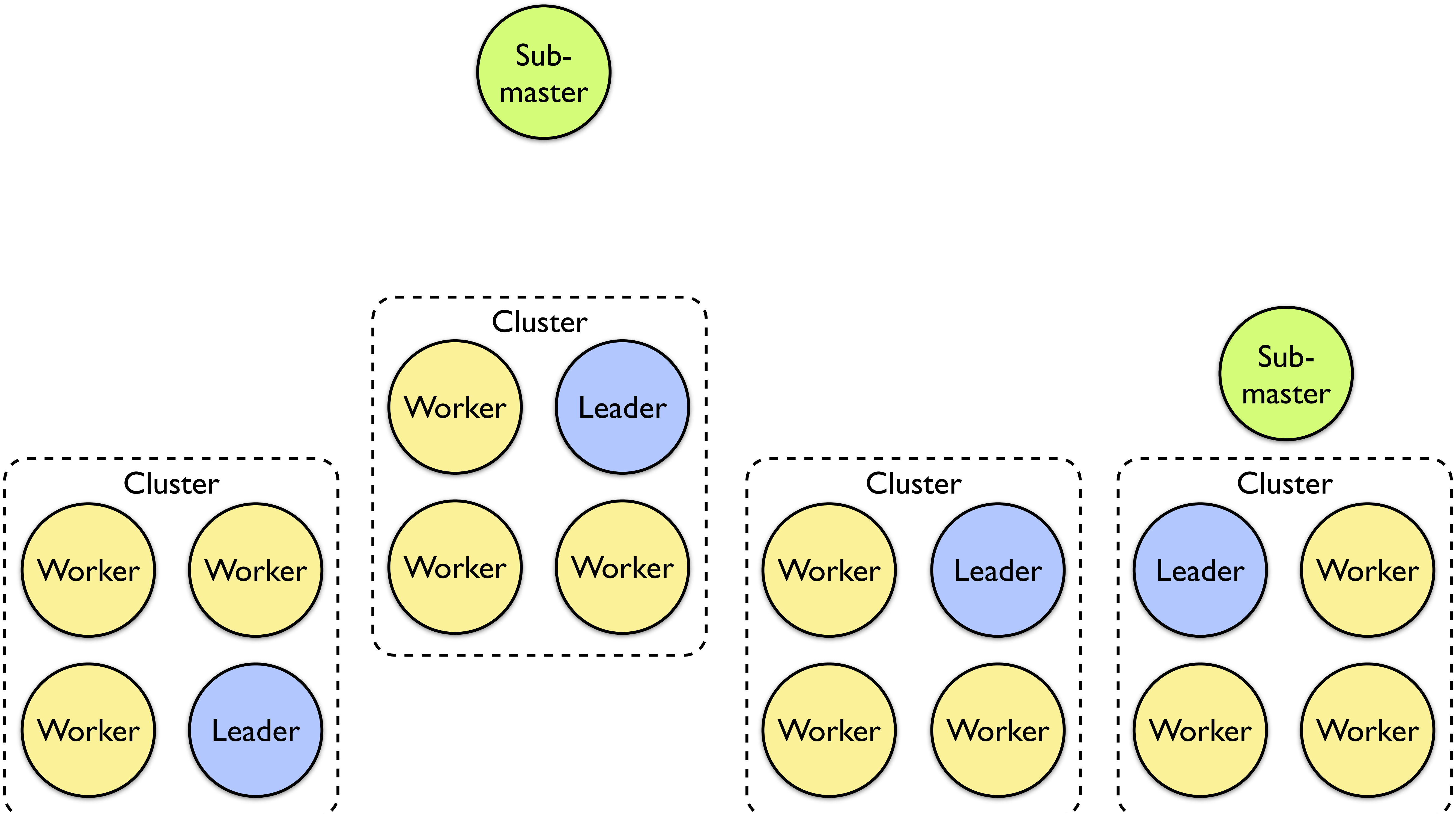
- Process to update Bounds:
  1. the Worker broadcasts the new Bound inside its group
  2. the group Leader broadcasts the new Bound to all Leaders
  3. each Leader broadcasts the new value inside their groups

BnB framework - Communications for Sharing Bound



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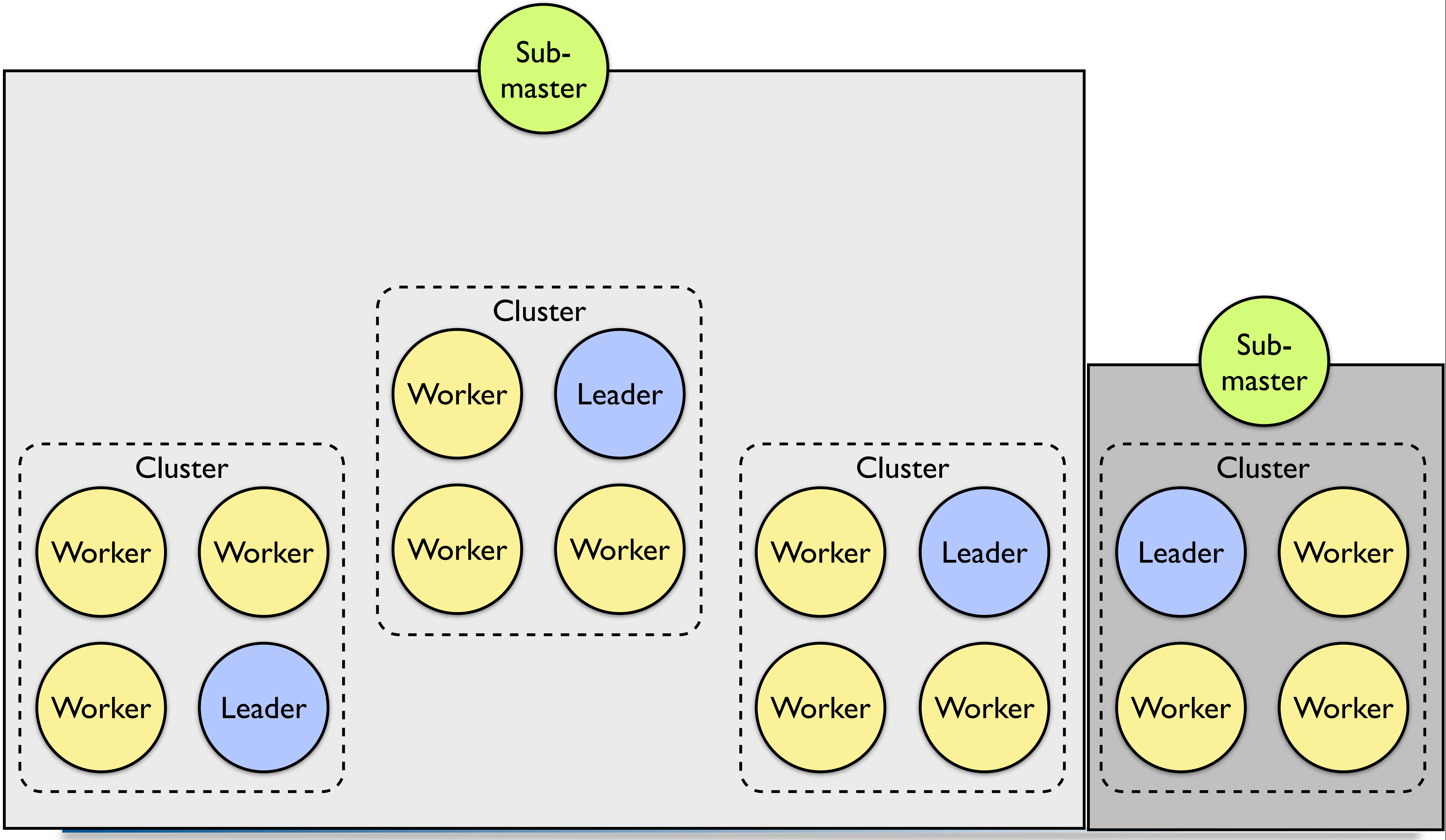

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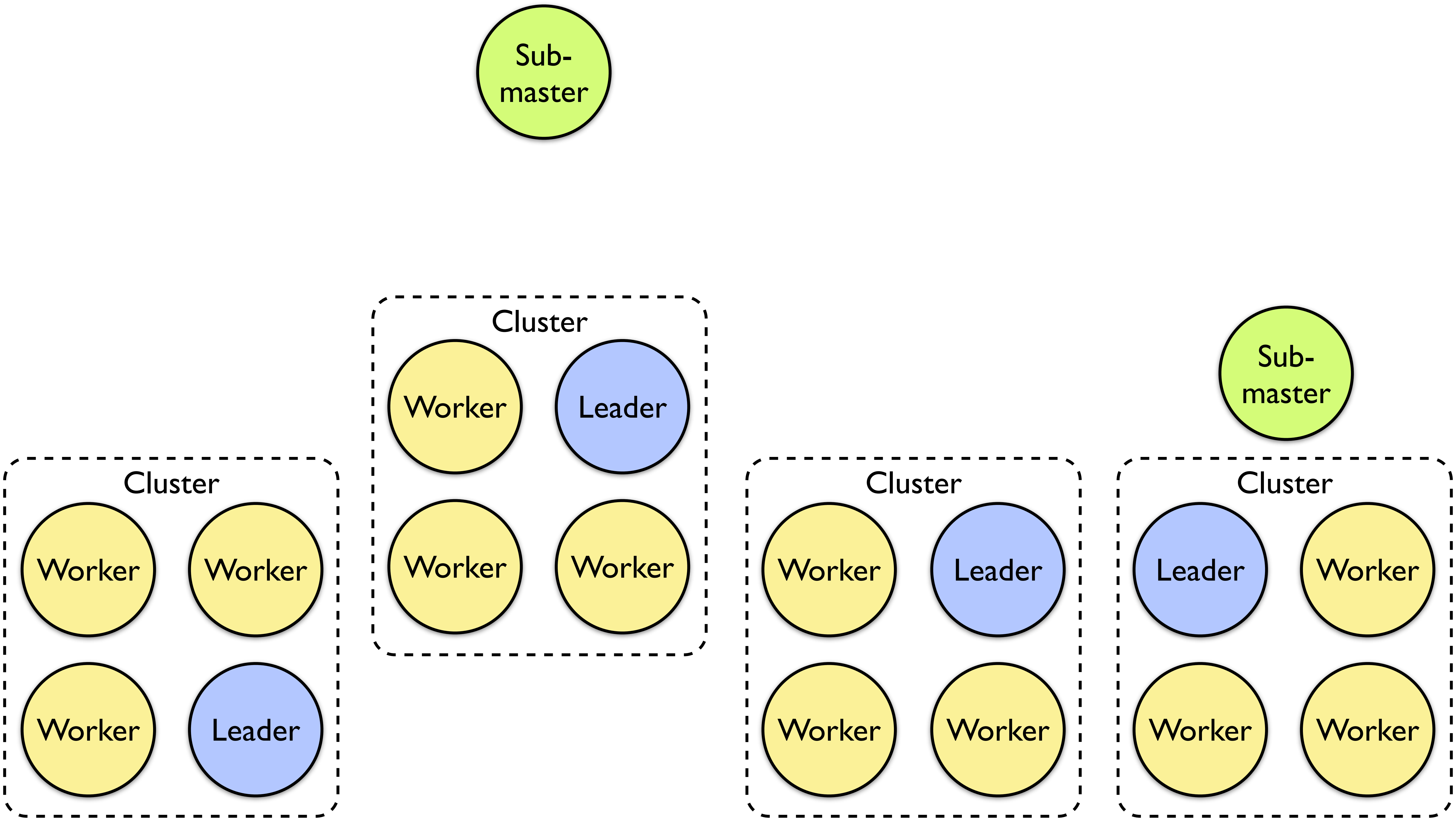

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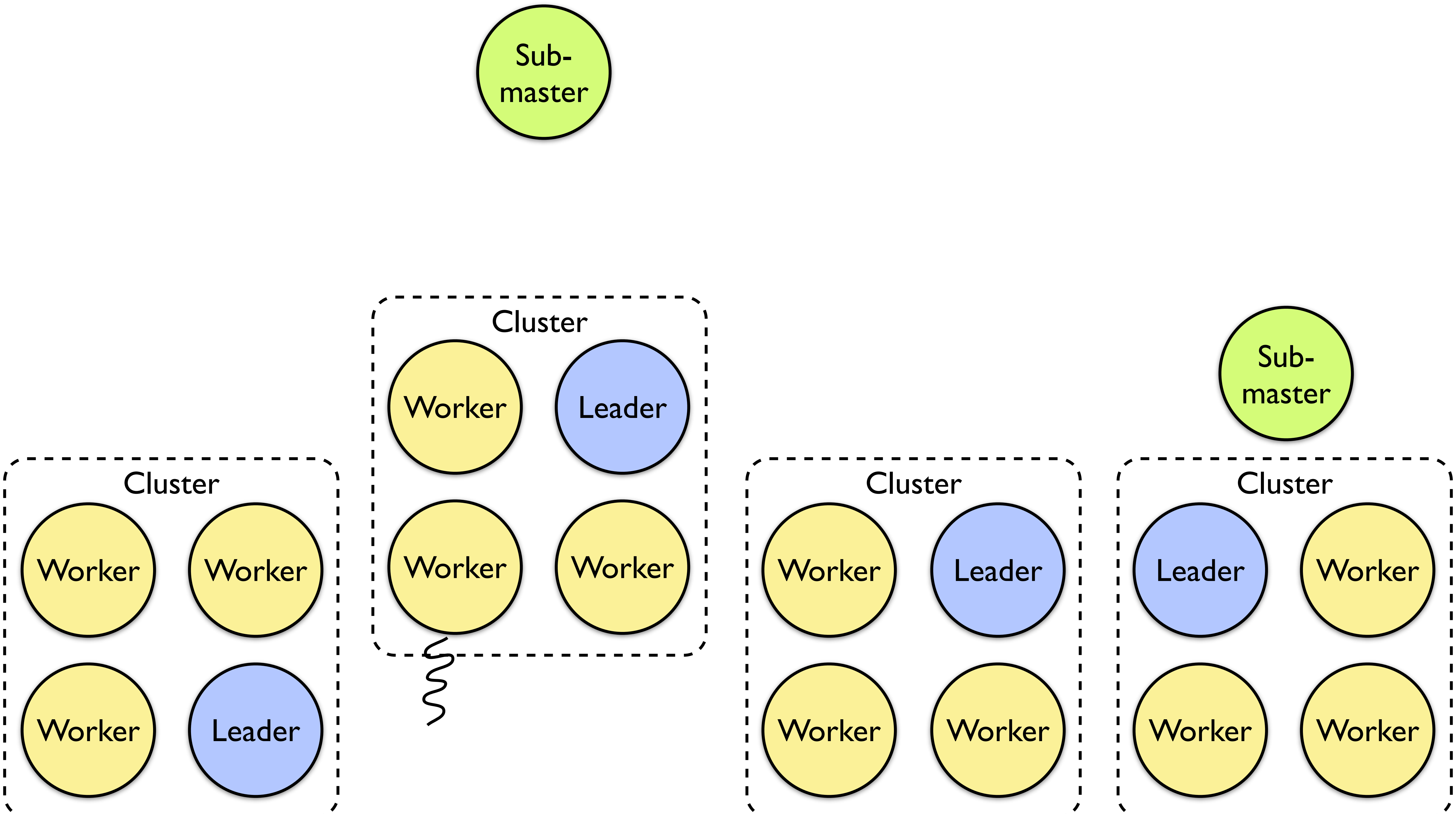

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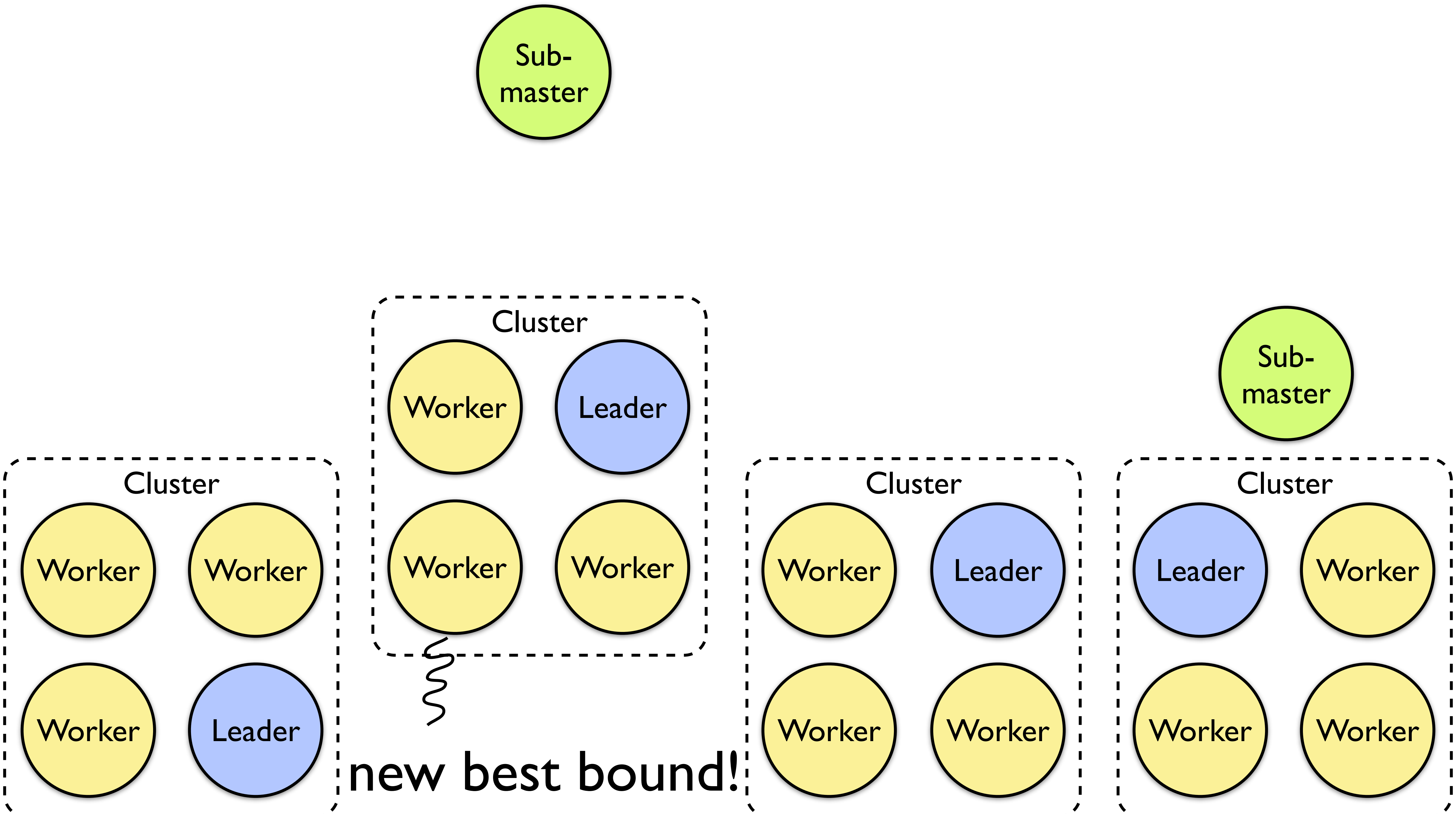

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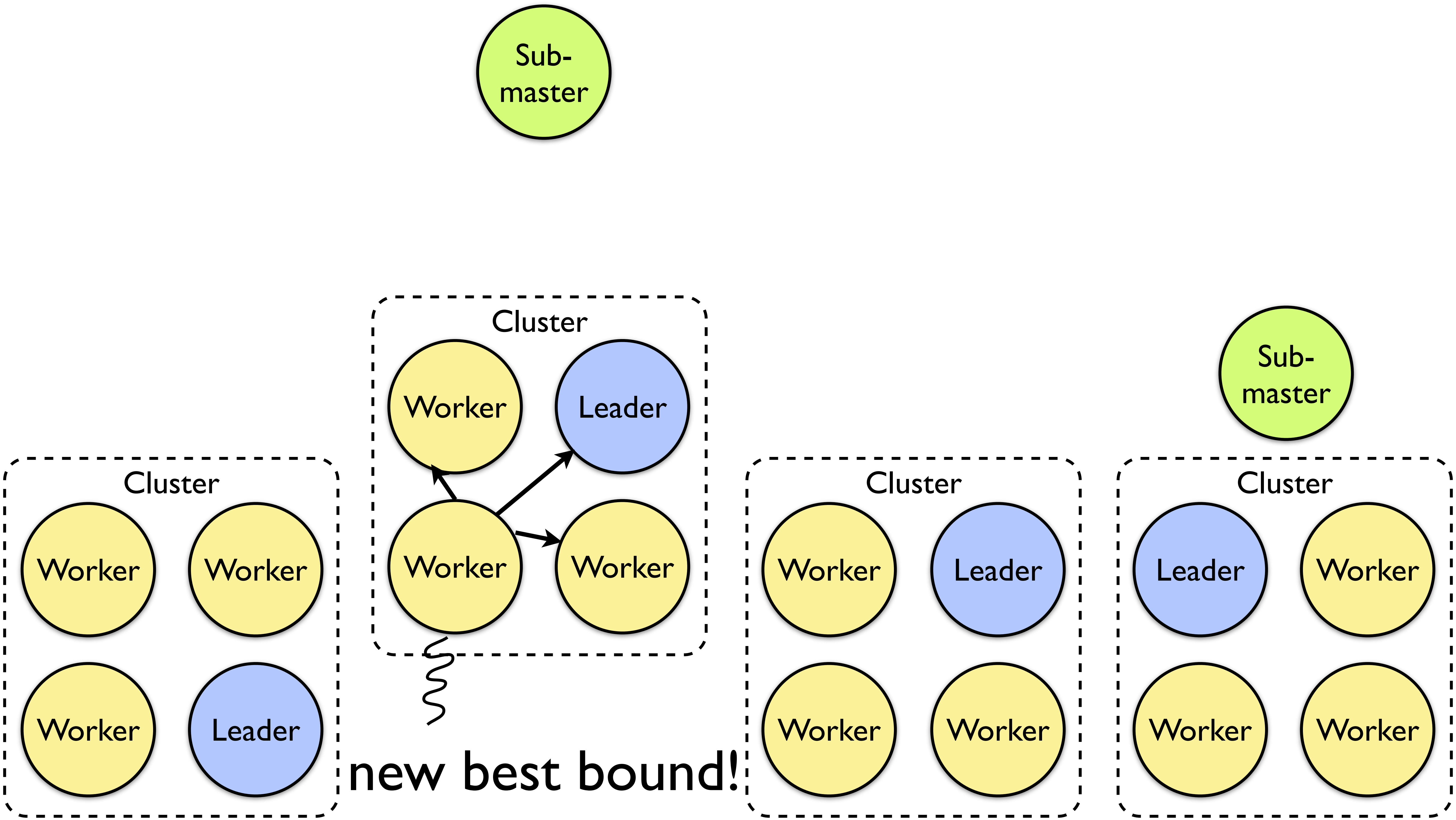

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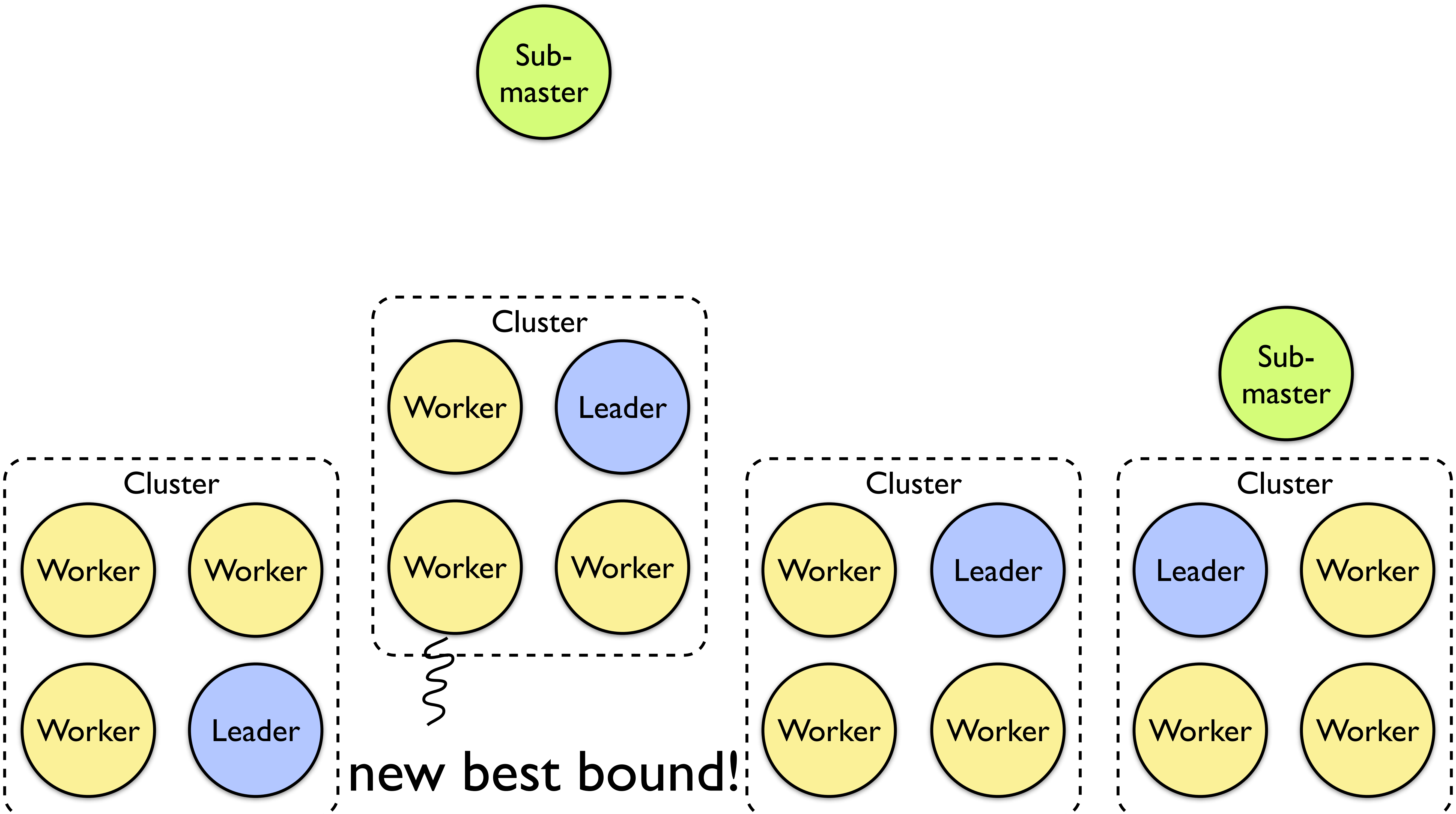

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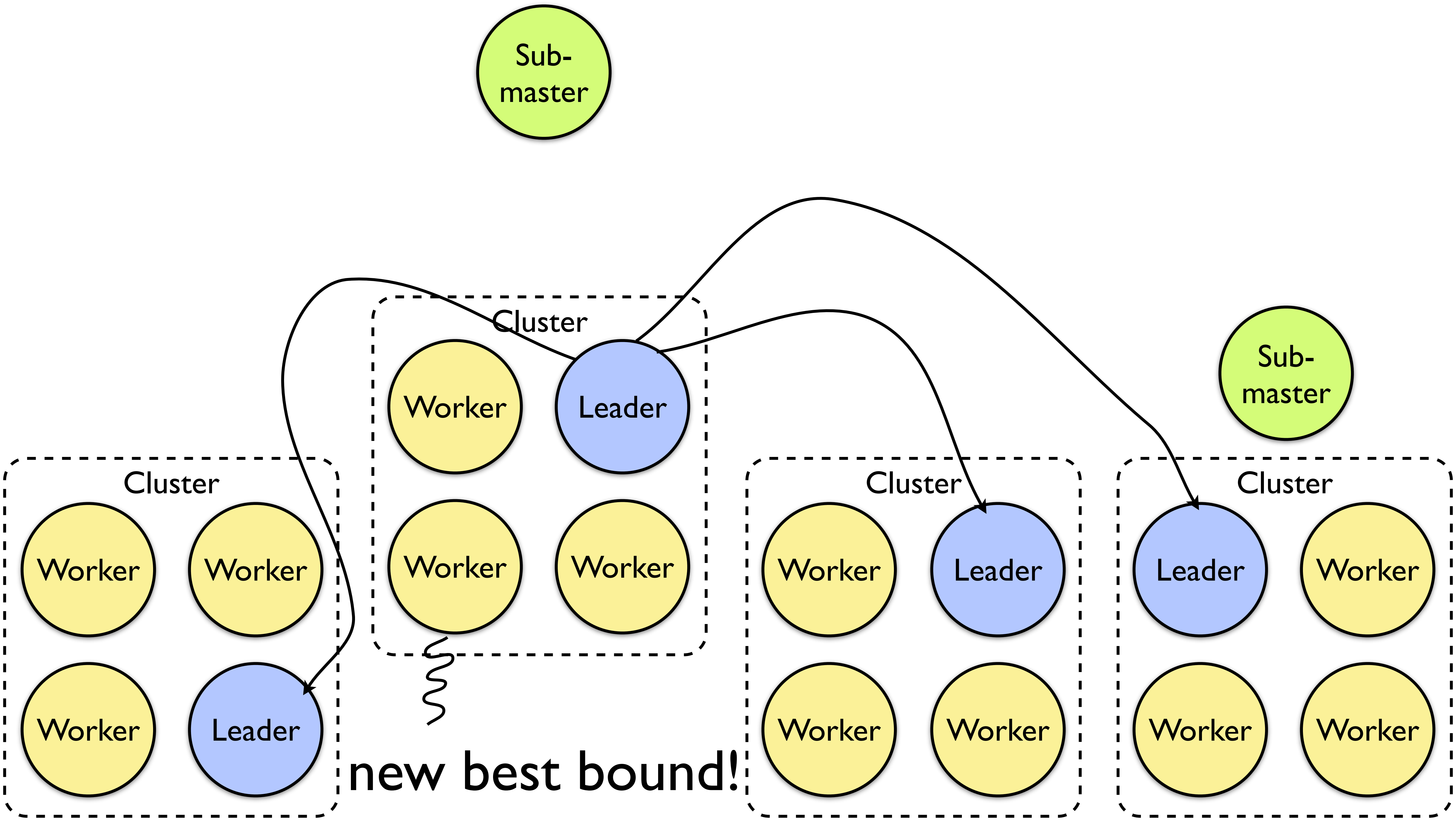

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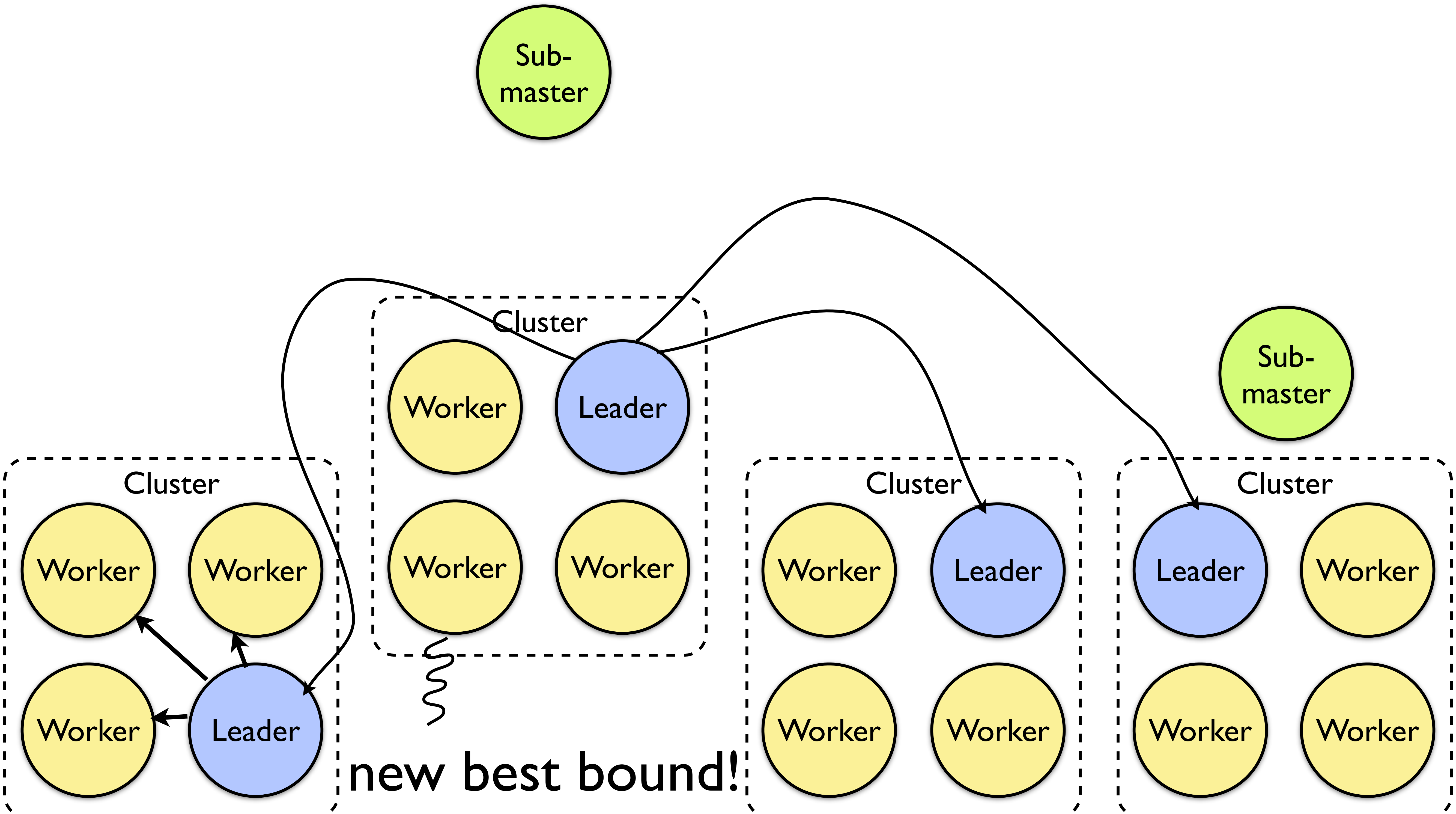
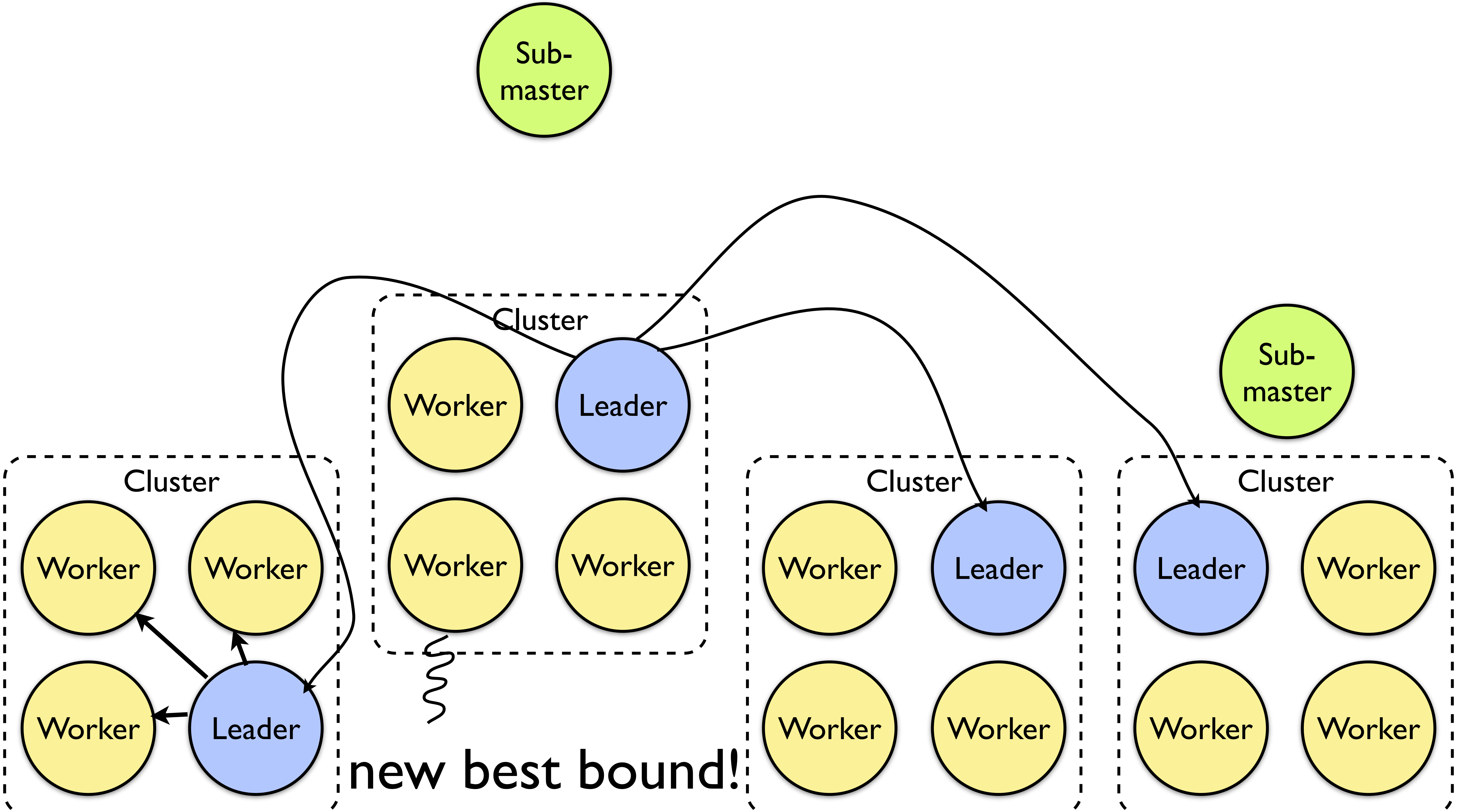


BnB framework - Communications for Sharing Bound

Grid middleware provides communications



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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Validate and Test Grid'BnB by experiments

- Hidden parallelism and Grid difficulties
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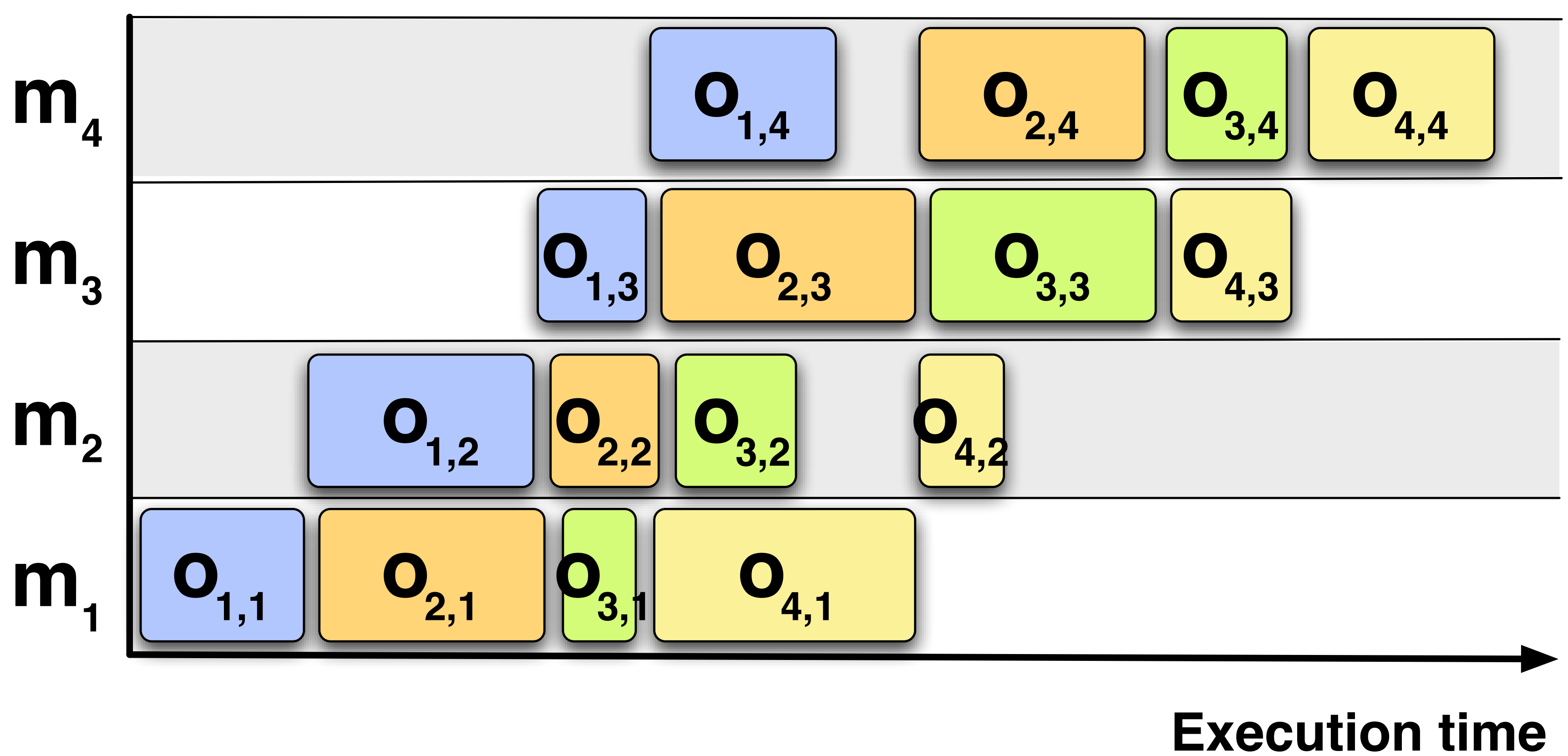
Users

Flow-Shop Experiments

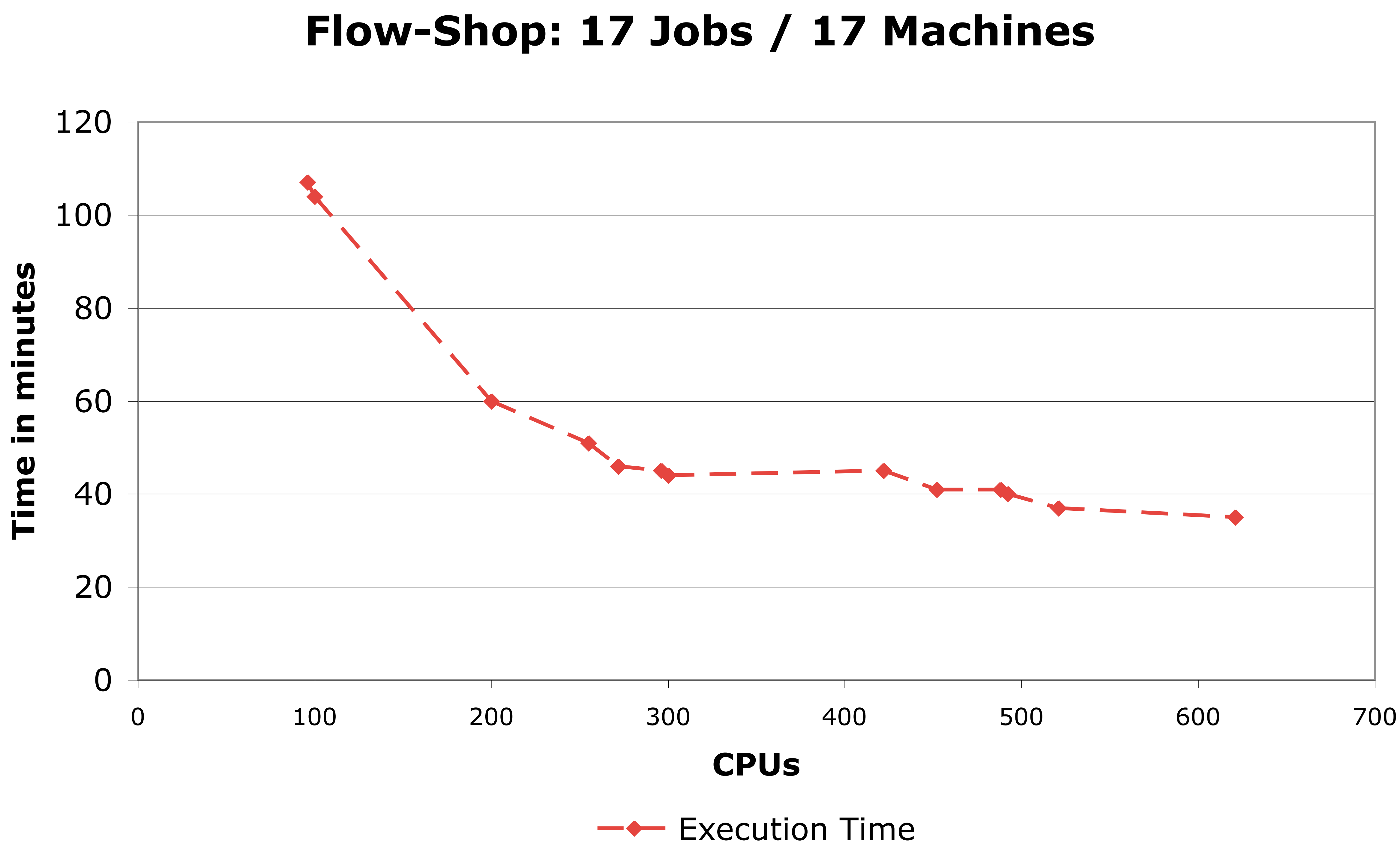
- NP-hard permutation optimization problem

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



Grid Experimentations

up to 621 CPUs on 5 sites



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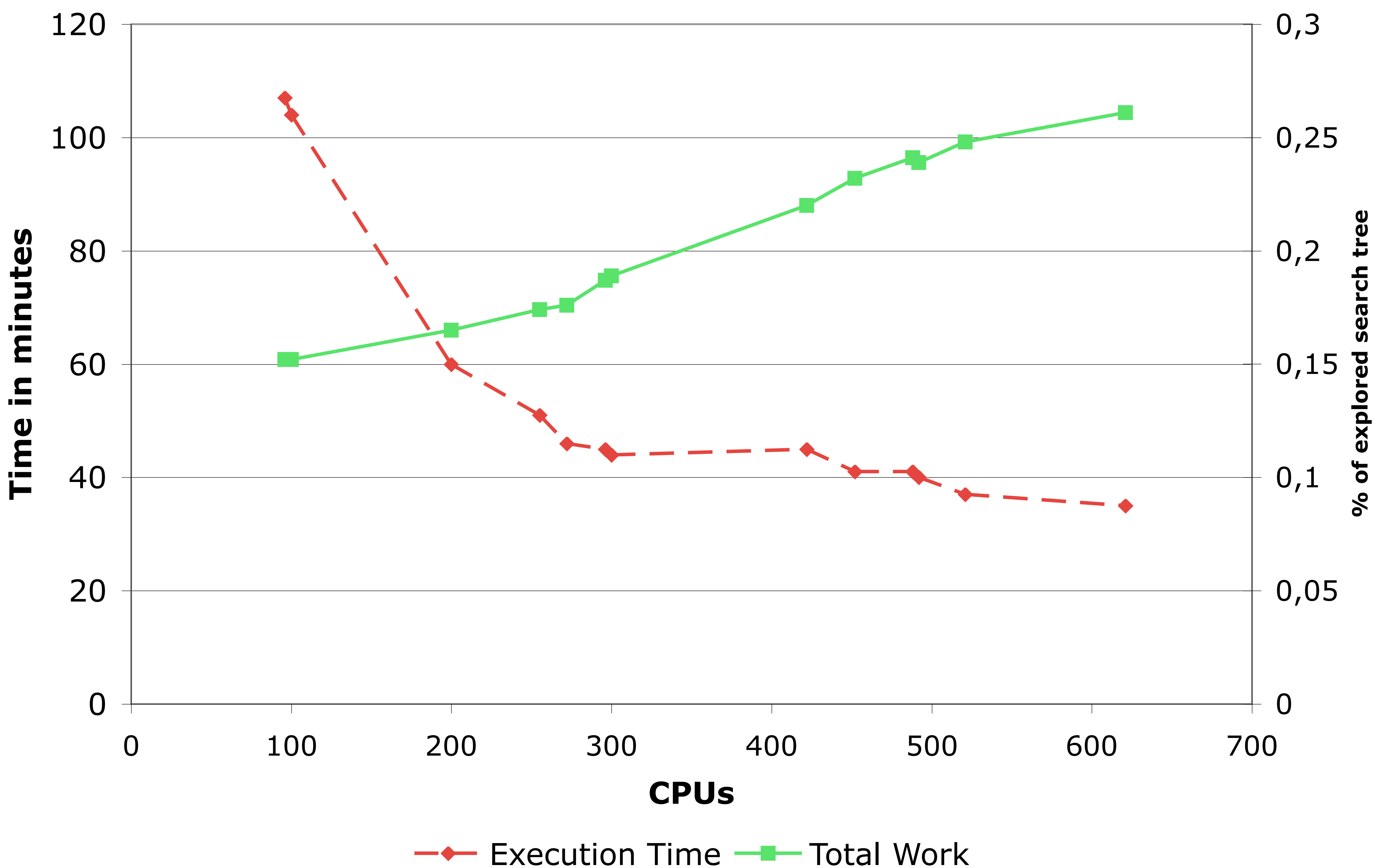
Flow-Shop: 17 Jobs / 17 Machines



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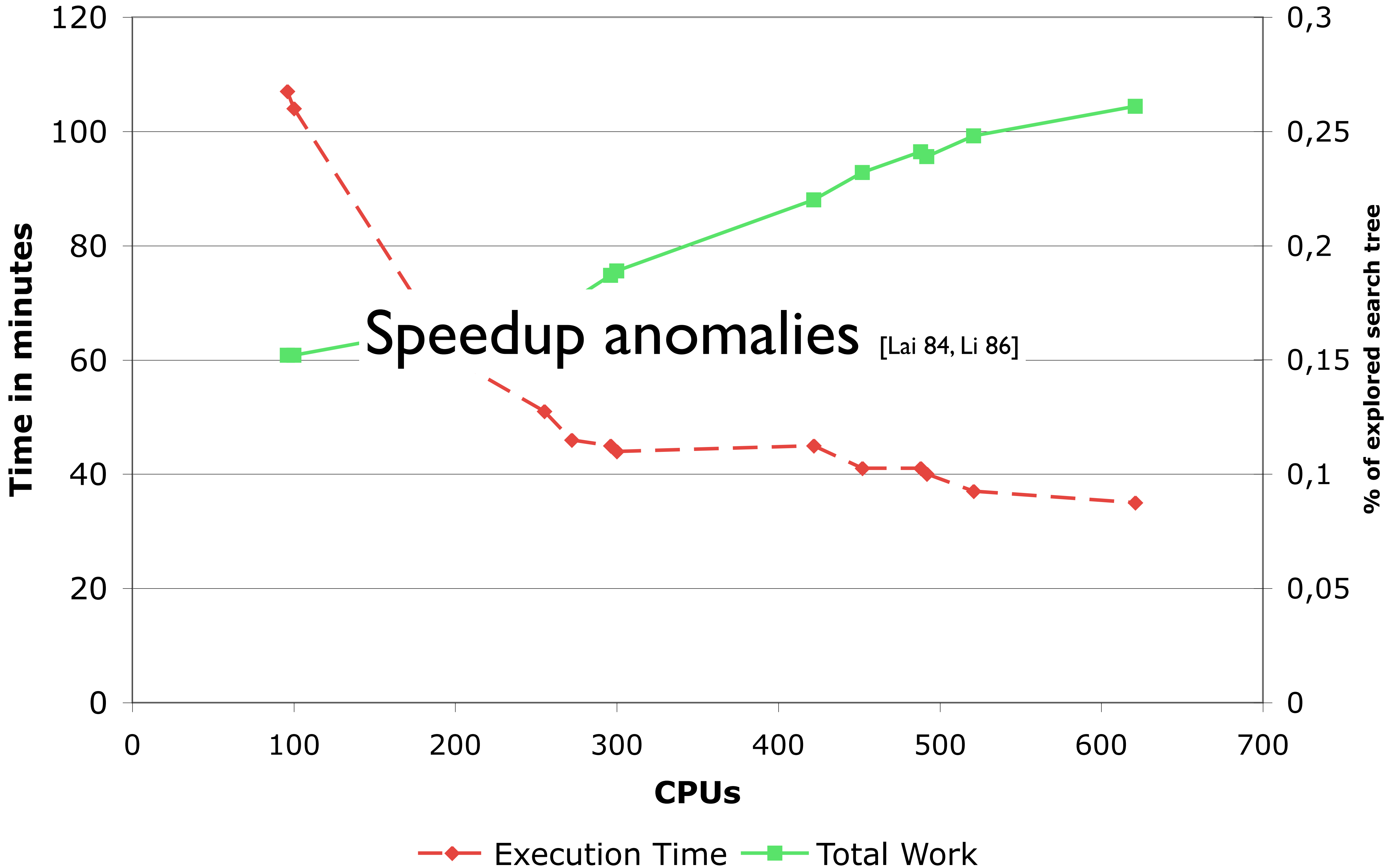
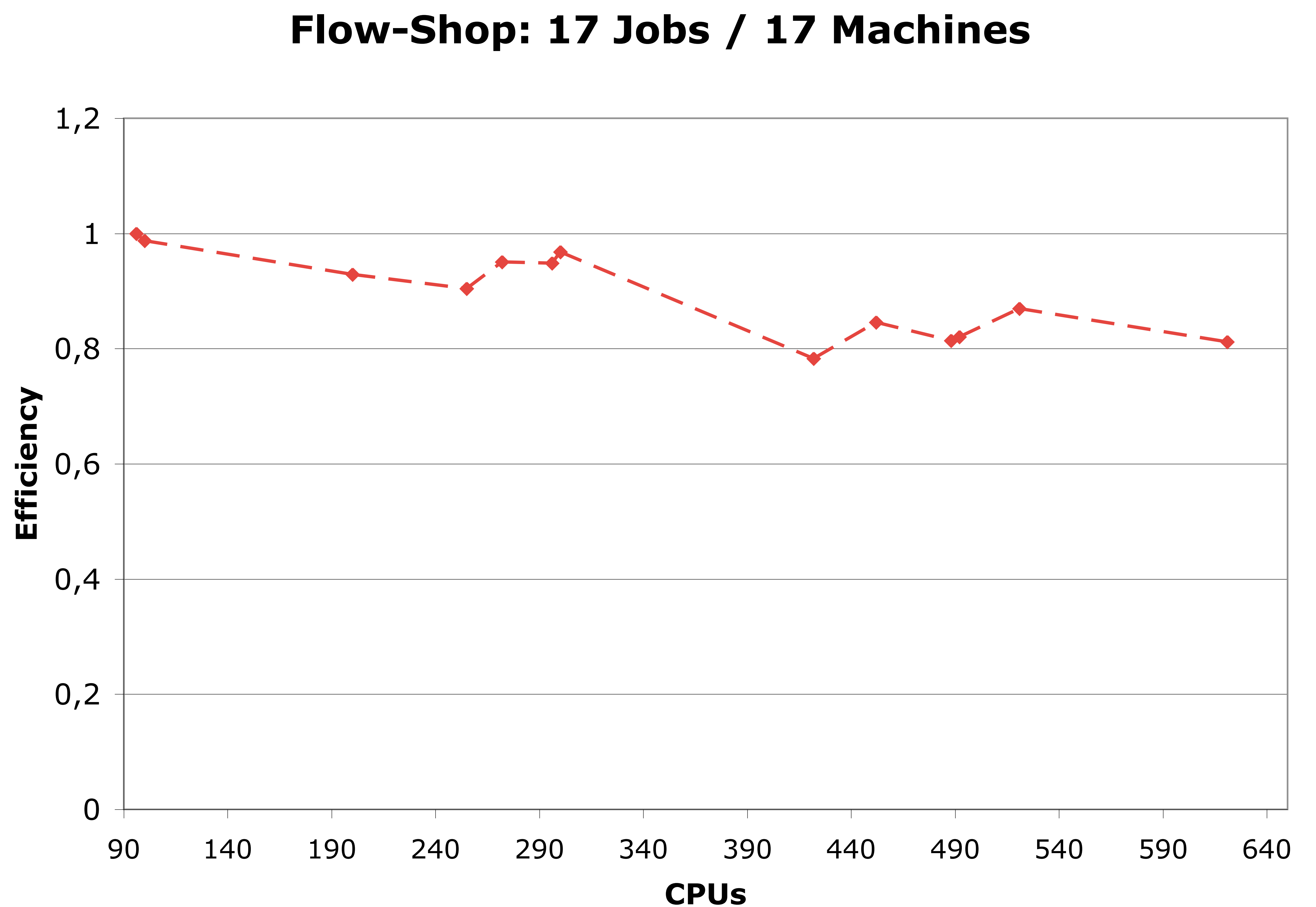


Speedup Anomalies & Efficiency

- 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



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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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  - dynamically acquiring new resources is difficult
  - popularity of Grid'5000
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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

- About Me / Previous Experience
- PhD Main Contributions
  - Branch-and-Bound Framework for Grids
  - **Desktop Grid with Peer-to-Peer**
  - Mixing Desktops & Clusters
  - Perspectives
- Possible Support & 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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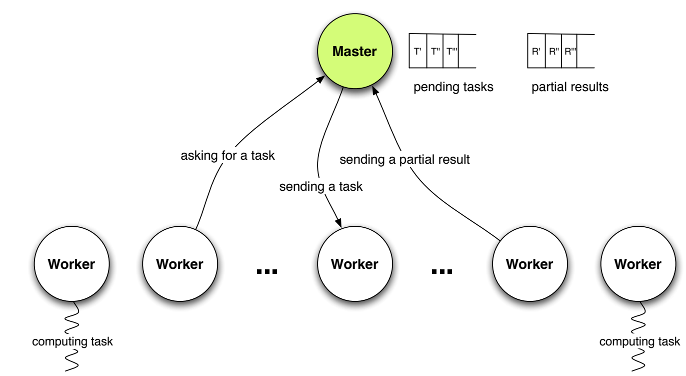
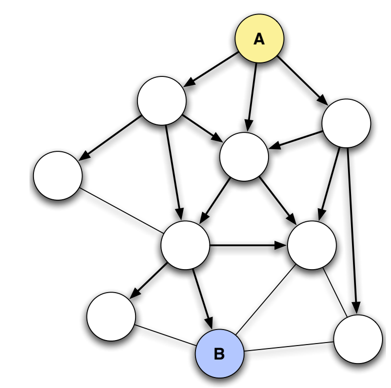
Objective: provide a P2P infrastructure for Grids and sharing computational resources

Which P2P Architecture?

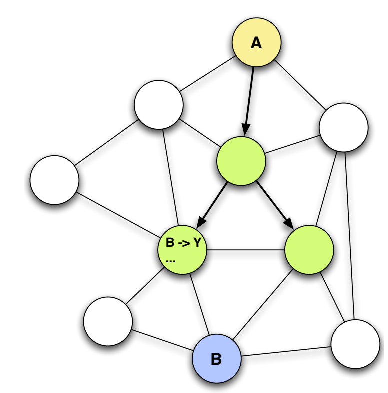
- Master-Worker (SETI@home)
  - • centralized
  - - targets only desktops
  - • good for embarrassingly parallel



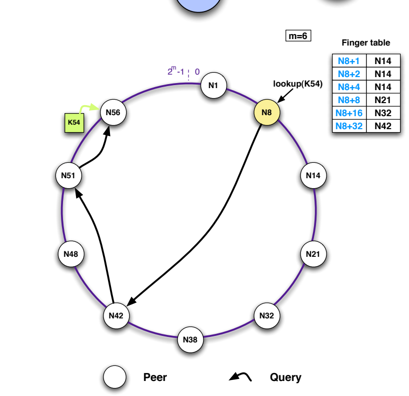
- Pure/Unstructured Peer-to-Peer (Gnutella)
  - - flooding problems
  - ✓ supports high-churn (good for Desktop Grids)
  - ✓ supports many kind of application (data, computational)



- 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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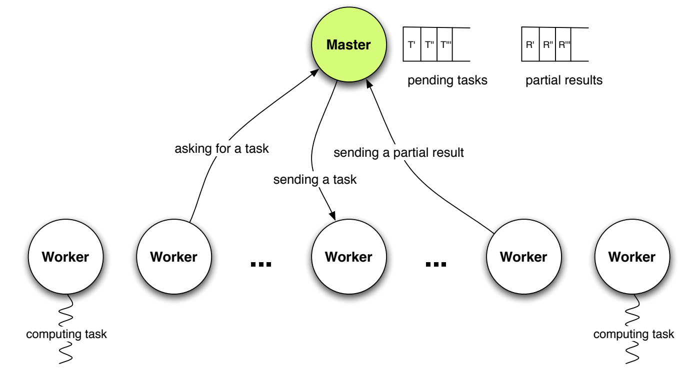

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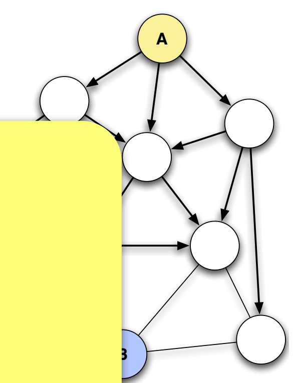
  - ✓
  - ✓



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

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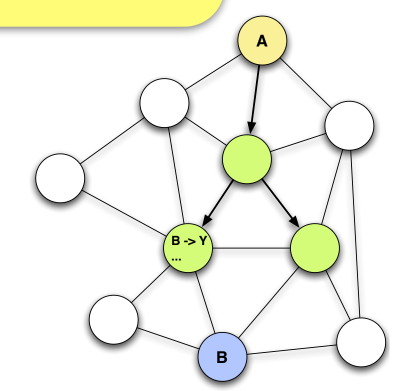

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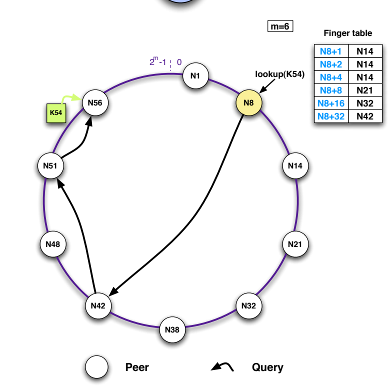
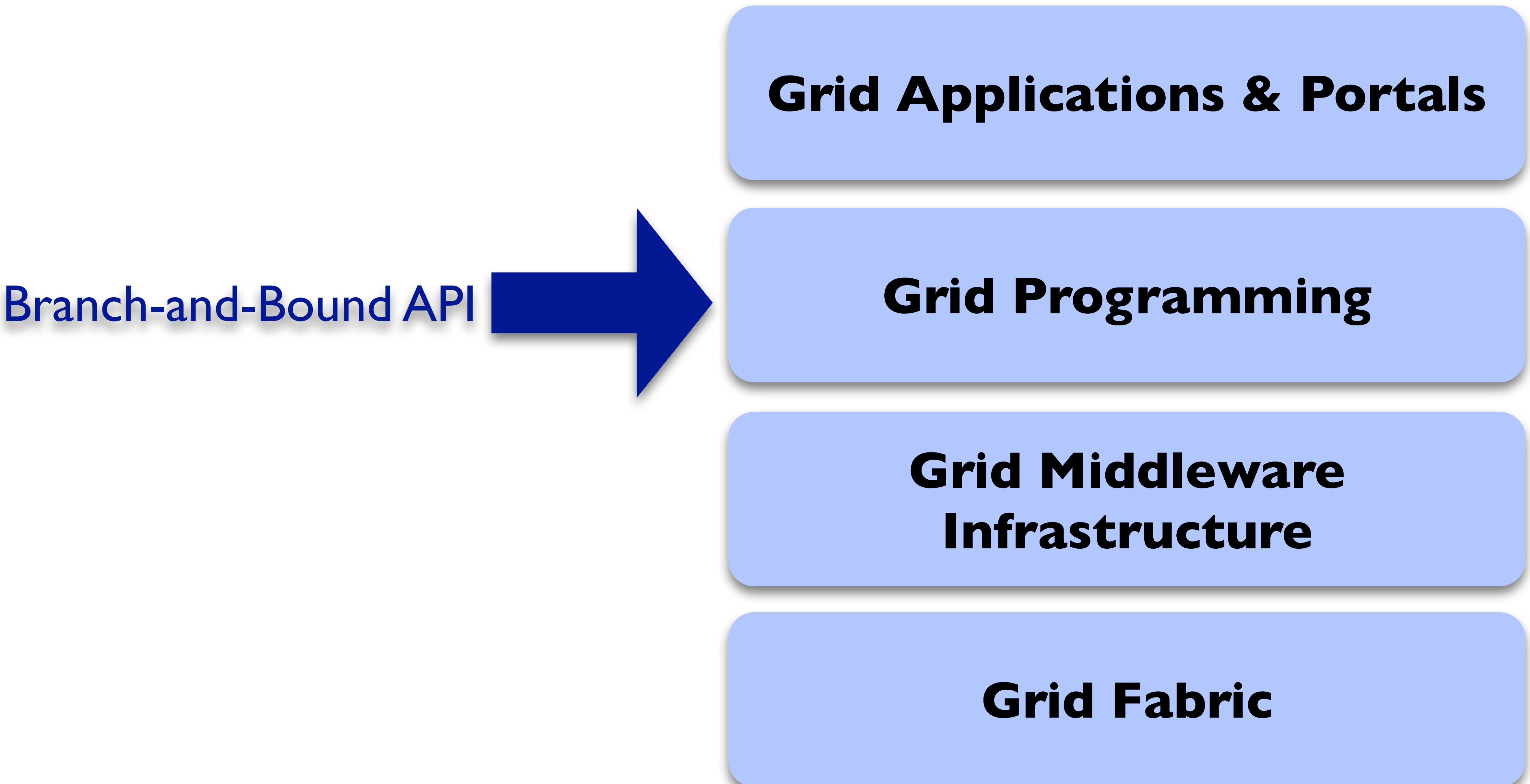


Contribution & Positioning



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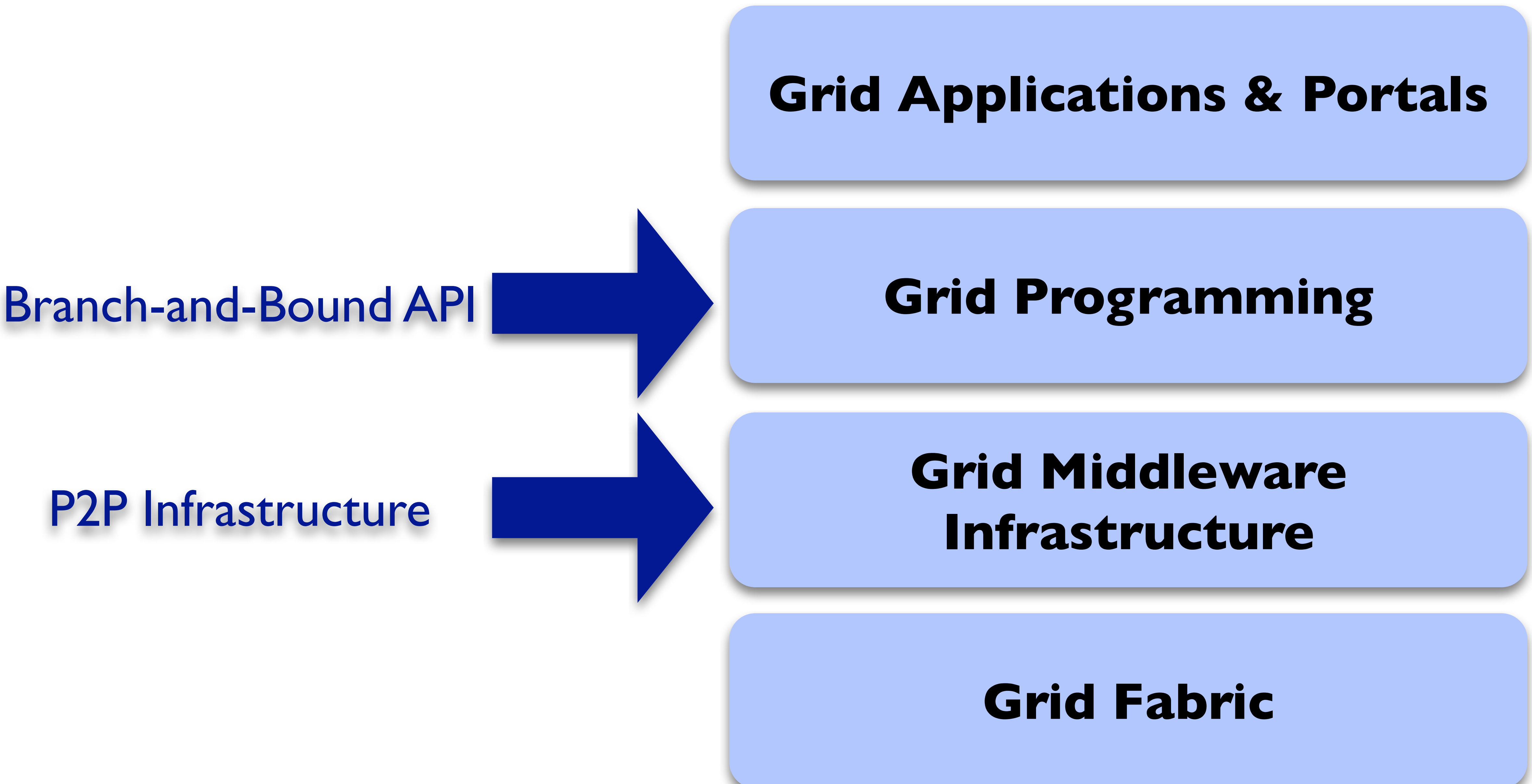

The Peer-to-Peer Infrastructure [CMST06]

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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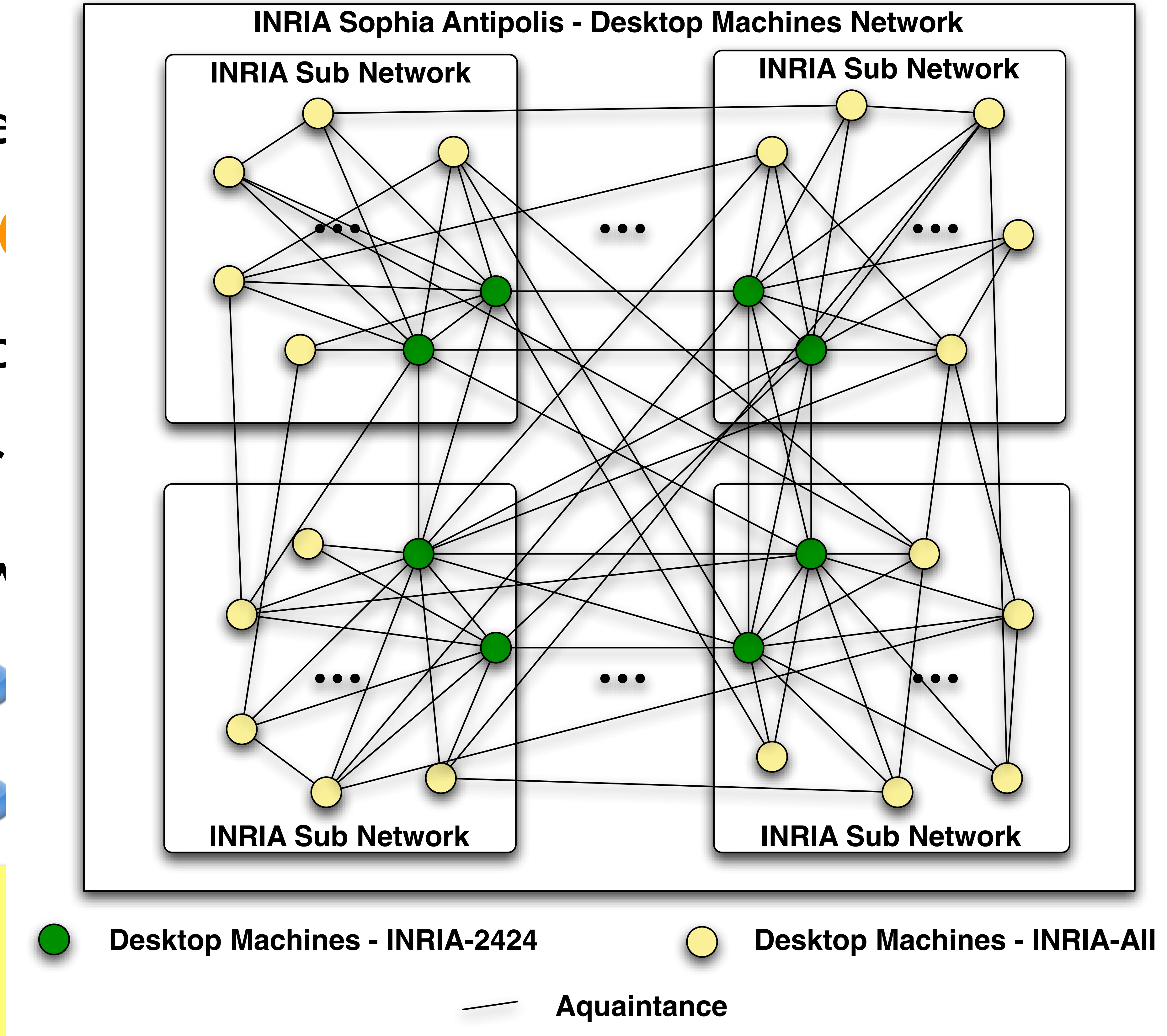
Deployed our P2P infrastructure as permanent Desktop Grid at INRIA Sophia

INRIA Sophia P2P Desktop Grid



Long Running Experiments with the P2P Desktop Grid

- Context: ETSI Grid Plugtests contest ➟ n-queens
- n-queens:
  - embarrassingly parallel / CPU intensive / master-worker

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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
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API for solving COPs &
Dynamic Grid Infrastructure

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Validate by experiments on a Grid of Desktops & Clusters

Mixing Desktops & Clusters [PARCO07]

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Parallel BnB Framework for Grid

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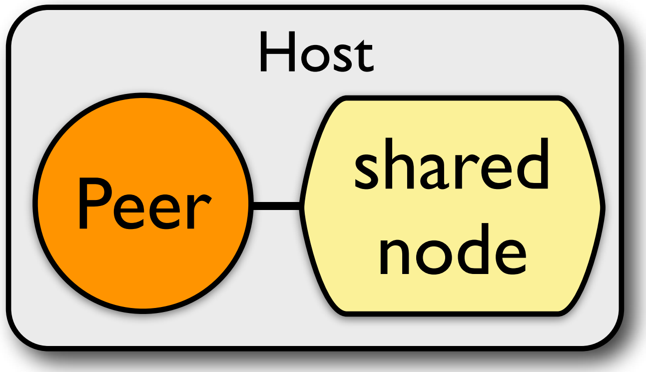
Validate by experiments on a Grid of Desktops & Clusters

New Problems:

firewalls ➡ forwarder

sharing clusters with the P2P infrastructure

Sharing Cluster's Nodes with P2P



Peer sharing local node

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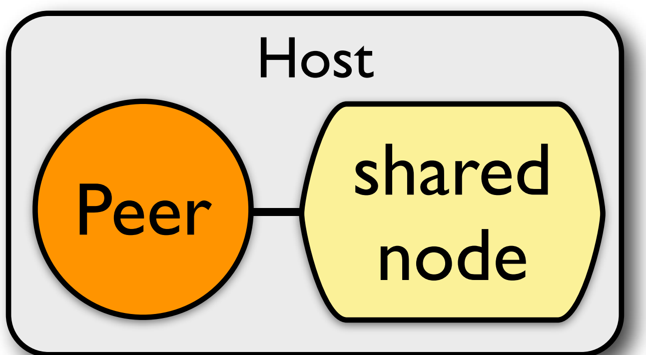

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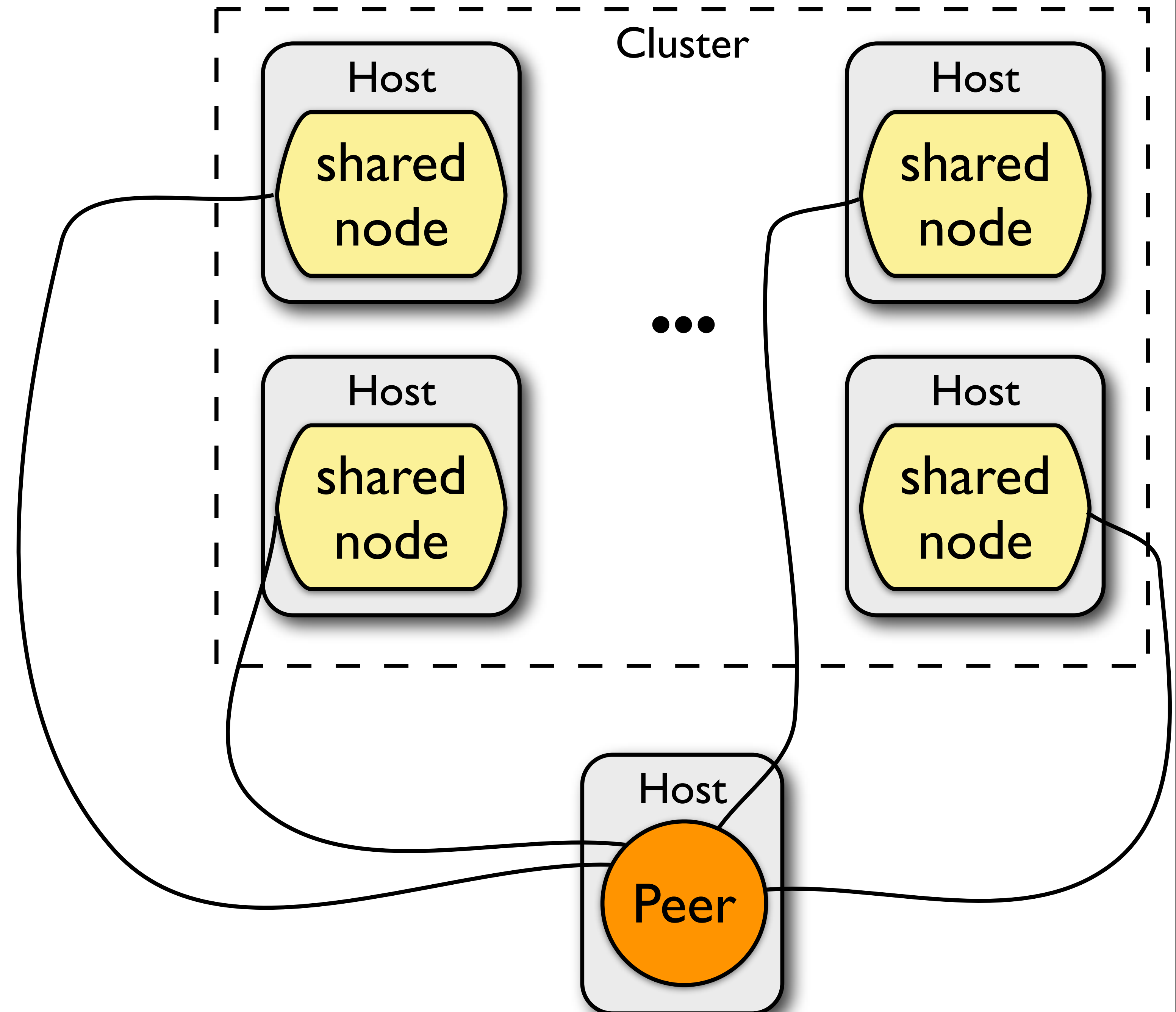
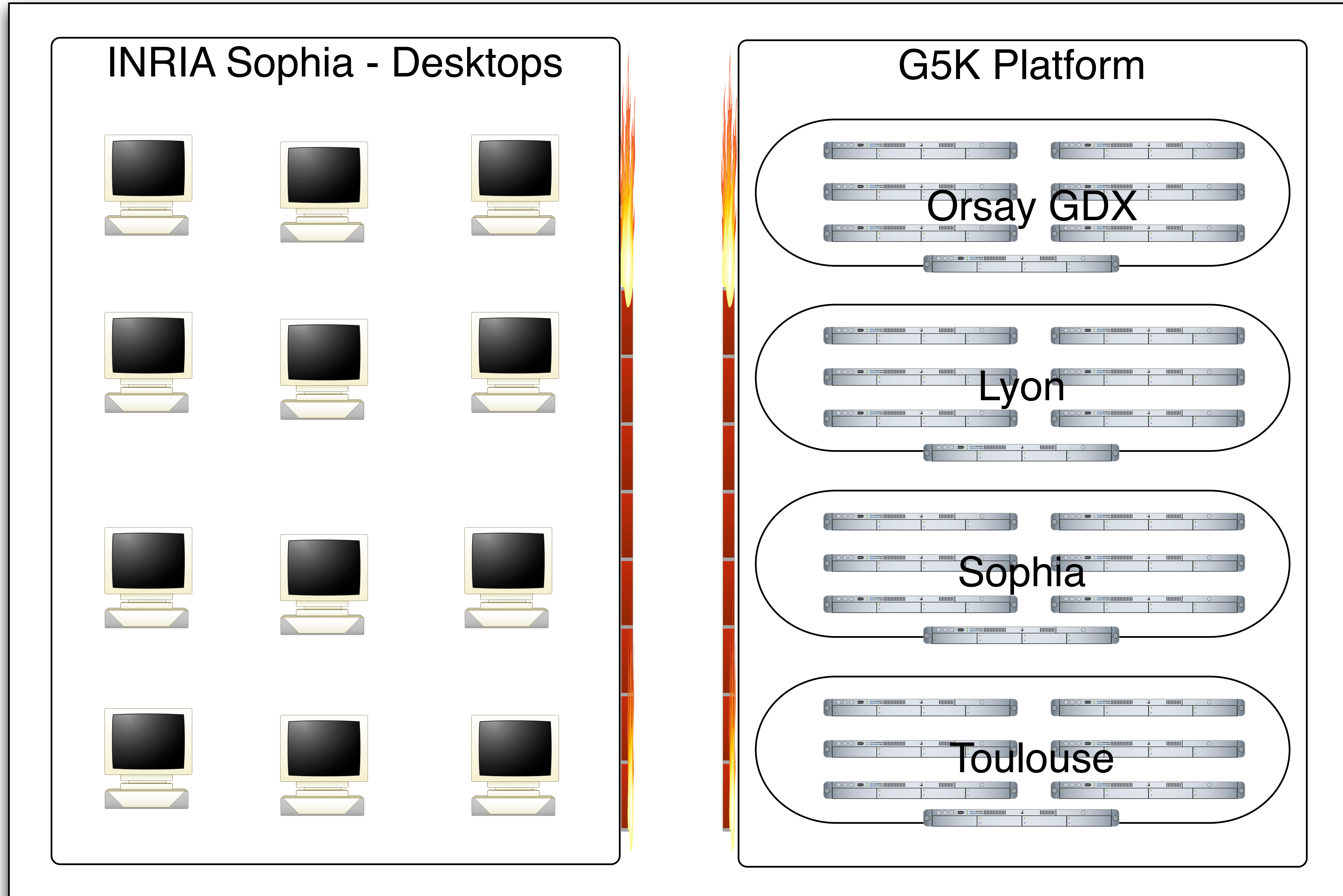


Peer sharing remote nodes

Testbed


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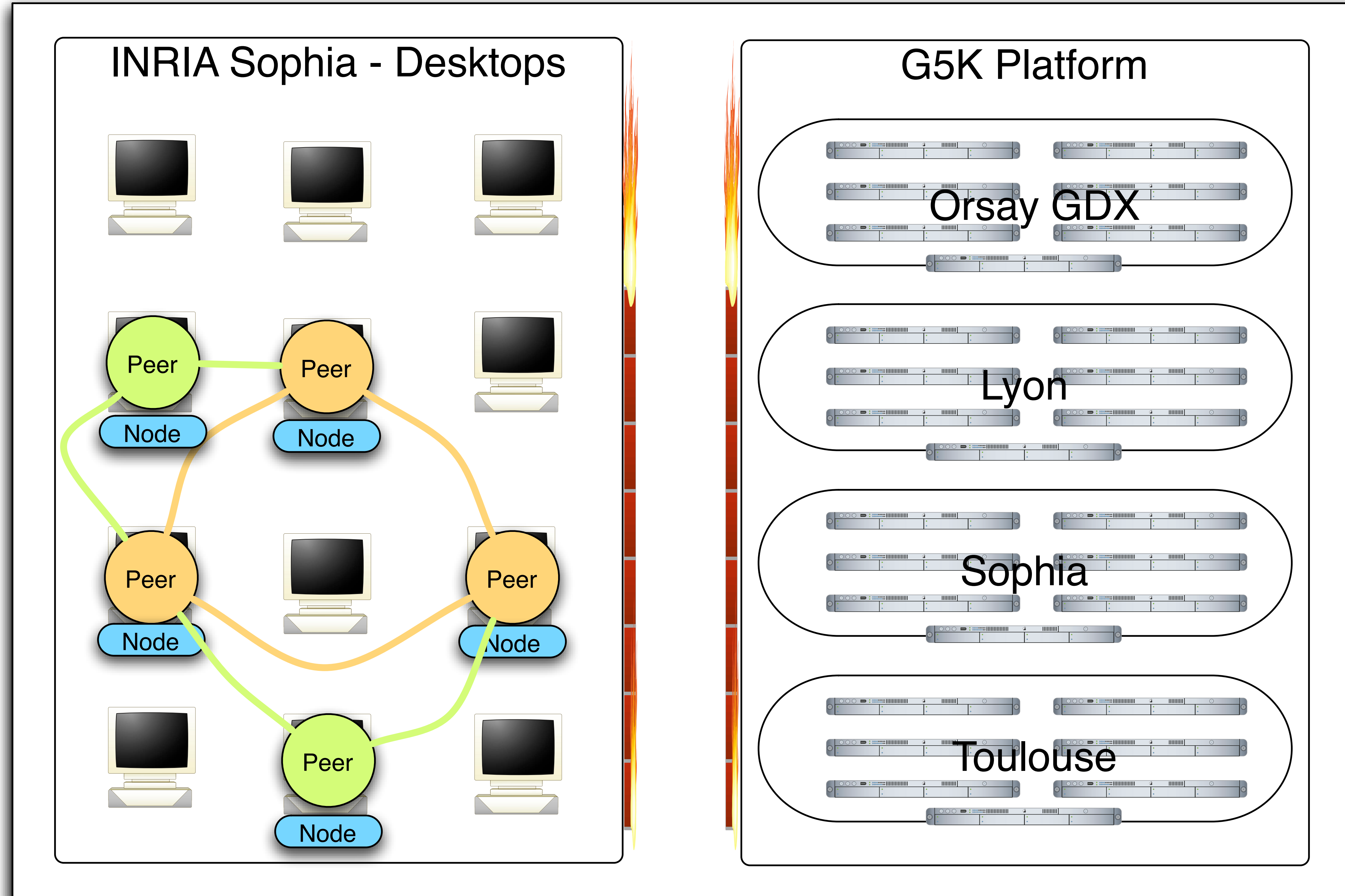
INRIA Sophia - Desktops
Peer
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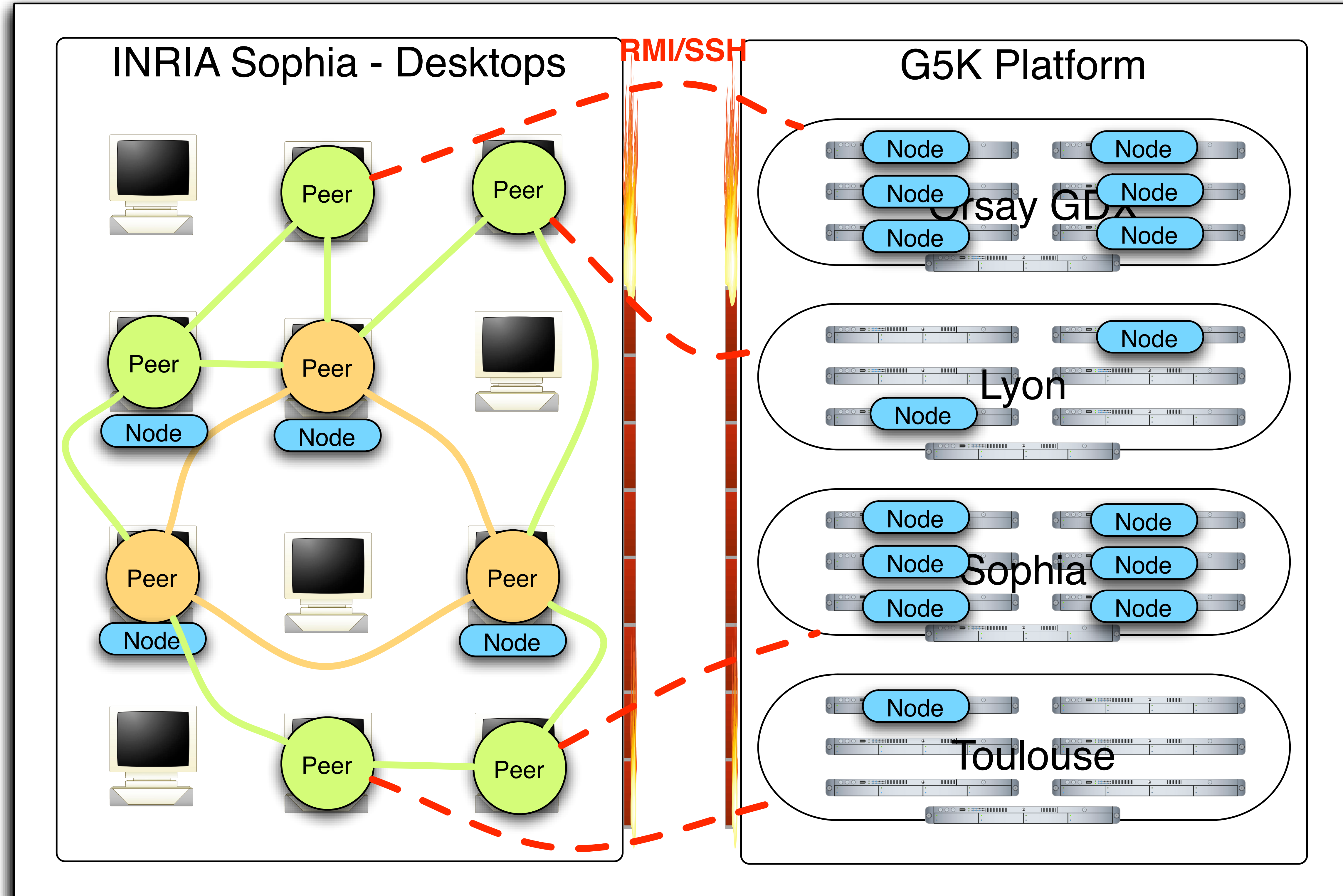
INRIA Sophia - Desktops
RMI/SSH
G5K Platform
Peer
Peer
Peer
Peer
Peer
Peer
Peer
Peer
Node
Node
Node
Node
Orsay GDX
Lyon
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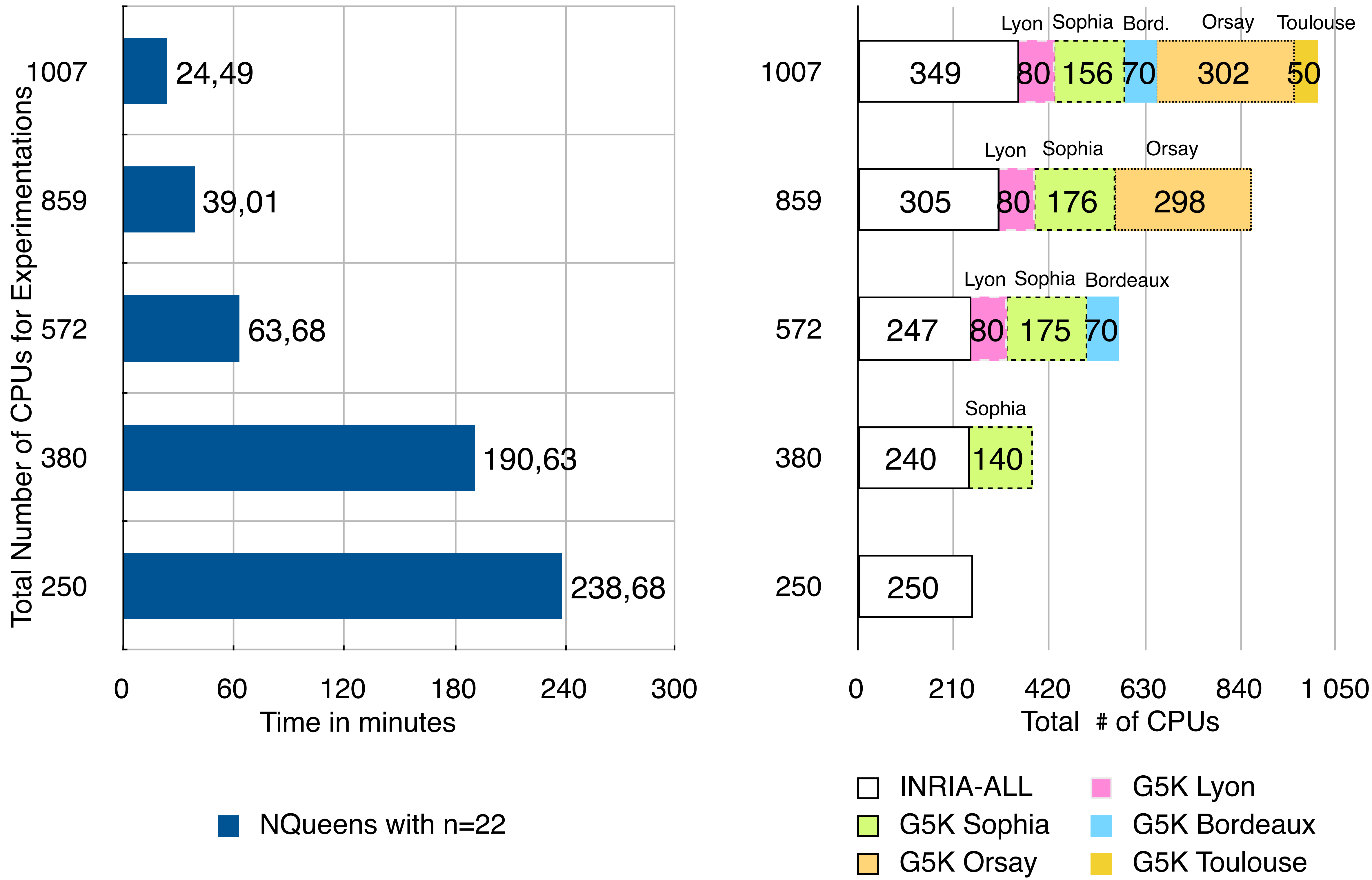
Large-Scale Experiments

- **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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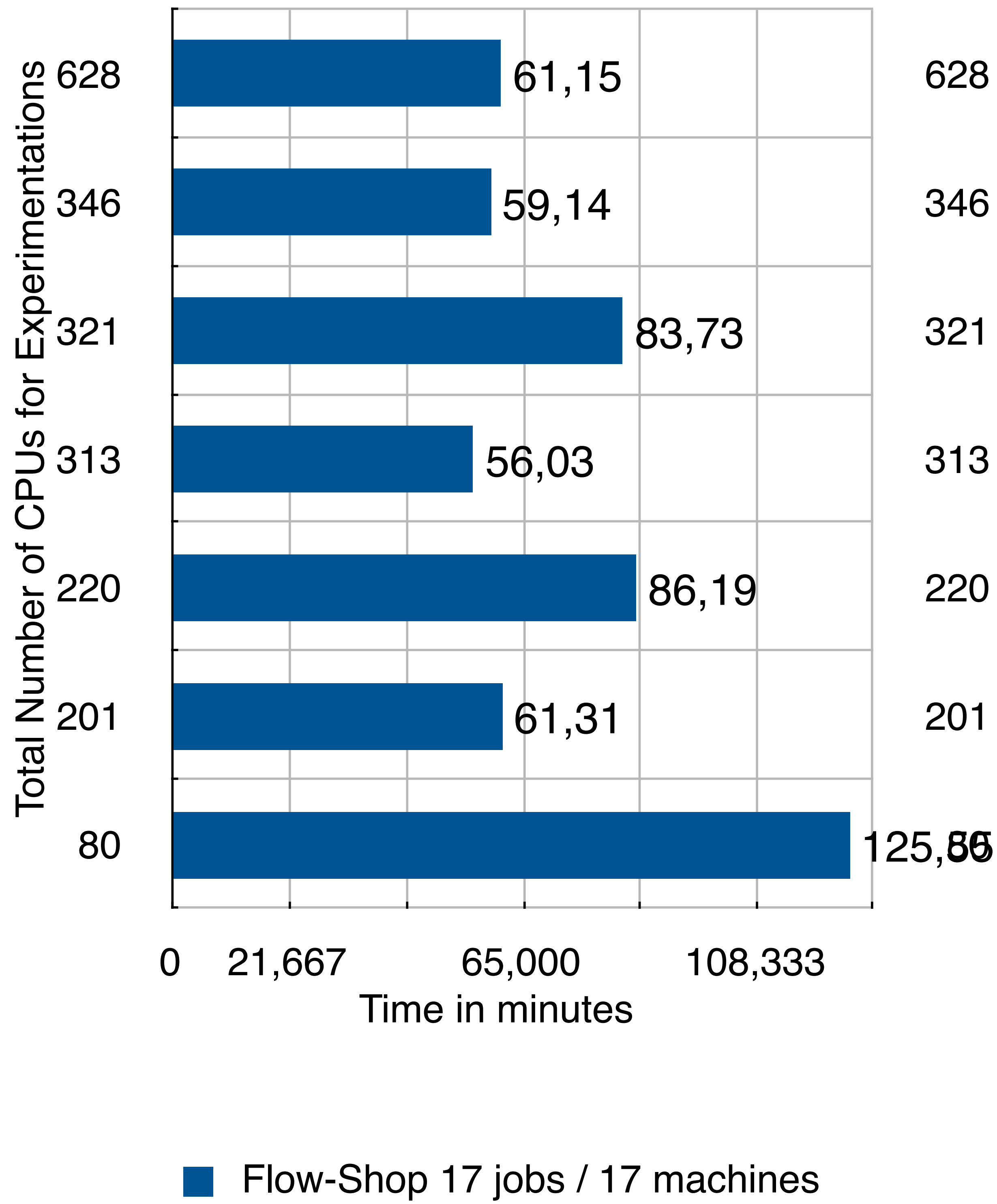

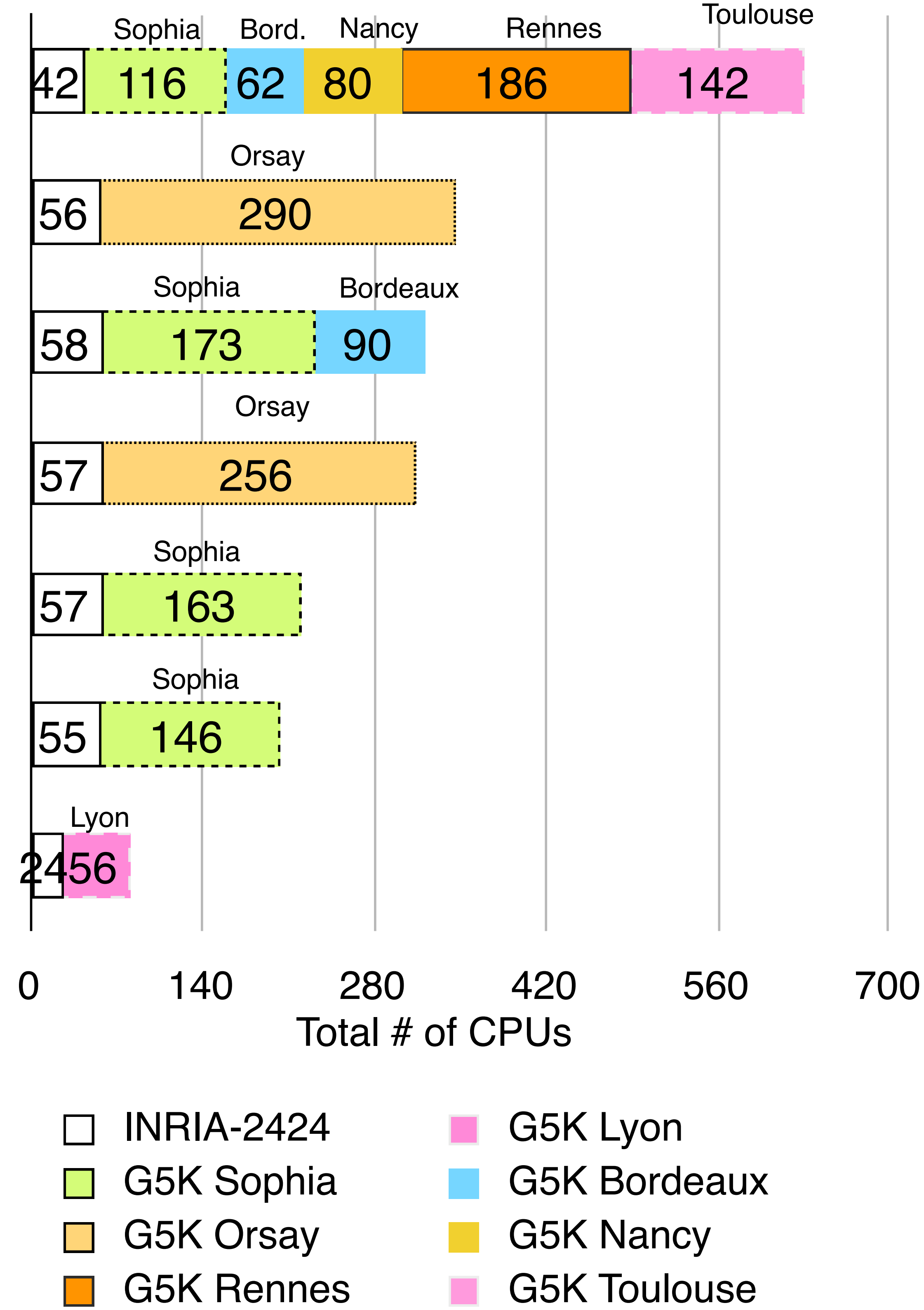

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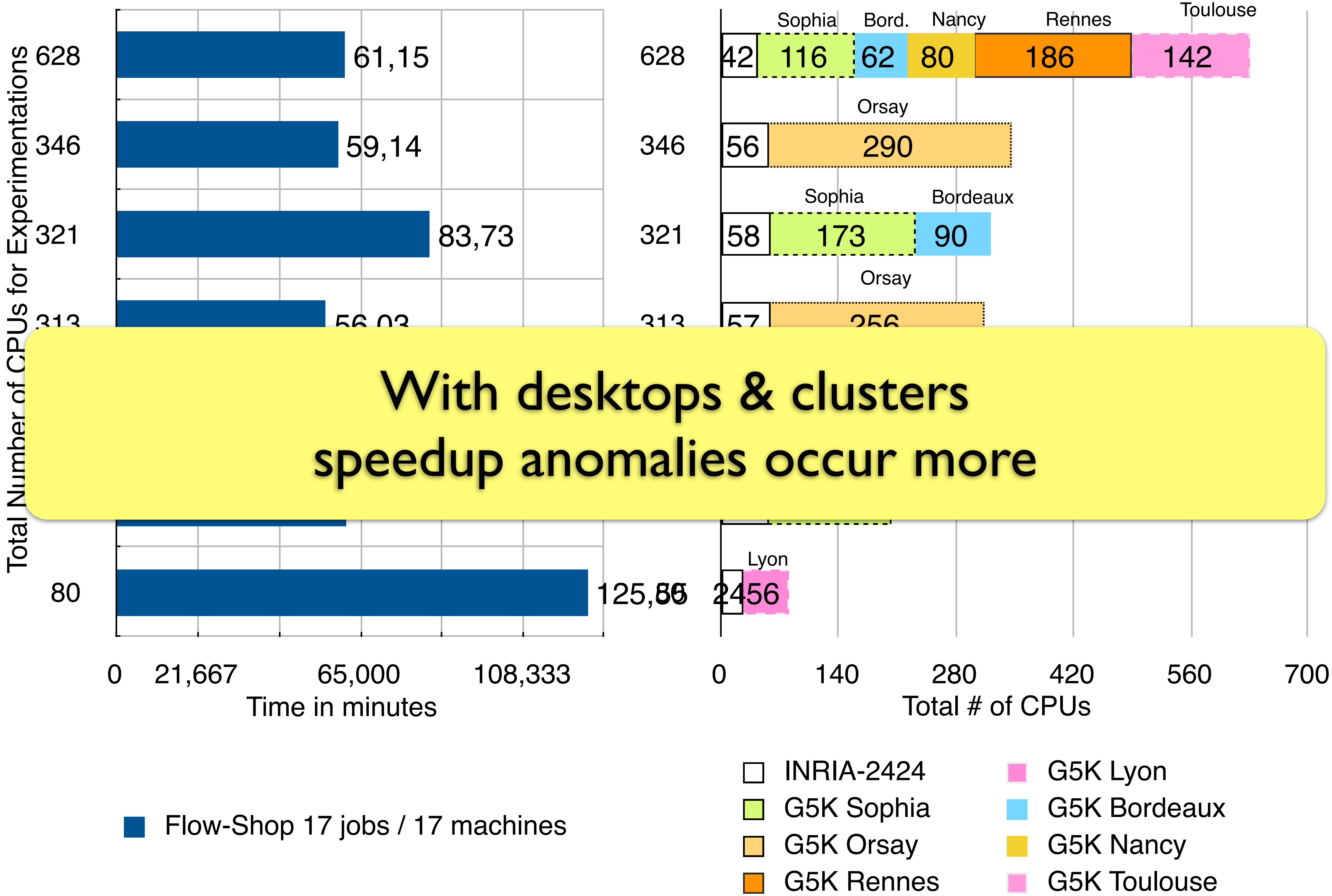

With desktops & clusters speedup anomalies occur more

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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- **Observation** from Grid'5000:
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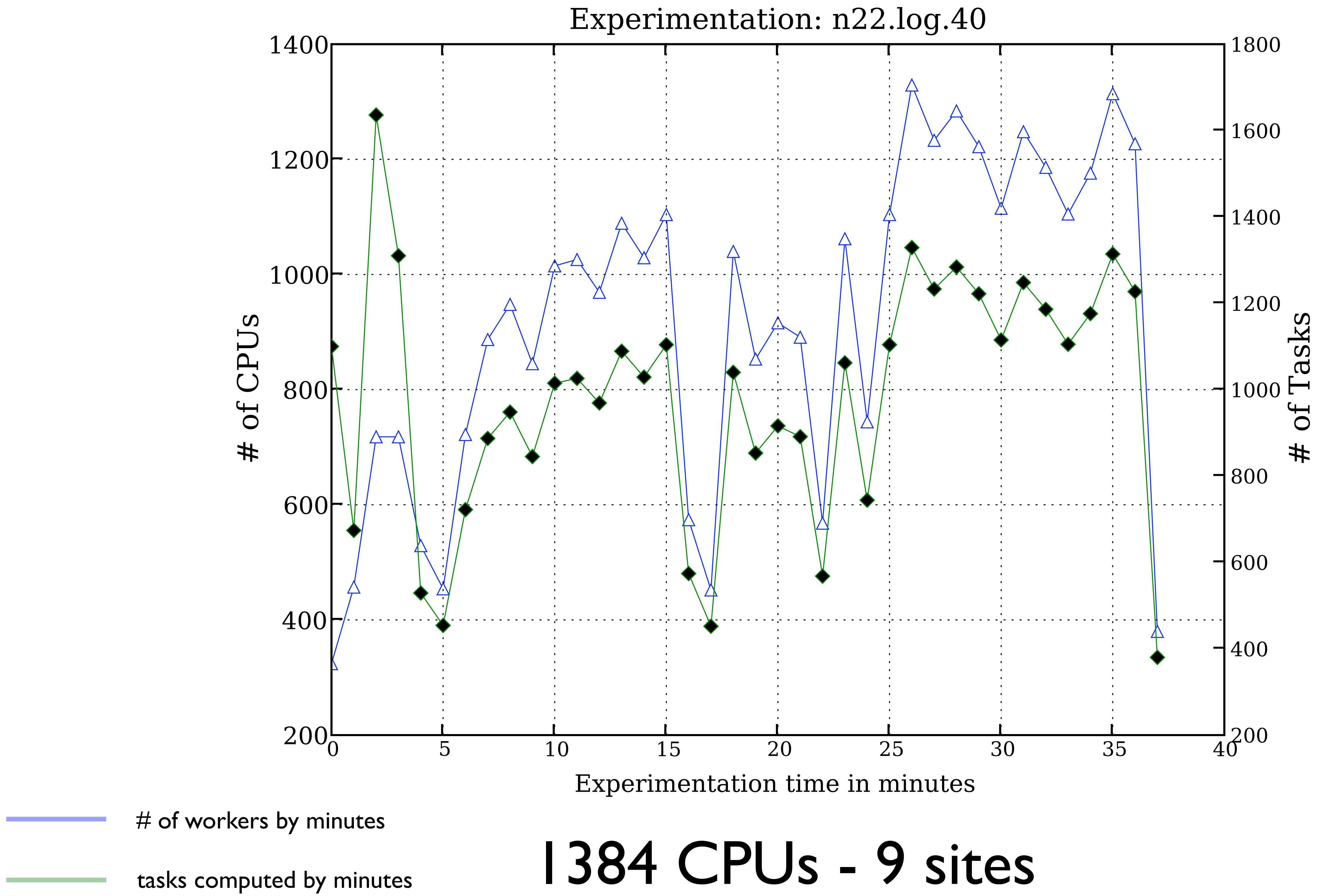
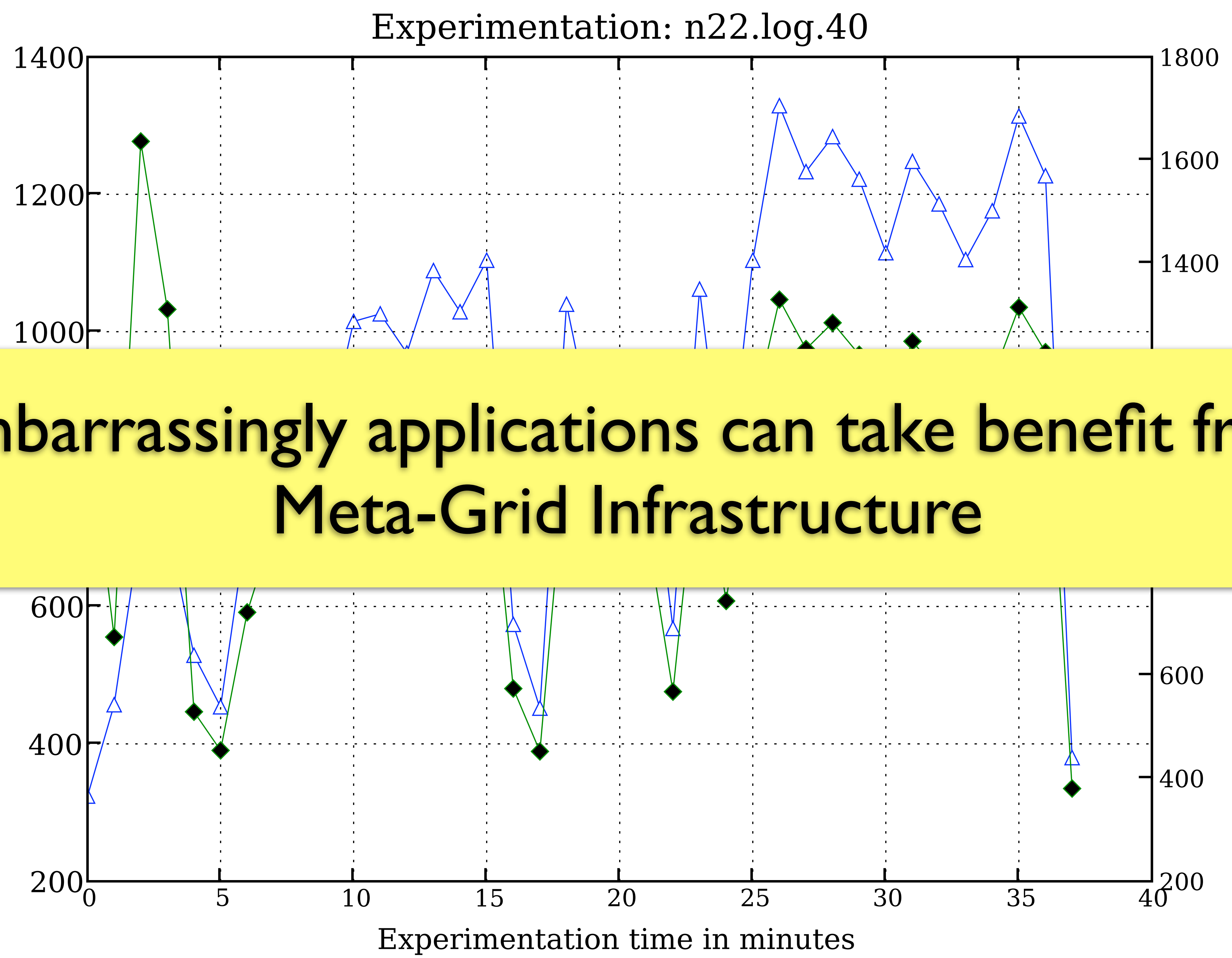
P2P infrastructure as a dynamic Grid middleware

P2P with N-Queens on Grid'5000



1384 CPUs - 9 sites

P2P with N-Queens on Grid'5000



Embarrassingly applications can take benefit from Meta-Grid Infrastructure

# of workers by minutes

tasks computed by minutes

1384 CPUs - 9 sites

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Perspectives & Ongoing Work

- 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

Conclusion

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

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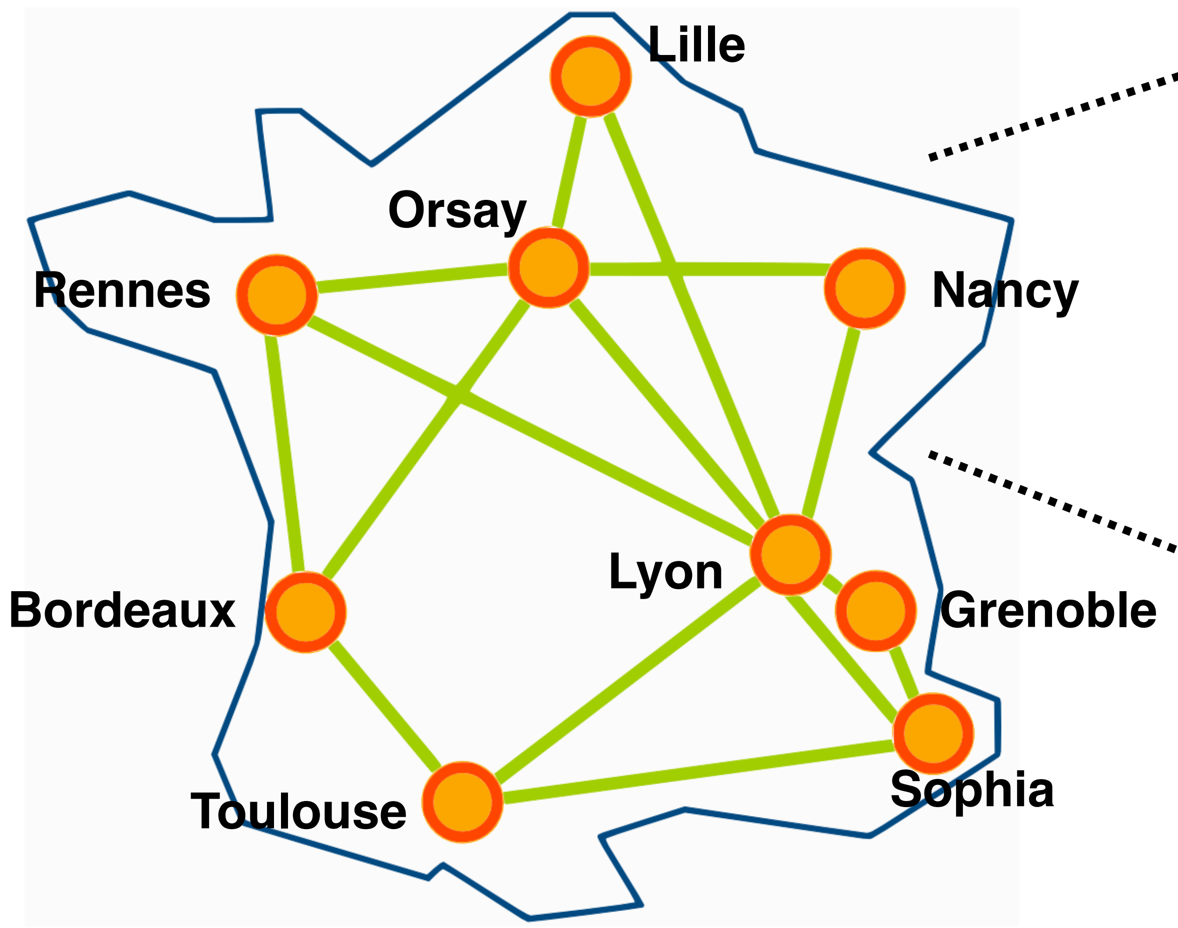
Grid'5000: The French Grid!



9 sites - 14 clusters - 4,790 Cores

Only large-scale experiments - aiming 3 sites / 1,000 cores

ProActive Grid Middleware

http://proactive.ow2.org

programming model	ASP formal model	Asynchronism	Component-based programming	Branch and bound
	Groups	Exception management	Legacy code wrapping	OOSPMD
middleware services	Mobility	Load balancing	Fault tolerance	Security
	Distributed garbage collector			
deployment	Deployment framework	Scheduler	Monitoring	Peer-to-Peer
communication	Multiple network protocols	Web services	File transfer	

ProActive
Programming, Composing, Deploying on the Grid

ActiveEon
SCALE BEYOND LIMITS

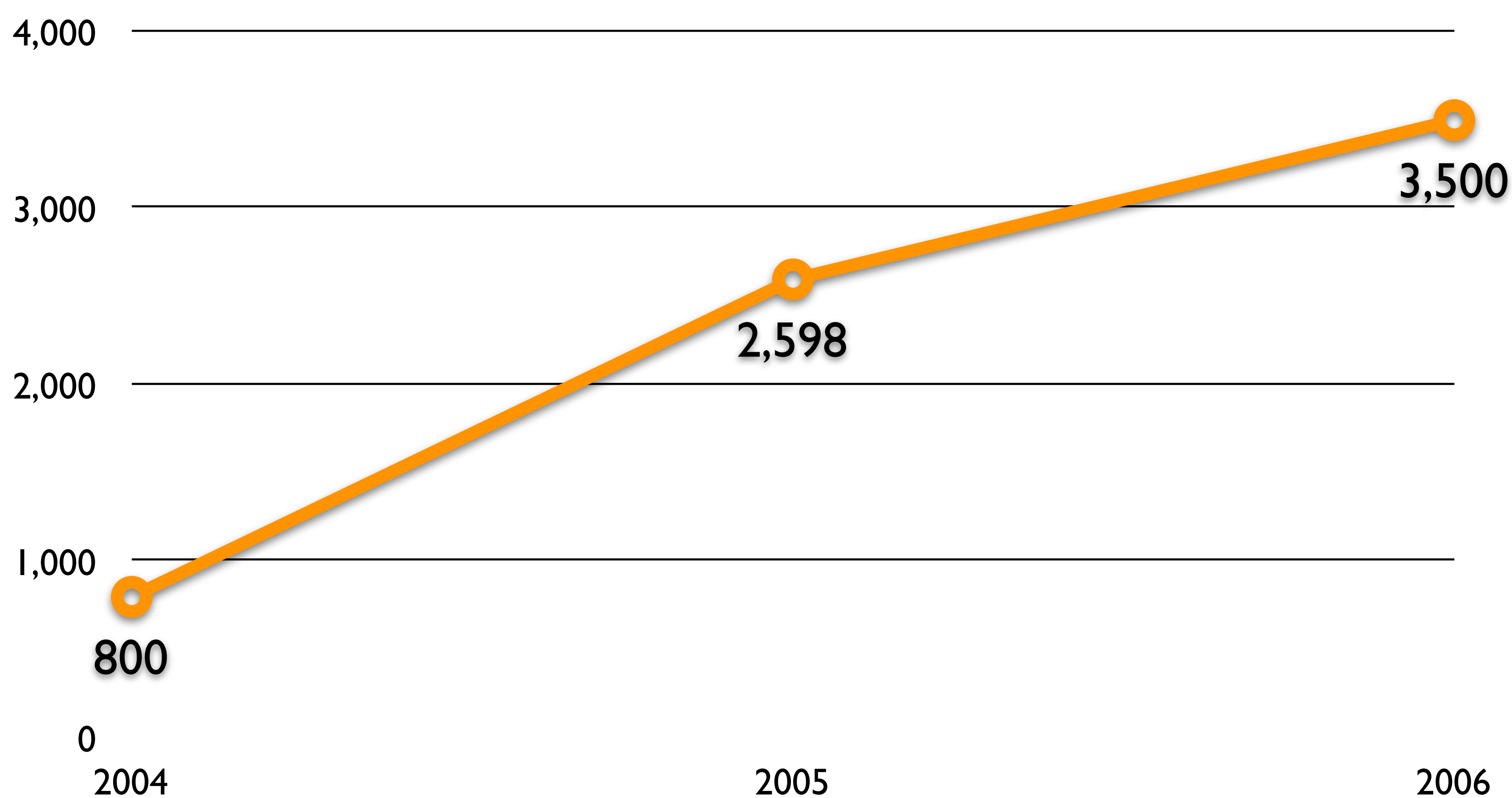
OW2
Consortium

GRID@WORK Plugtest

- Taking place in Sophia Antipolis, France
- 20-24 October 2008
- **V Edition**
- CoreGrid meetings
- Conferences / Tutorials
- Grid Programming Challenge: Barrier Option Pricing

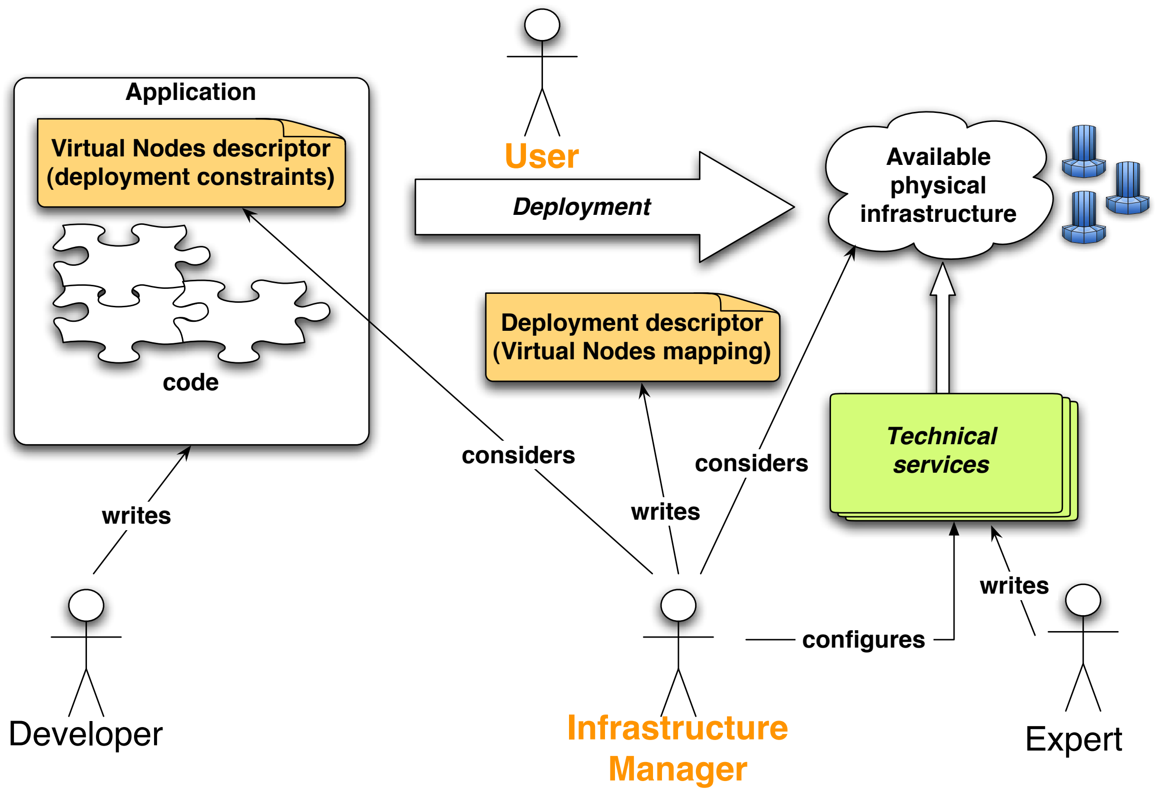
http://www.etsi.org/plugtests/GRID2008/About_GRID.htm

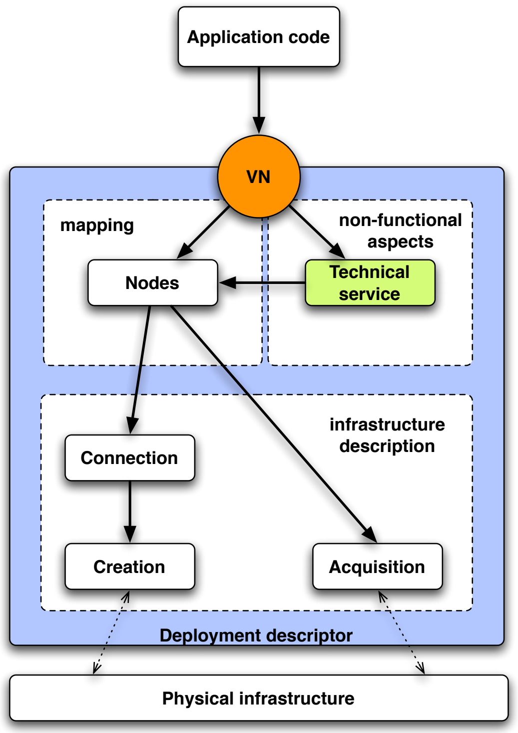
GRID@WORK Plugtest



24 sites | 43 sites | ~20 sites

GCM Deployment





- Part of GridComp Project in collaboration with ETSI
- Aim to standardize the Grid in complement of GGF
- Standard draft based on parts of my PhD

Support

- ***Grid'5000:*** Account creation & Experiment help
- **ProActive Java Grid Middleware**
- **Grid Plugtest and Challenge**
- **GCM Deployment**
- Java / Eclipse / Python

Last Things...

- **Office Room 5.21**
- **adc@csse.unimelb.edu.au**
- **http://www.csse.unimelb.edu.au/~adc**

[SCCC05] Balancing Active Objects on a Peer to Peer Infrastructure
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