Rhizoma: A Runtime for Self-deploying, Self-managing Overlays

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Cloud computing infrastructures are emerging

amazon web services EC2

CPU	1	4	8
Memory	1.7G	7.5G	15G
Disk	160G	850G	1690G
Unit	1	2	2
Price	$0.125	$0.50	$1.00

amazon web services S3

Storage	$0.150 per GB
Transfer	$0.100 per GB
Requests	$0.01 per 10,000 GET

Deploying an online service

Challenge 1:

Selecting appropriate providers and resources

Service deployed with one provider

Service gains popularity

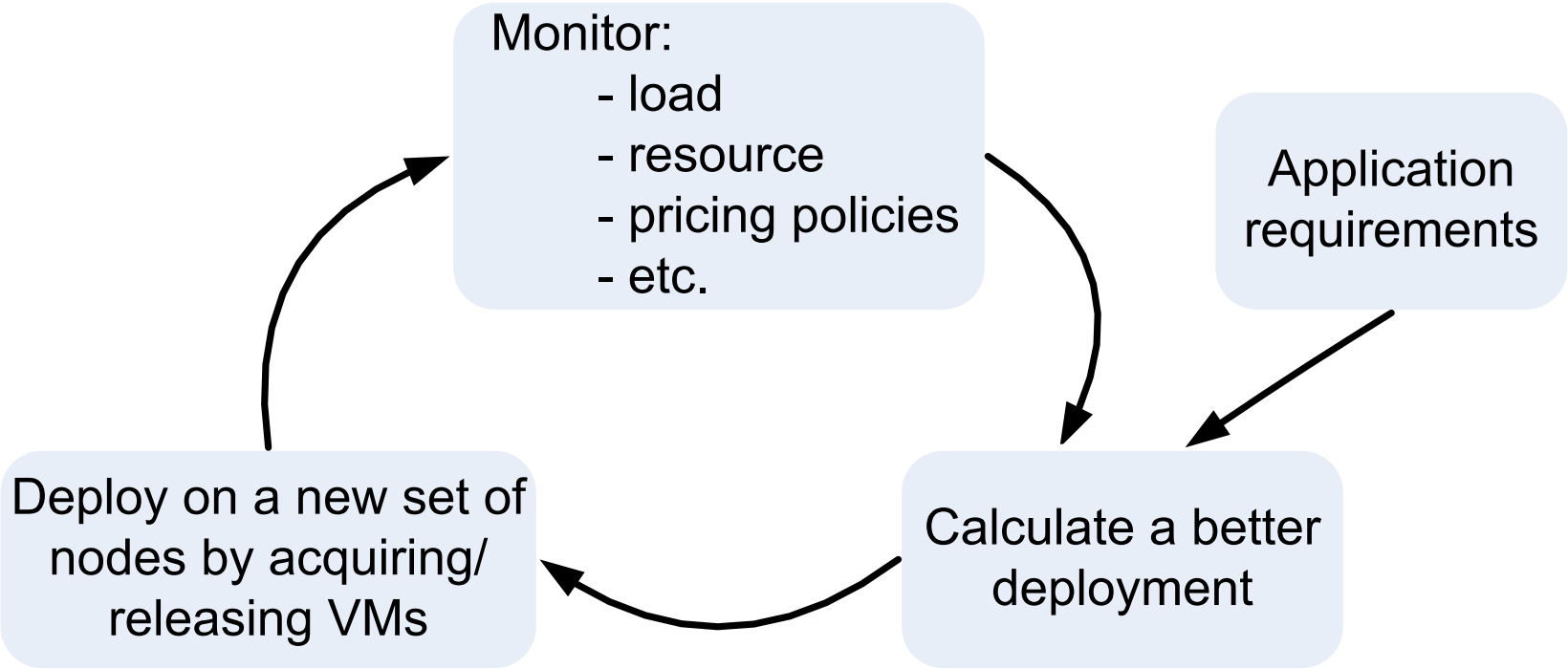
Provider outage

Problem summary

- Challenges
  - Changing resource availability
  - Changing application requirements
  - Changing pricing policies
- Current solutions
  - Human-in-the-loop
  - Separate management console (e.g. Rightscale)

Alternative approach: bundle management

- Management logic integrated with application instances
  - Instances use P2P-style self-organization
- Application "deploys itself"



Related work

- We build on existing work
  - Early PARC “worm” programs (1982)
  - Intelligent and mobile agents (1990s)
  - Autonomic computing (2000-)
- Apply the ideas to cloud environments…
  - Span multiple providers and configurations
  - Application controls resource allocation

Example application requirements (PsEPR)

- Planetary Scale Event Propagation and Router (PsEPR)
  - A unified reporting and event service for PlanetLab

P.Brett et al., “A Shared Global Event Propagation System to Enable Next Generation Distributed Services”, WORLDS’04.

- Requirements
  - 6-10 well-connected nodes
  - Lightly-loaded
  - Geographically distributed

  - Maximize CPU cycles
  - Minimize network diameter
  - Reduce budget and migration cost

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- Constraint Optimization Problem

Idea: Apply constraint logic programming (CLP)

- Constraint Programming
  - Constraints
  - Objective function = Utility function - Cost function

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Utility function: value of a given configuration

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Cost function: cost of moving to a new configuration

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- Constraint Programming
  - Constraints
  - Objective function = Utility function - Cost function

- Logic Programming
  - Heterogeneous resource information
  - Inference rules

PsEPR requirements in CLP

CONSTRAINTS

```
node_constraint(Host) :-
  comonnode{hostname: Host},
  alive(Host),
  light_loaded(Host),
  is_avail(Host),
  get_node_attr(Host, cpuspeed, Cpuspeed),
  get_node_attr(Host, freecpu, Freecpu),
  Cpuspeed*Freecpu/100 > 1.5.
```

```
group_constraint(NodeList) :-
  assemble_values(NodeList, location, Locs),
  length(NodeList, Len),
  Max is ((Len-1)//4)+1,
  ( for(I, 1, 4), param(Locs, Max) do
      count_element(I, Locs, Num),
      Num =< Max ).
```

```
path_constraint(LenList, Max) :−
  max(LenList, Max),
  diameterUtil(_, DiameterMax, _),
  Max < DiameterMax.
```

COST FUNCTION

```
migration_cost(Actions, MigrateCost) :-
  count_element(add, Actions, AddLen),
  count_element(remove, Actions, RmvLen),
  addCostParam(AddParam),
  removeCostParam(RmvParam),
  MigrateCost is AddParam*AddLen +
                 RmvParam*RmvLen.
```

UTILITY FUNCTION

```
util_function(NodeList, Util, Params) :-

  % Compute utility values for different node attributes
  fiveminloadUtil(LoadMin, LoadMax, LoadWeight),
  assemble_values(NodeList, fiveminload, LoadList),
  util_value("<", LoadList, LoadMin, LoadMax, LoadUtil),

  % Omitting utility values for liveslices and freecpu, the same as above

  % Utility of max distance from fixed nodes to the overlay
  findall(P, fixednode(P), Fixed),
  minlatency(MinLat),
  maxneighUtil(_, NeighMax, NeighWeight),
  get_nearest_neighbor_list(Fixed, NodeList, NeighList),
  max(NeighList, MaxDist),
  util_value("<", [MaxDist], MinLat, NeighMax, NeighUtil),

  % Utility of overlay network diameter
  diameterUtil(_, DiamMax, DiamWeight),
  util_value("<", Params, MinLat, DiamMax, DiamUtil),

  % Weighted average of the utilities above
  weighted_avg([LoadUtil, SliceUtil, CpuUtil, NeighUtil, DiamUtil],
  [LoadWeight, SliceWeight, CpuWeight, NeighWeight, DiamWeight], Util).
```

Definition of util_value:

$\mathbf{util\_value}_{<} = \text{avg}_i\ ((x_{max} - \text{bound}(x_i))/(x_{max} - x_{min}))$

$\mathbf{util\_value}_{>} = \text{avg}_i\ ((\text{bound}(x_i) - x_{min})/(x_{max} - x_{min}))$

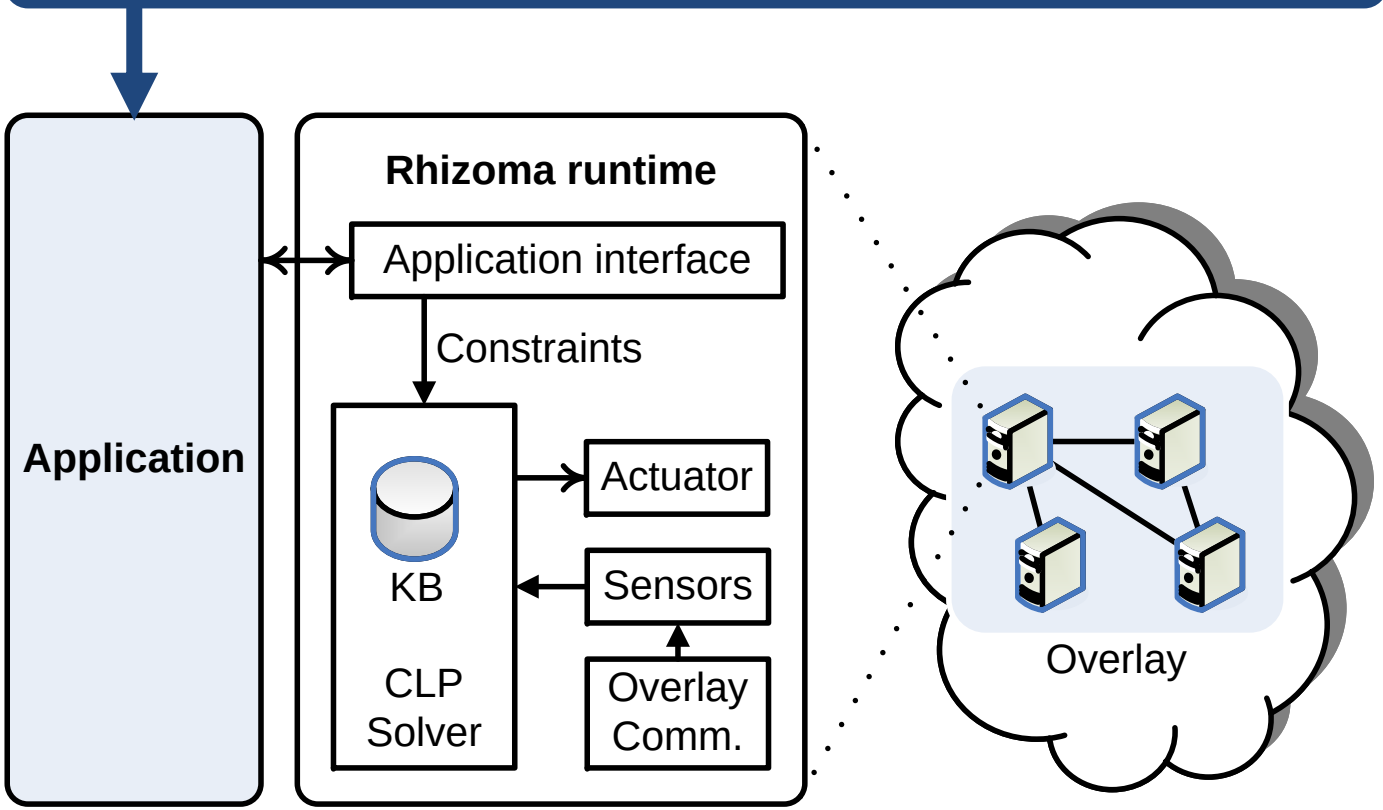
$\text{bound}(x) = \max(\min(x, x_{max}), x_{min})$

CONFIGURATIONS

fiveminloadUtil(0, 10, 2). *liveslicesUtil*(0, 10, 1). *freecpuUtil*(1, 4, 3). *maxneighUtil*(0, 500, 2). *diameterUtil*(0, 1000, 2).
addCostParam(*0.012*). *removeCostParam*(0).

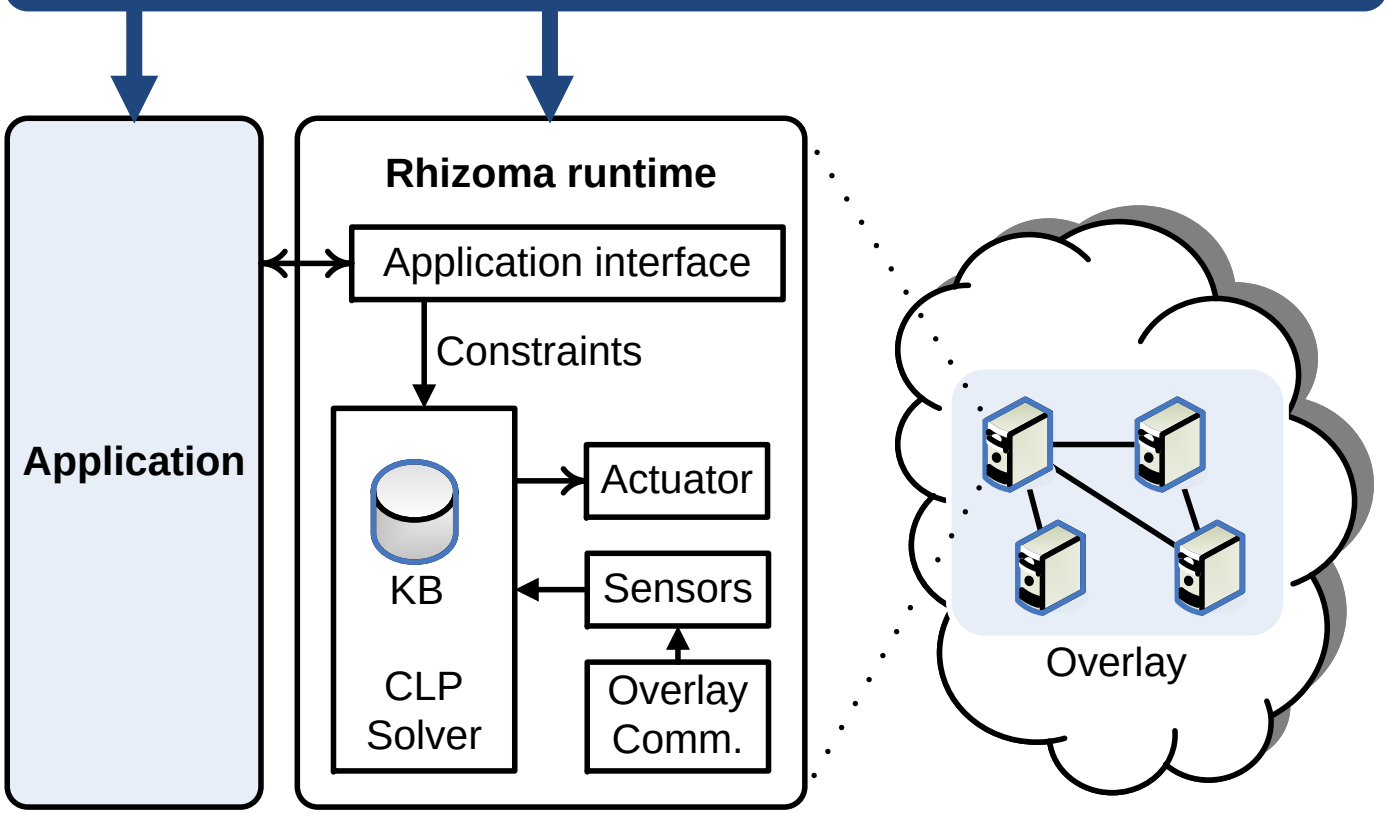
Our system: Rhizoma

- Application is a self-organizing overlay



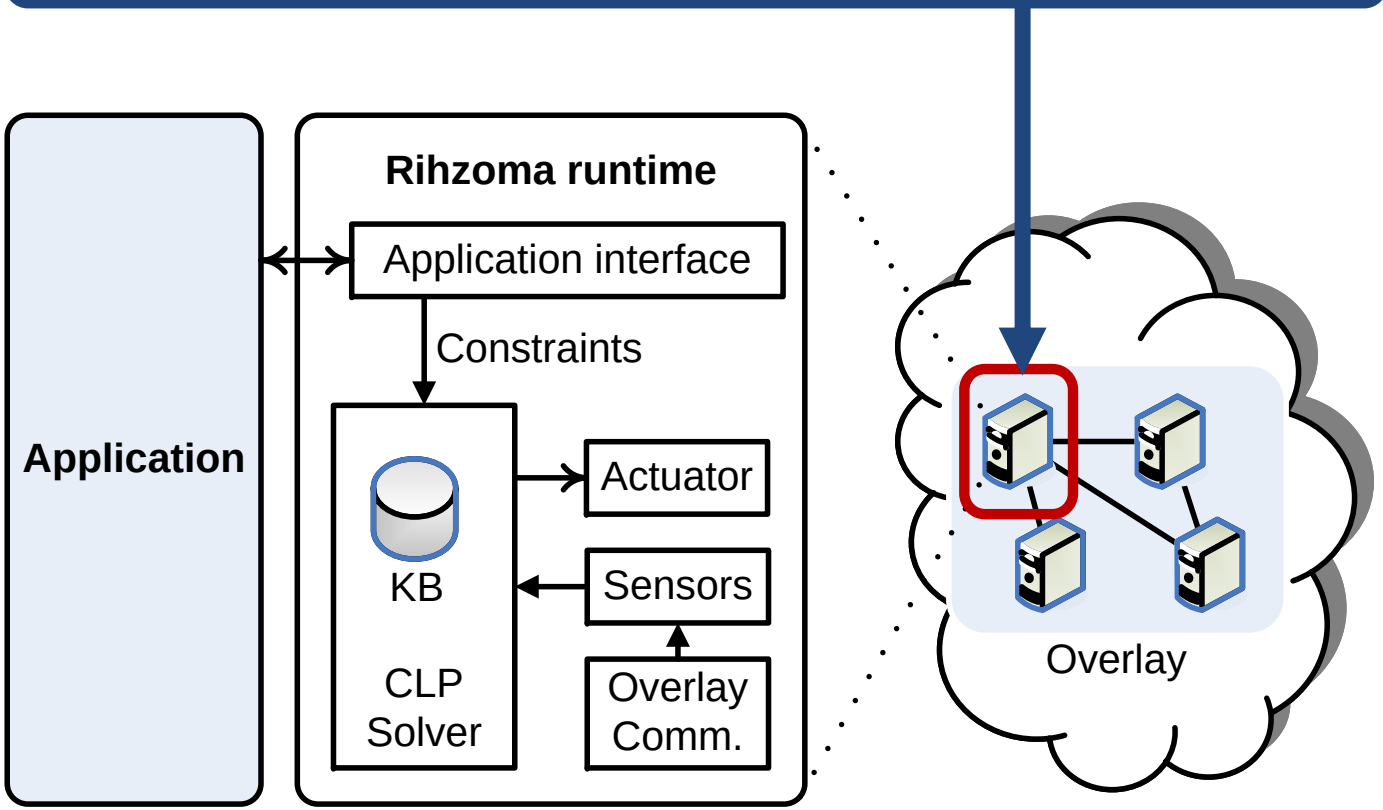
Our system: Rhizoma

- Rhizoma runtime runs alongside application



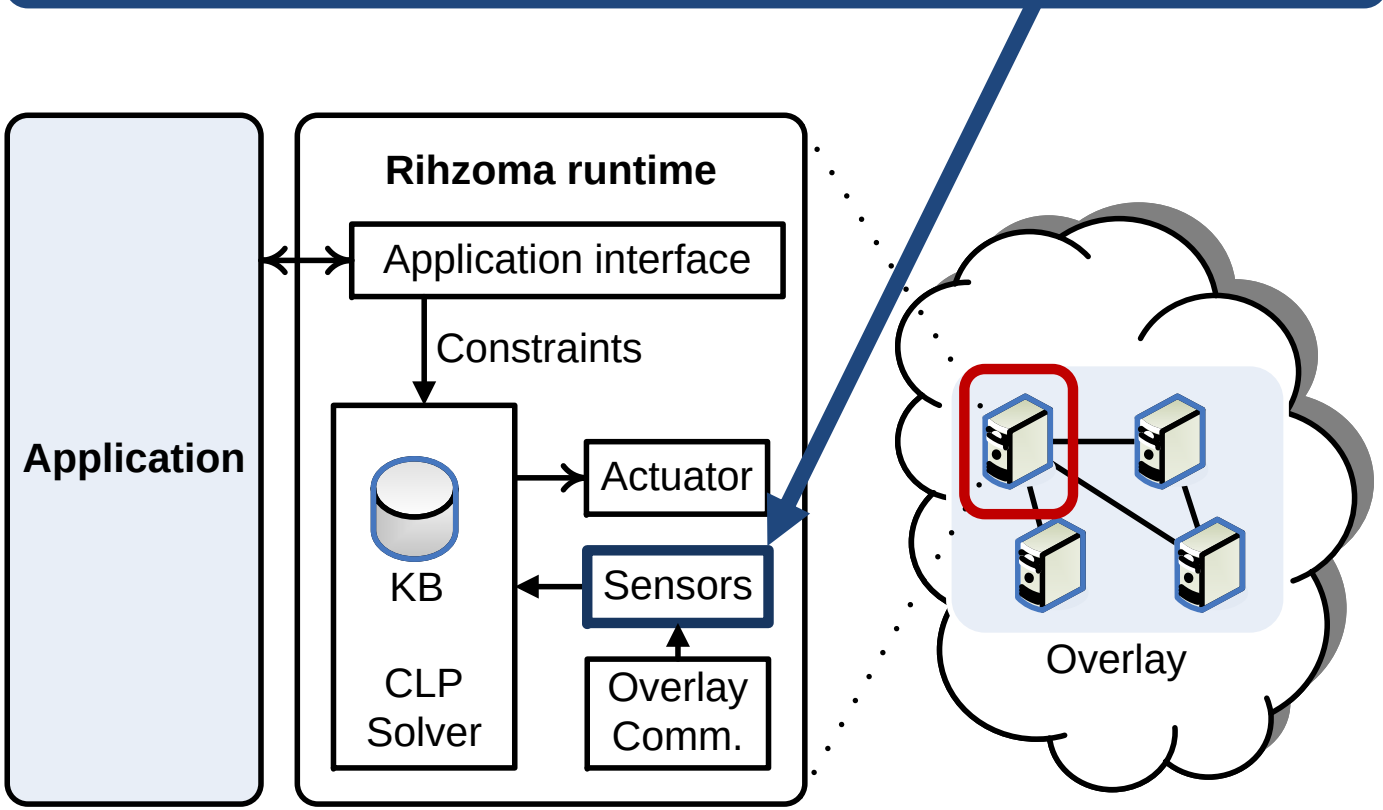
Our system: Rhizoma

- One node is elected as *coordinator* and runs CLP solver



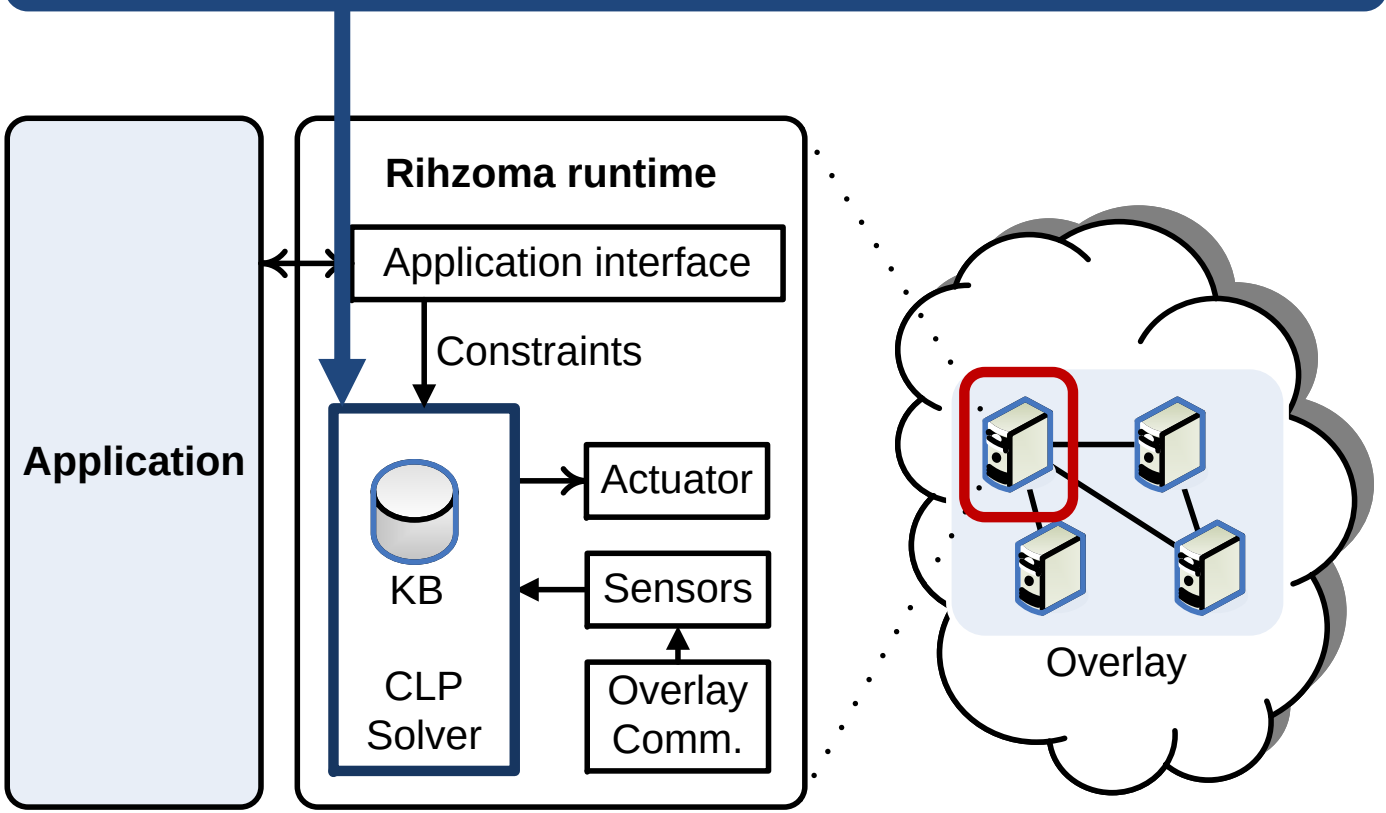
Our system: Rhizoma

- Sensors gather info from overlay and external service



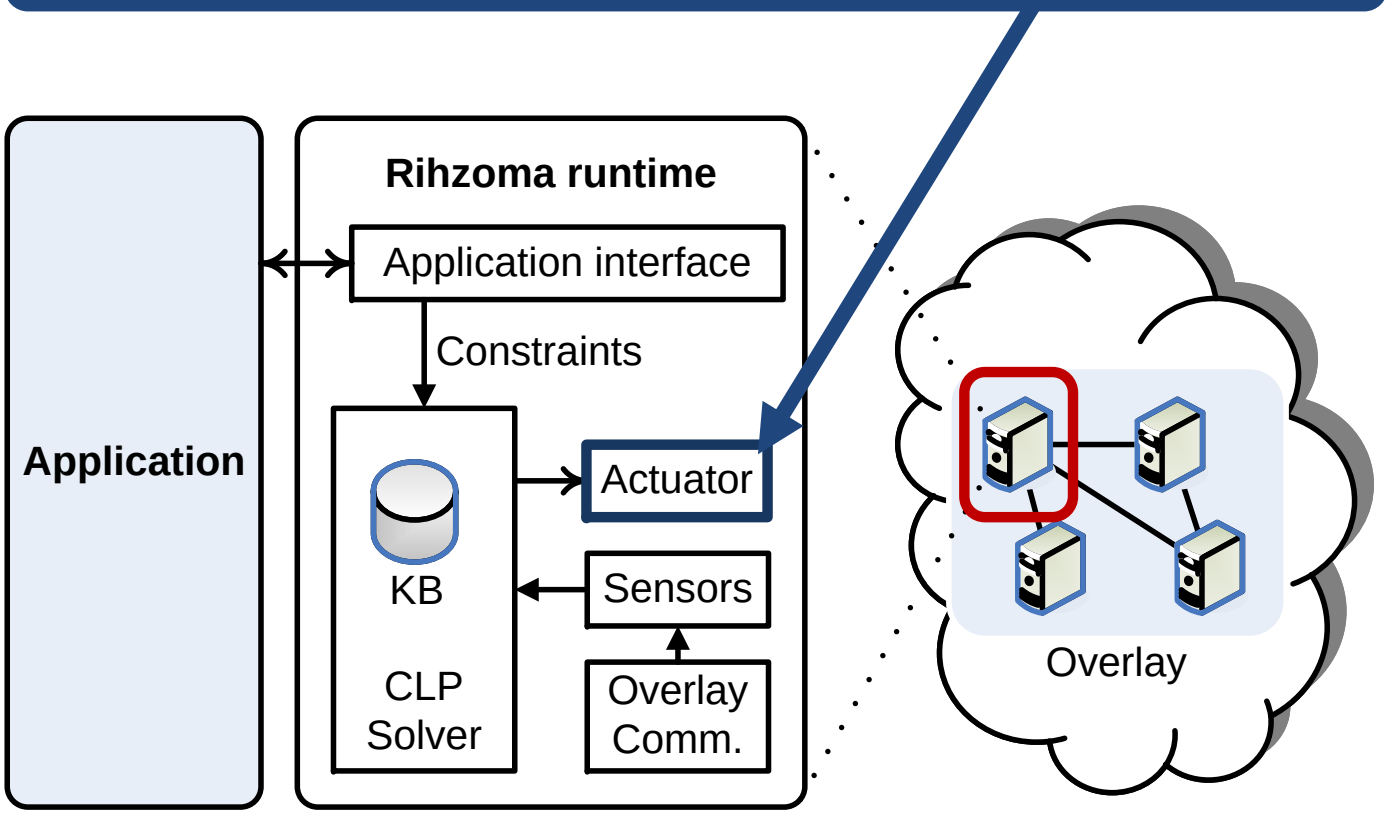
Our system: Rhizoma

- CLP solver calculates better deployment



Our system: Rhizoma

- Actuator acquires/releases VMs, starts/stops application



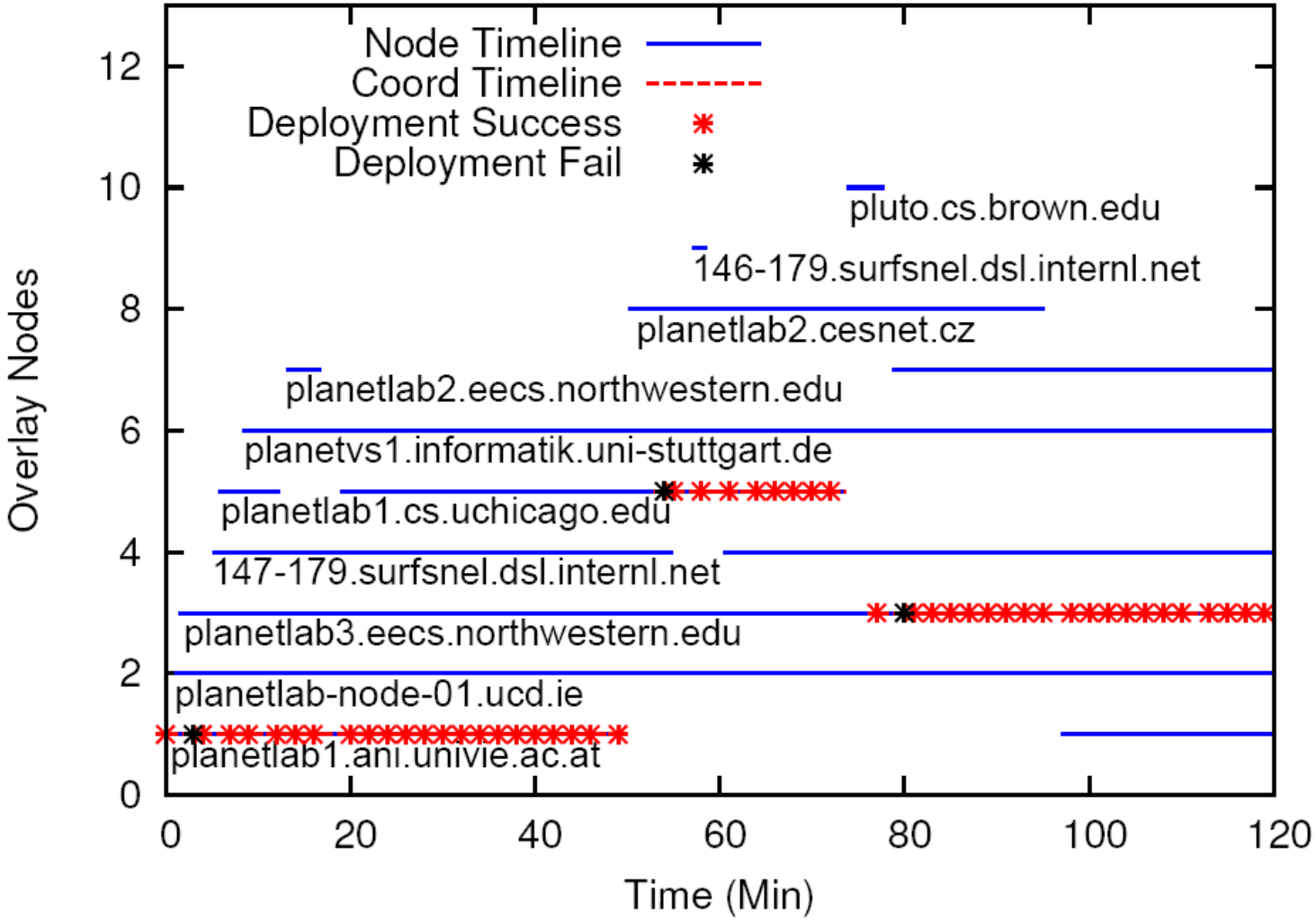
Evaluation

- Rhizoma runtime
- PsEPR requirements

- 8 hour trace running on PlanetLab

- Overlay behavior
- Utility value
- Weighted attributes

Rhizoma hosting PsEPR on PlanetLab



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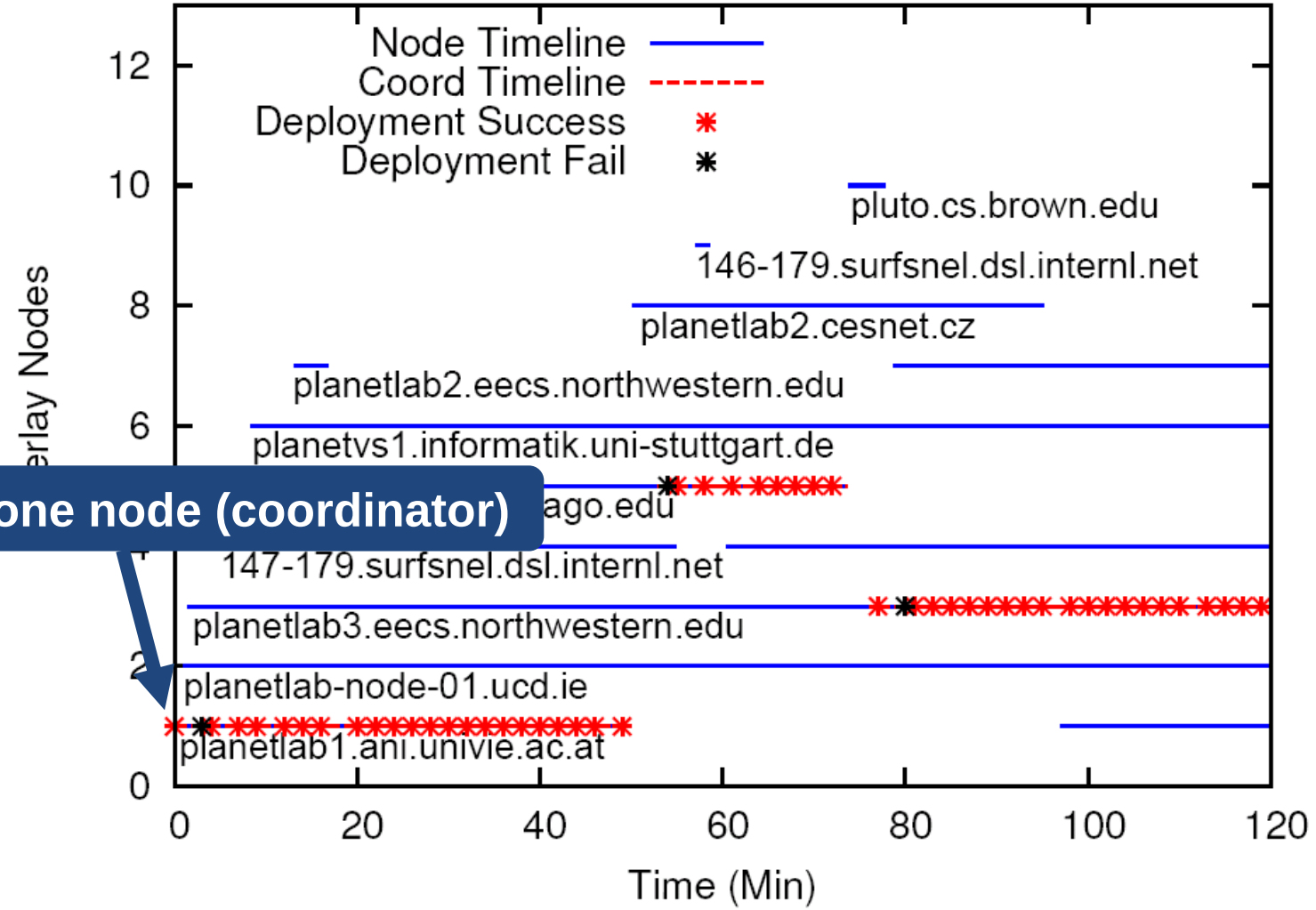
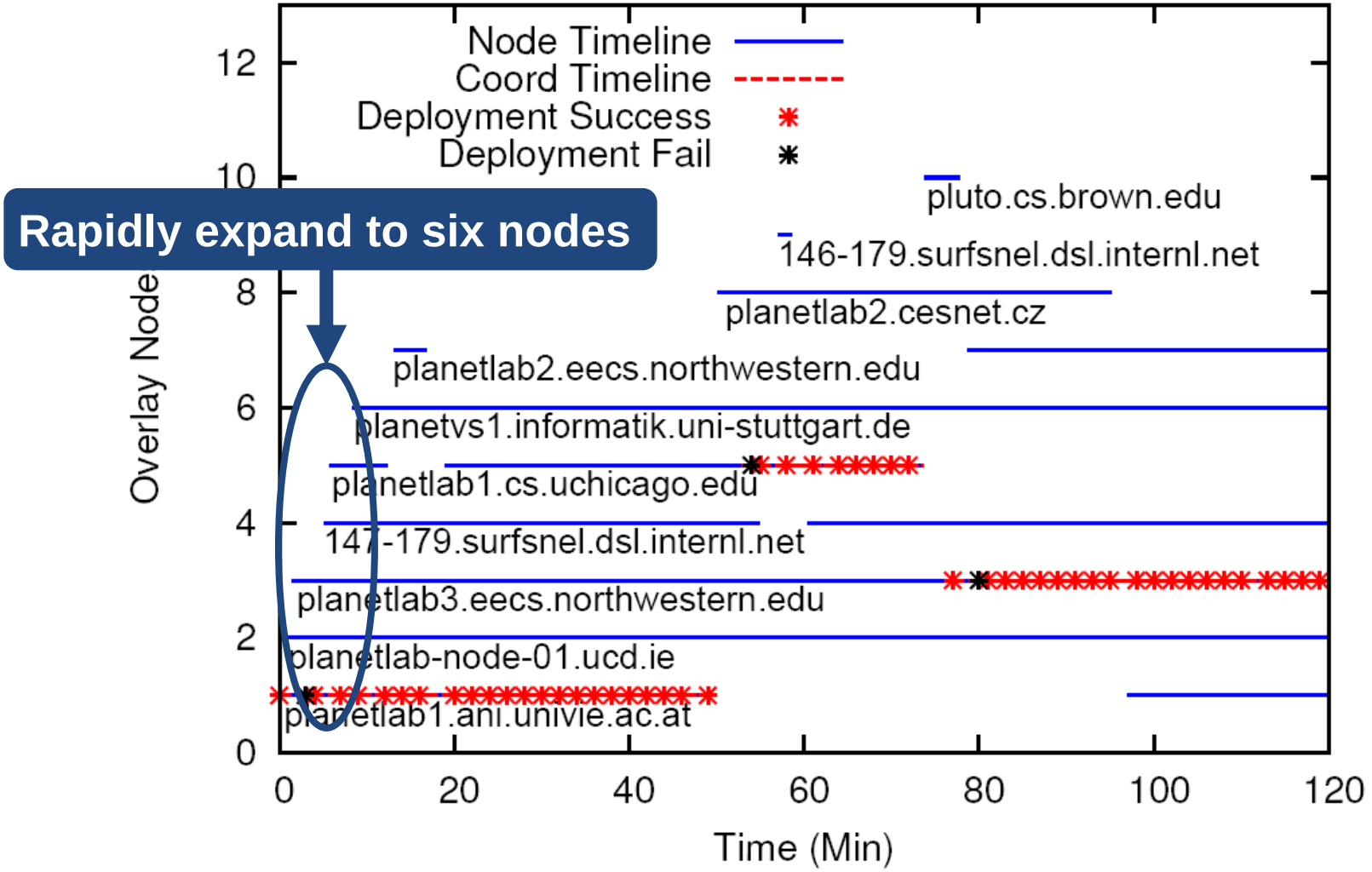


Start on one node (coordinator)

Rhizoma hosting PsEPR on PlanetLab



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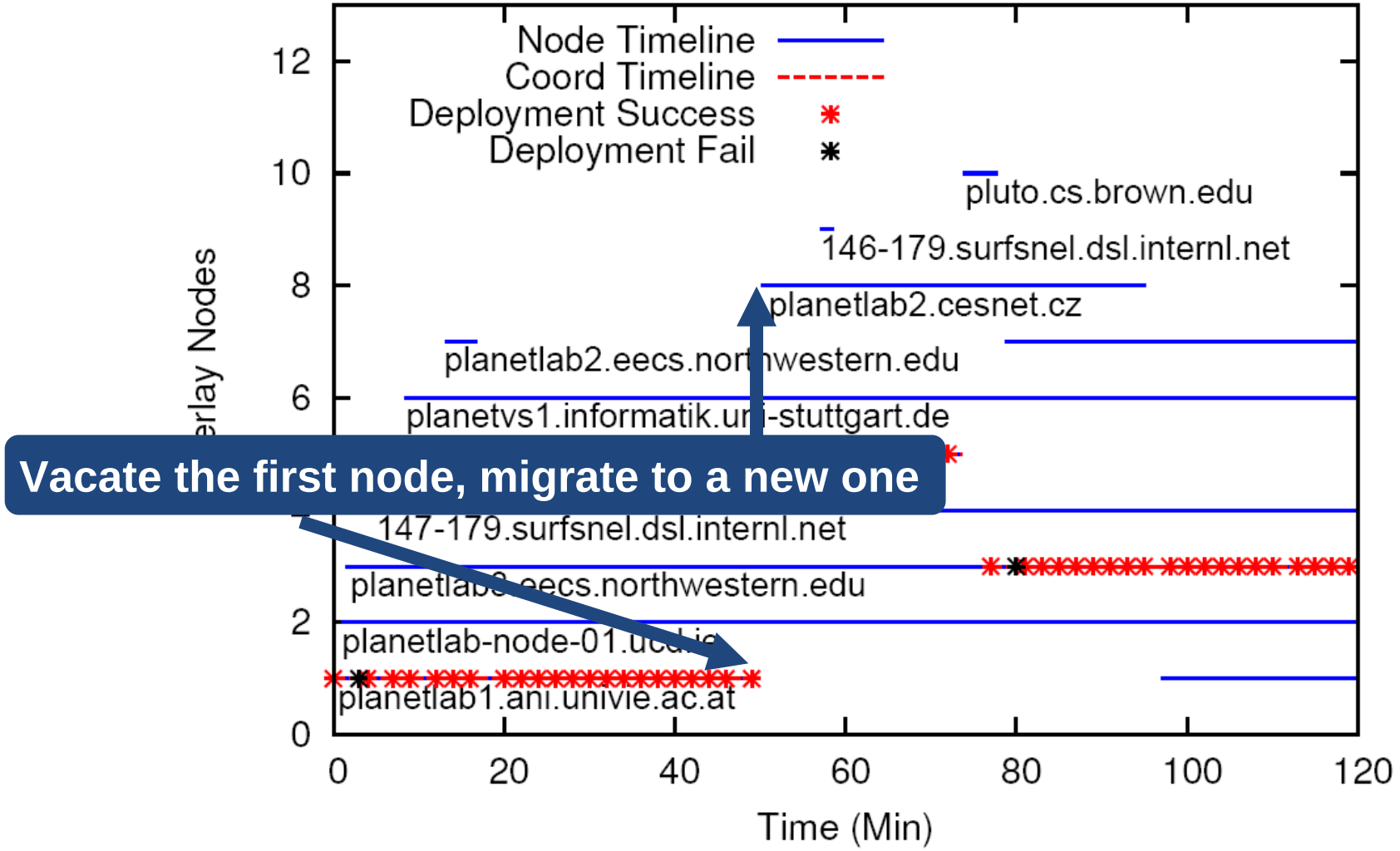

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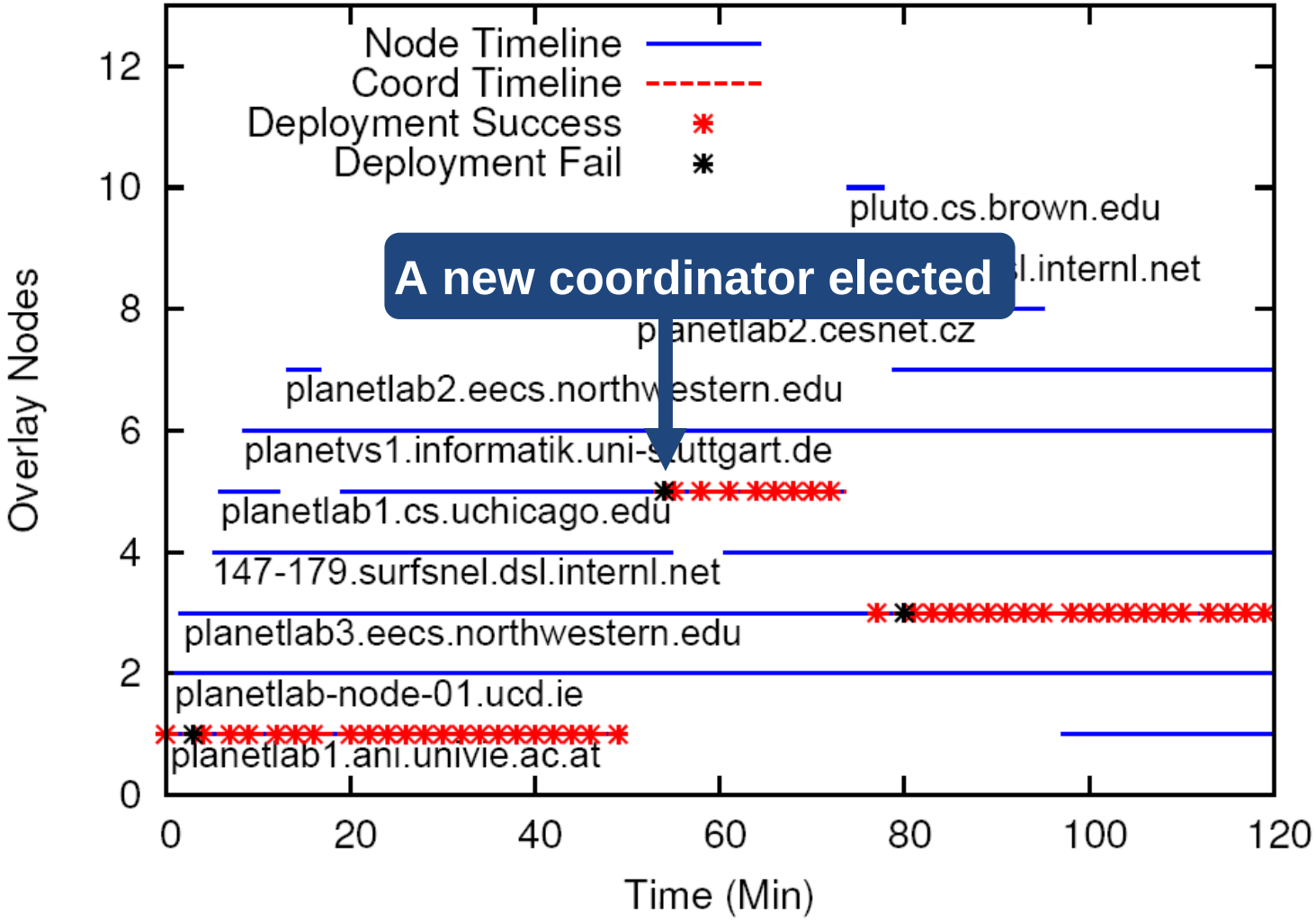
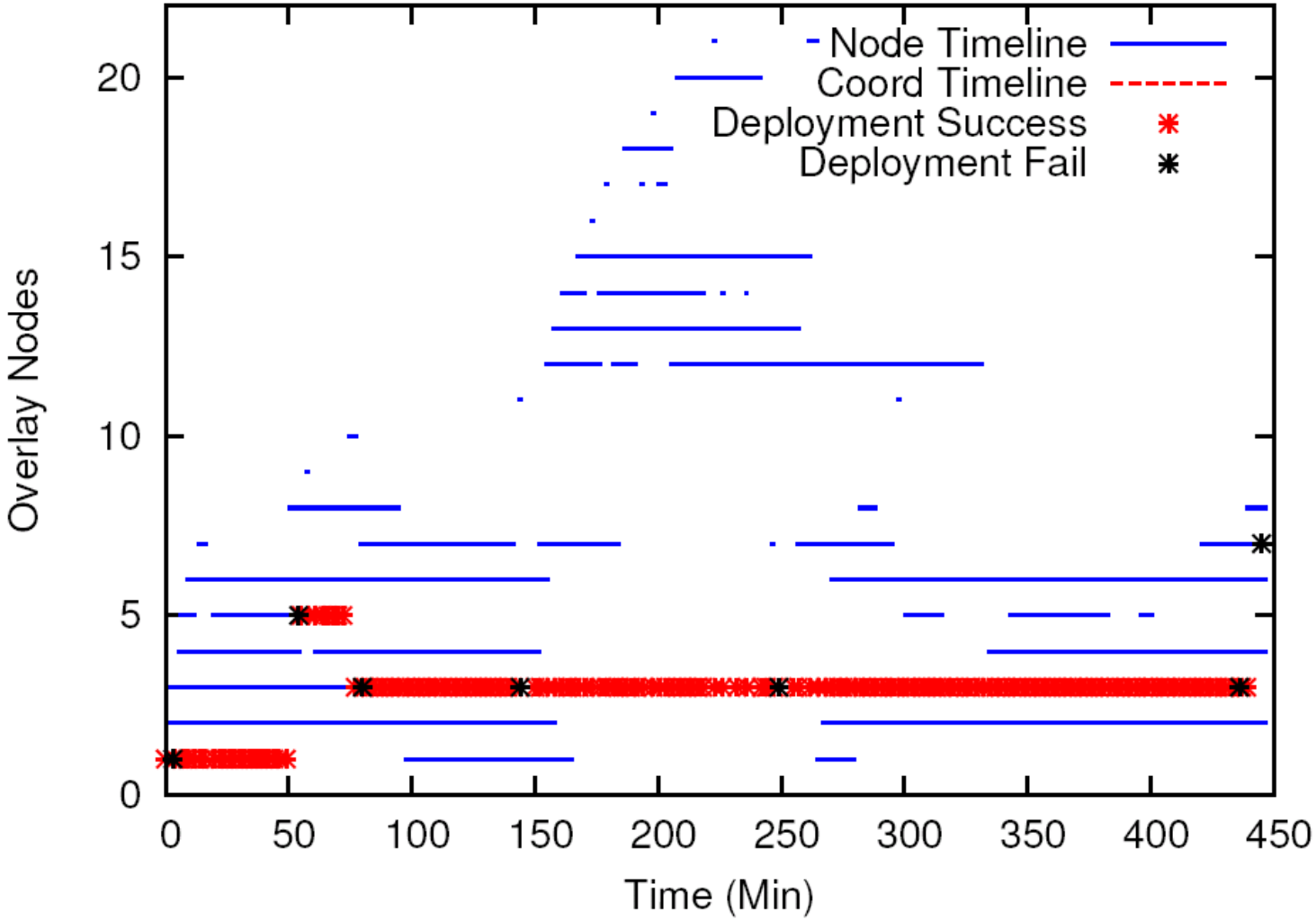


Rhizoma hosting PsEPR – longer trace



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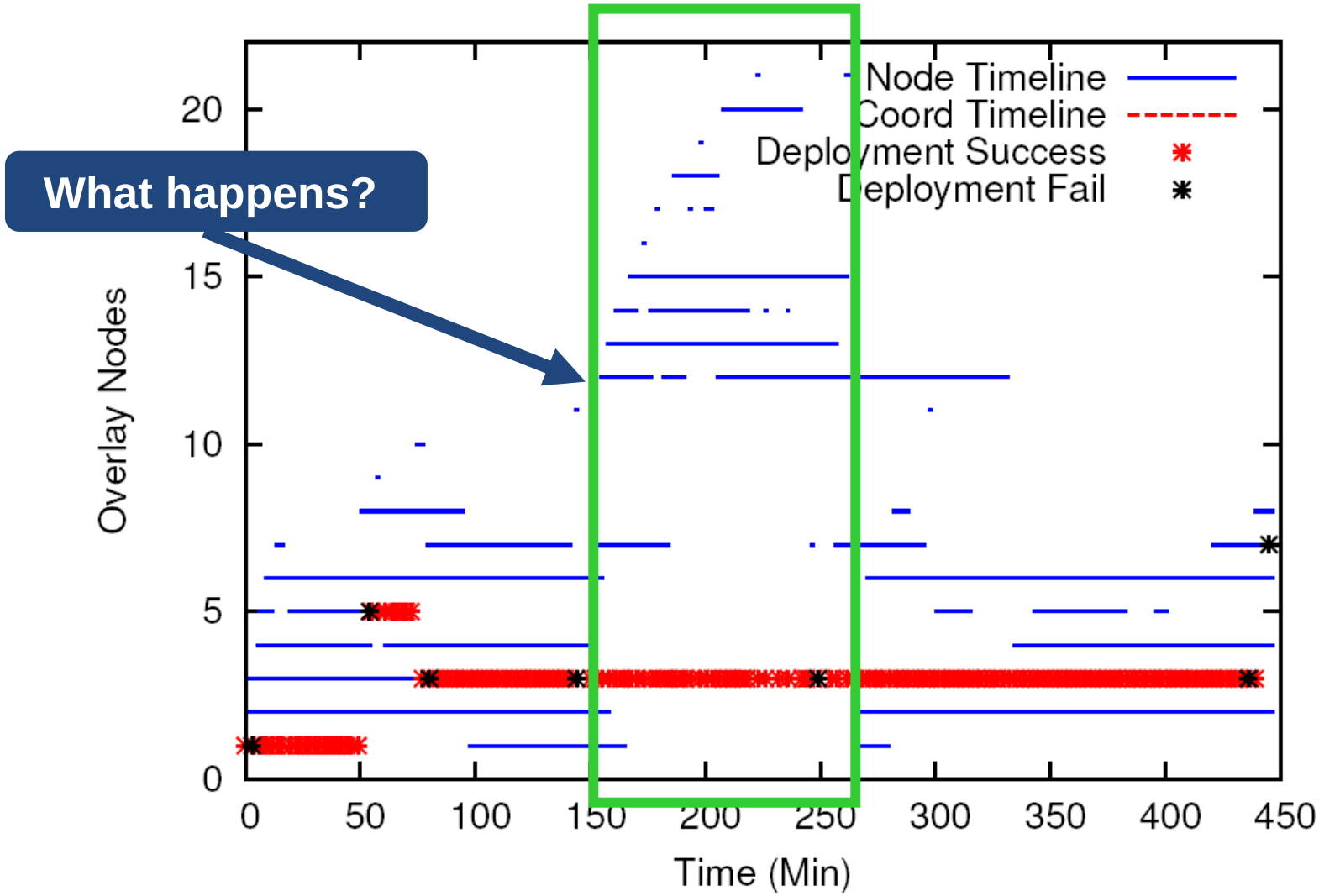

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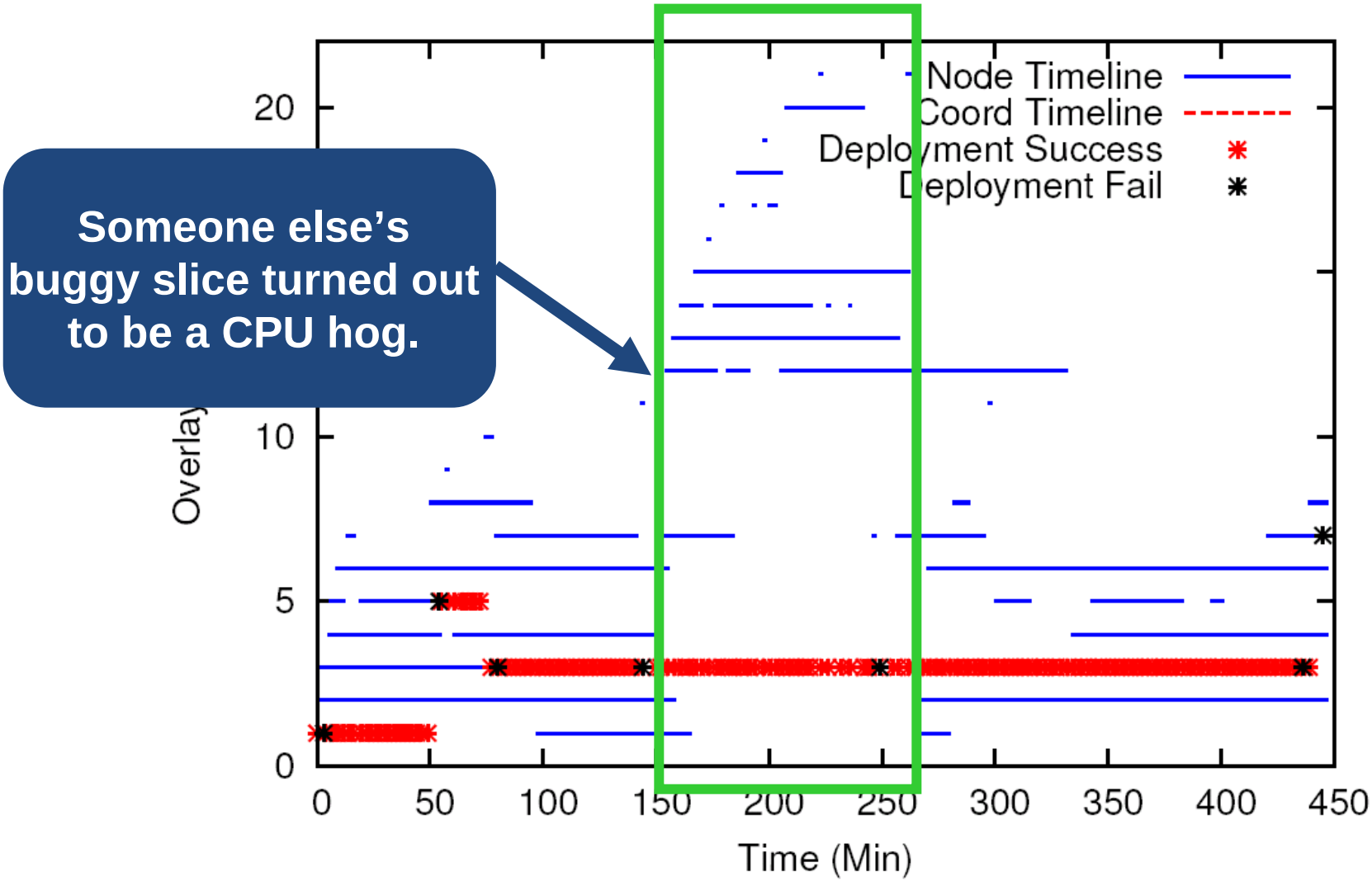

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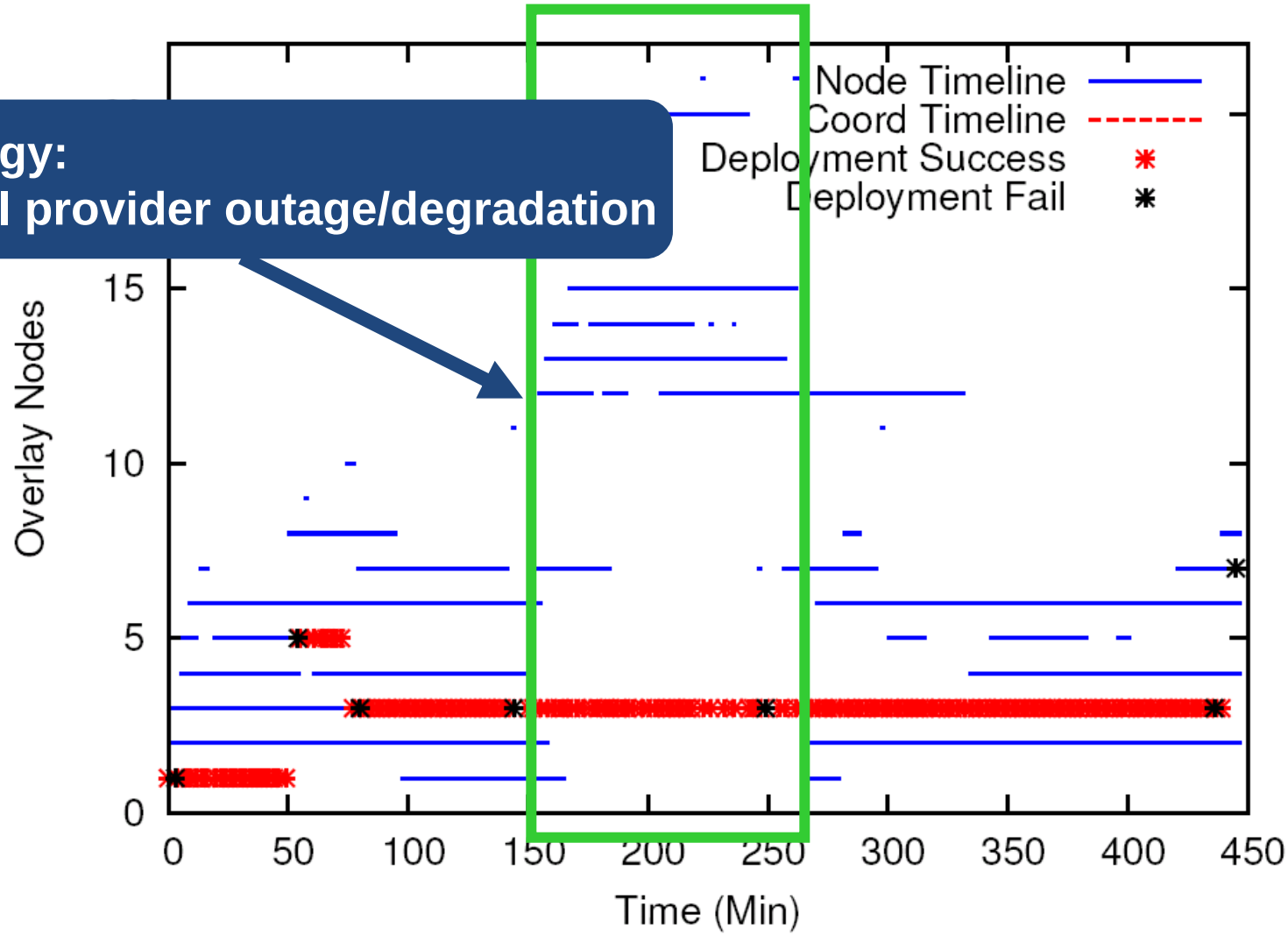
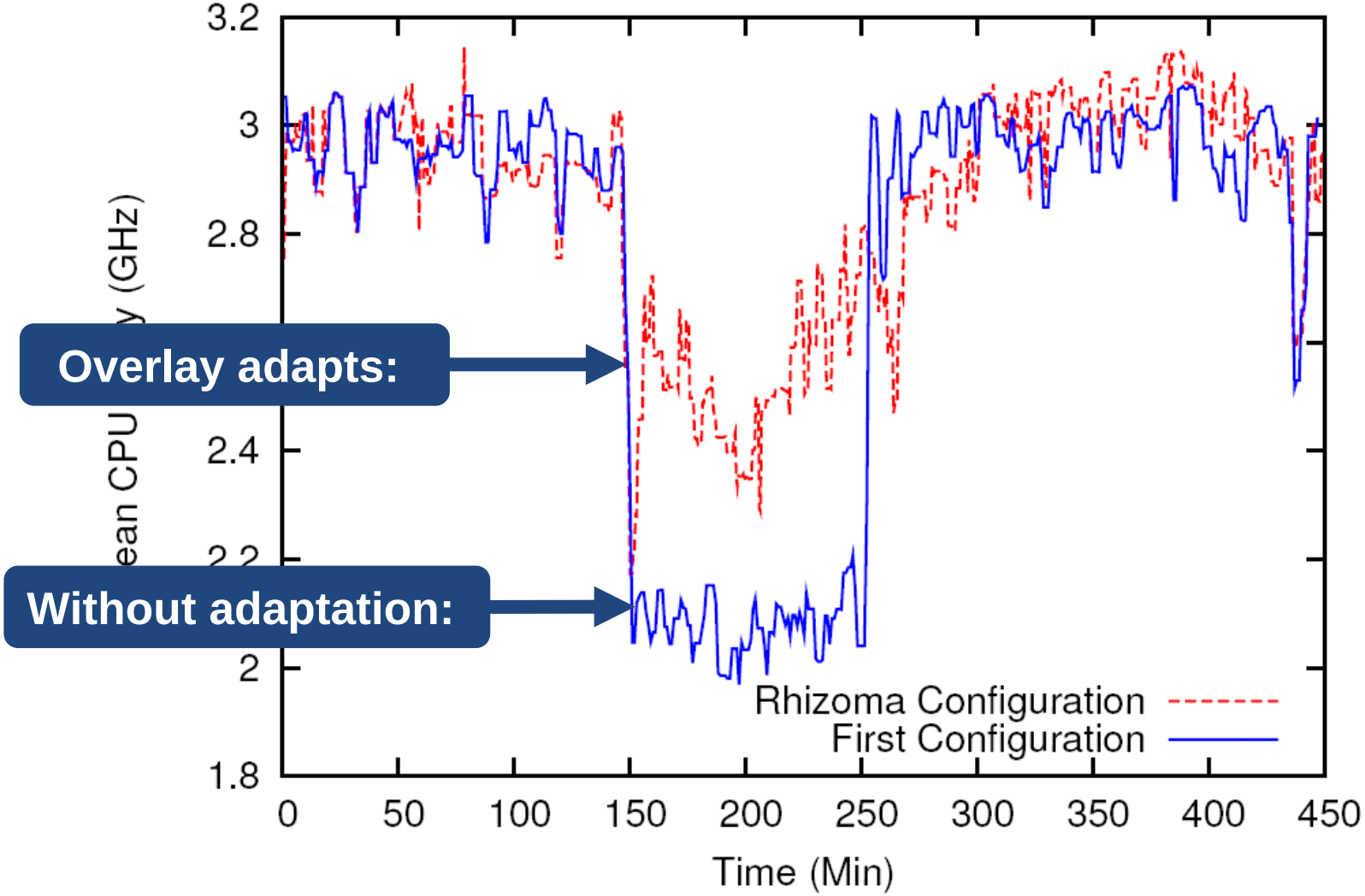
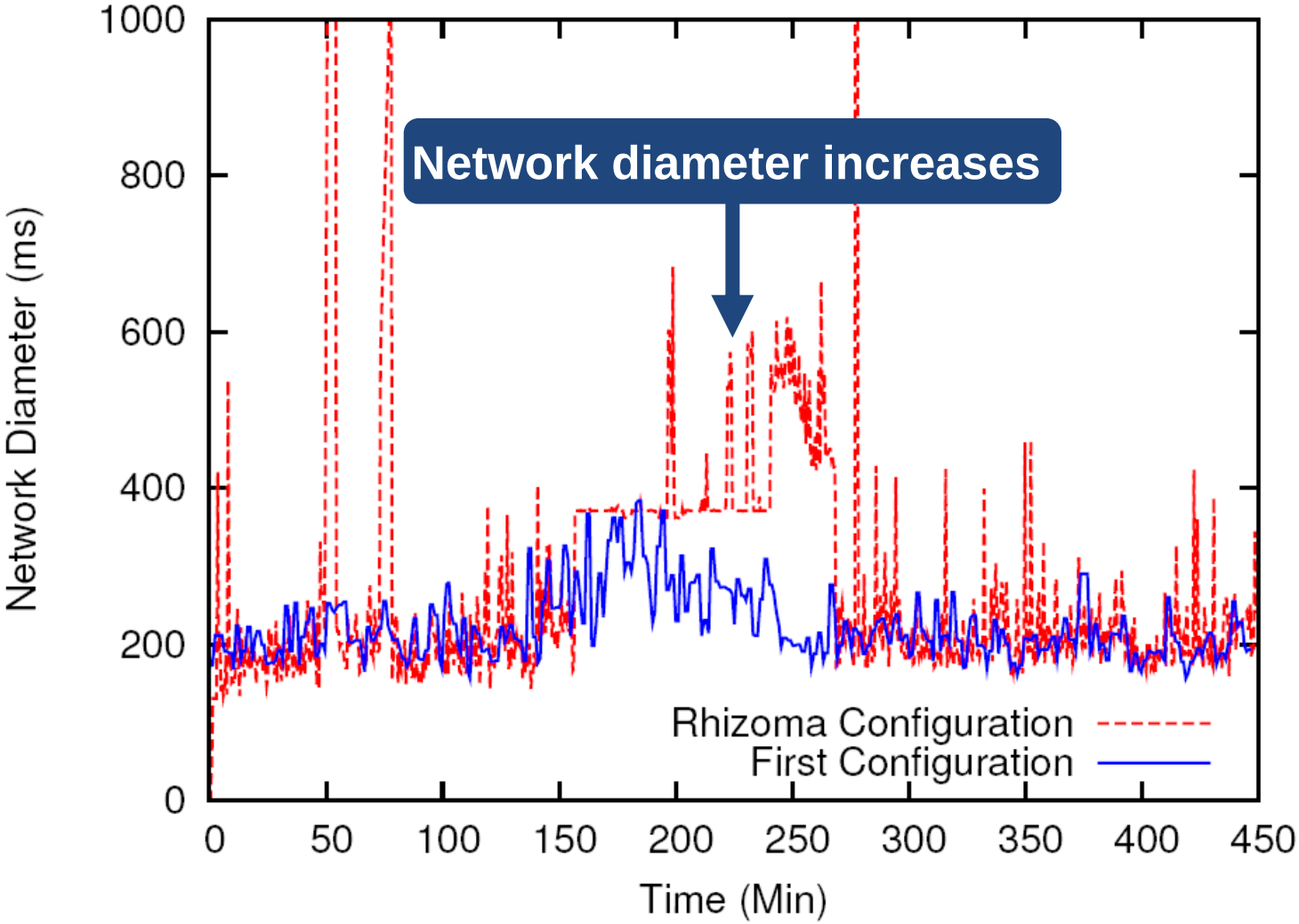
Analogy:
Partial provider outage/degradation



Mean CPU (GHz)

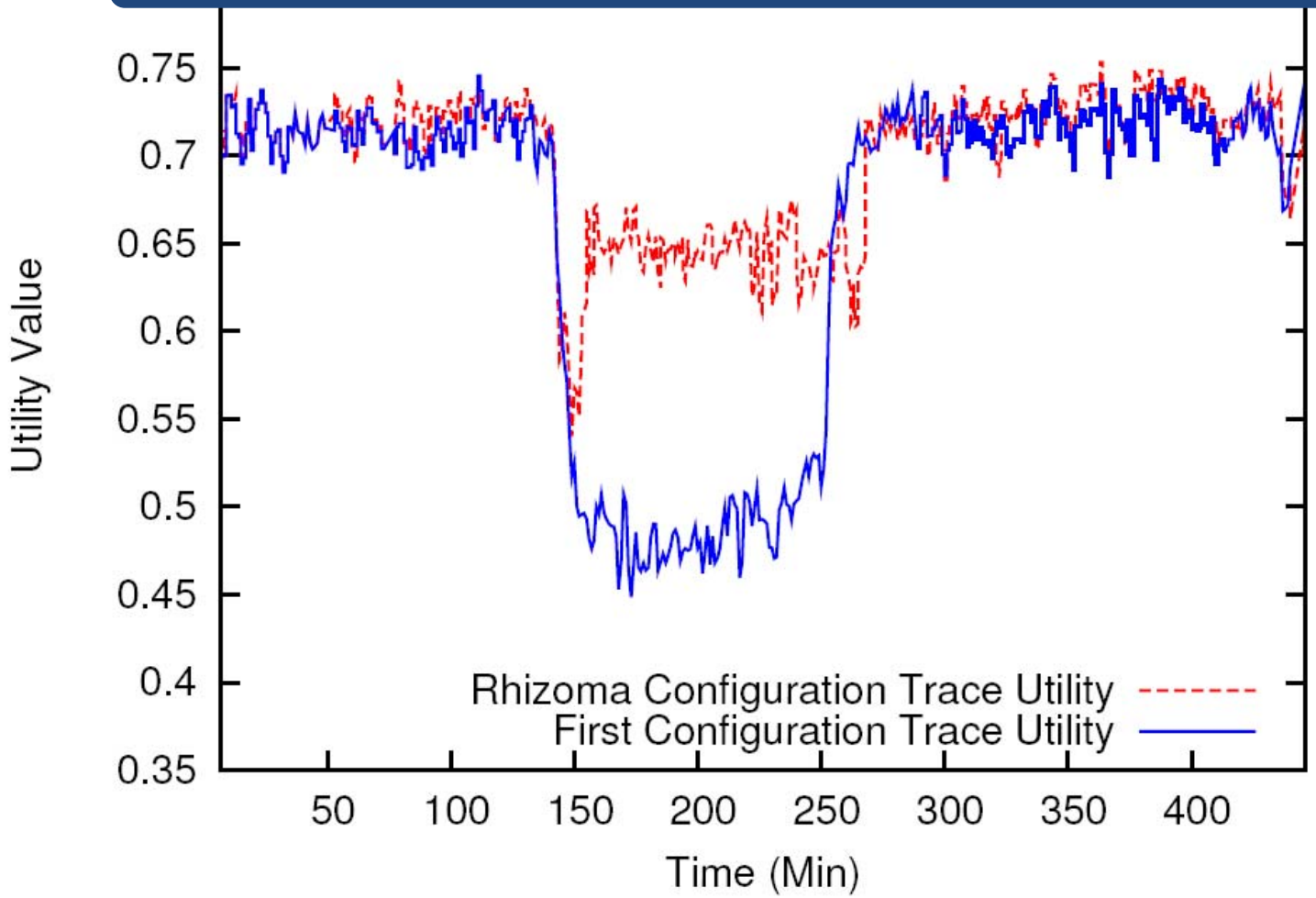

Overlay adapts:
Without adaptation:
3.2
3
2.8
2.4
2.2
2
1.8
0
50
100
150
200
250
300
350
400
450
Time (Min)
Rhizoma Configuration
First Configuration

Network diameter (ms)



Utility values

Mean CPU is weighted more than network diameter



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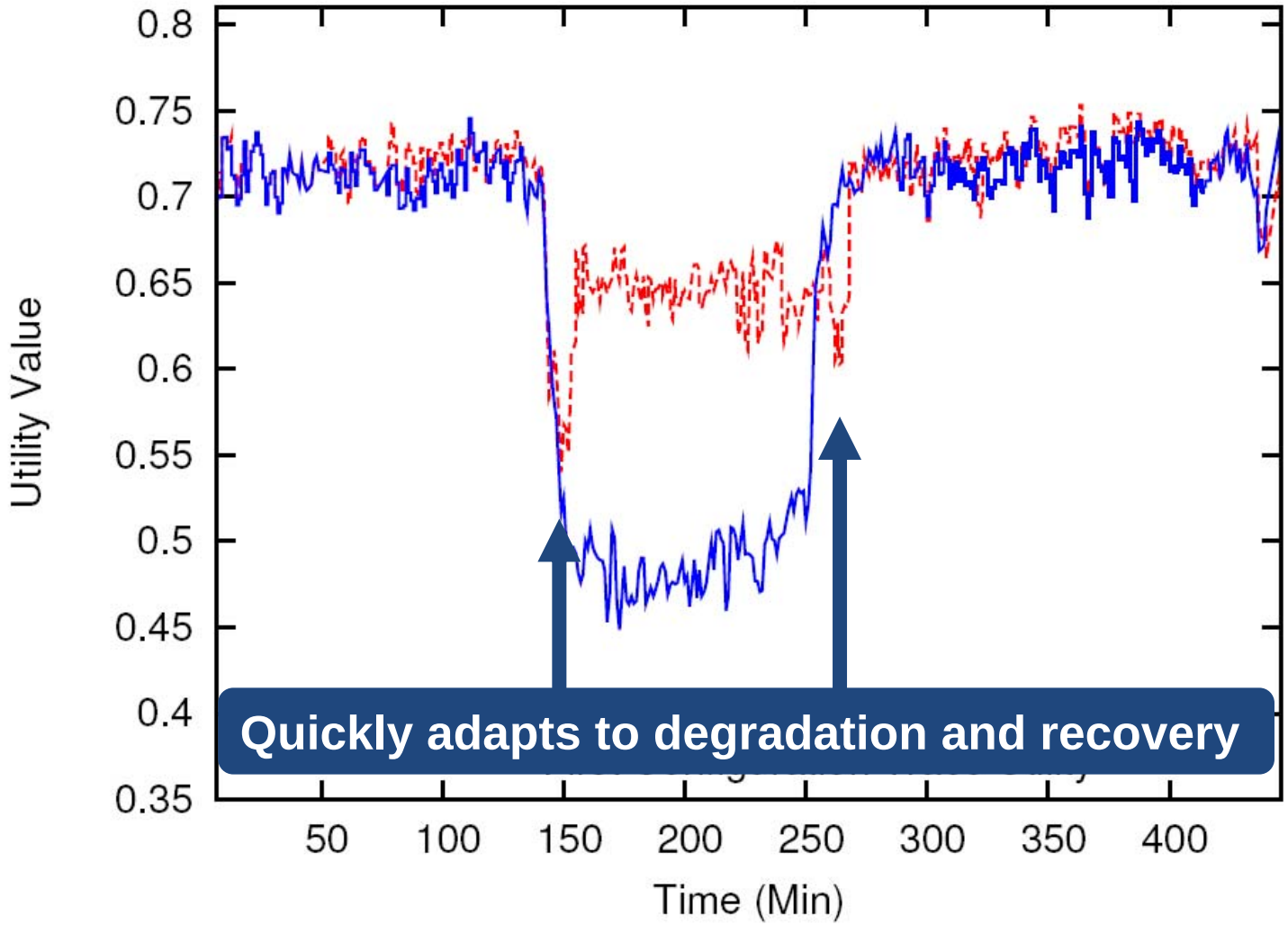

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  - **CLP** to express desired application behavior

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  - **Expressiveness** of applications' resource requirements
  - **Optimization** in terms of performance and cost
  - **Responsiveness** to changes in resources, load, policies

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- Key ideas:
  - **Runtime** for **self-deploying, self-managing** overlays
  - **CLP** to express desired application behavior
- Appealing features:
  - **Expressiveness** of applications' resource requirements
  - **Optimization** in terms of performance and cost
  - **Responsiveness** to changes in resources, load, policies
- Future work:
  - Platform integration (cluster, PlanetLab, Amazon EC2)
  - Feed application-level metrics to optimization process