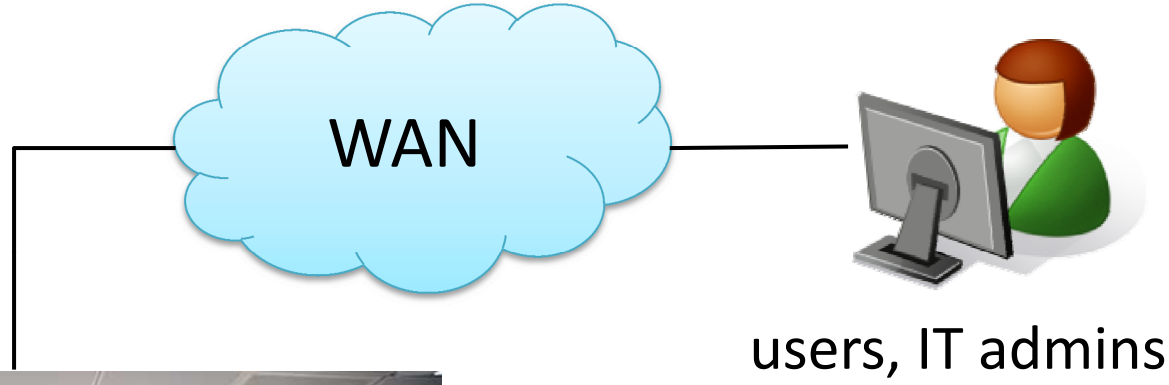
Don't Lose Sleep Over Availability: The GreenUp Decentralized Wakeup Service

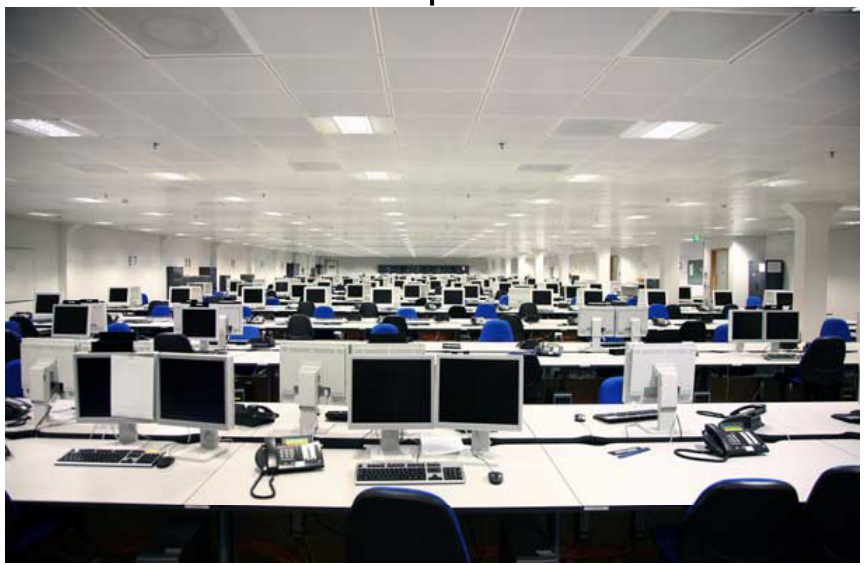
Siddhartha Sen, Princeton University

Jacob R. Lorch, Richard Hughes, Carlos G. J. Suarez,
Brian Zill, Weverton Cordeiro, and Jitendra Padhye

Enterprise networks

Enterprise networks





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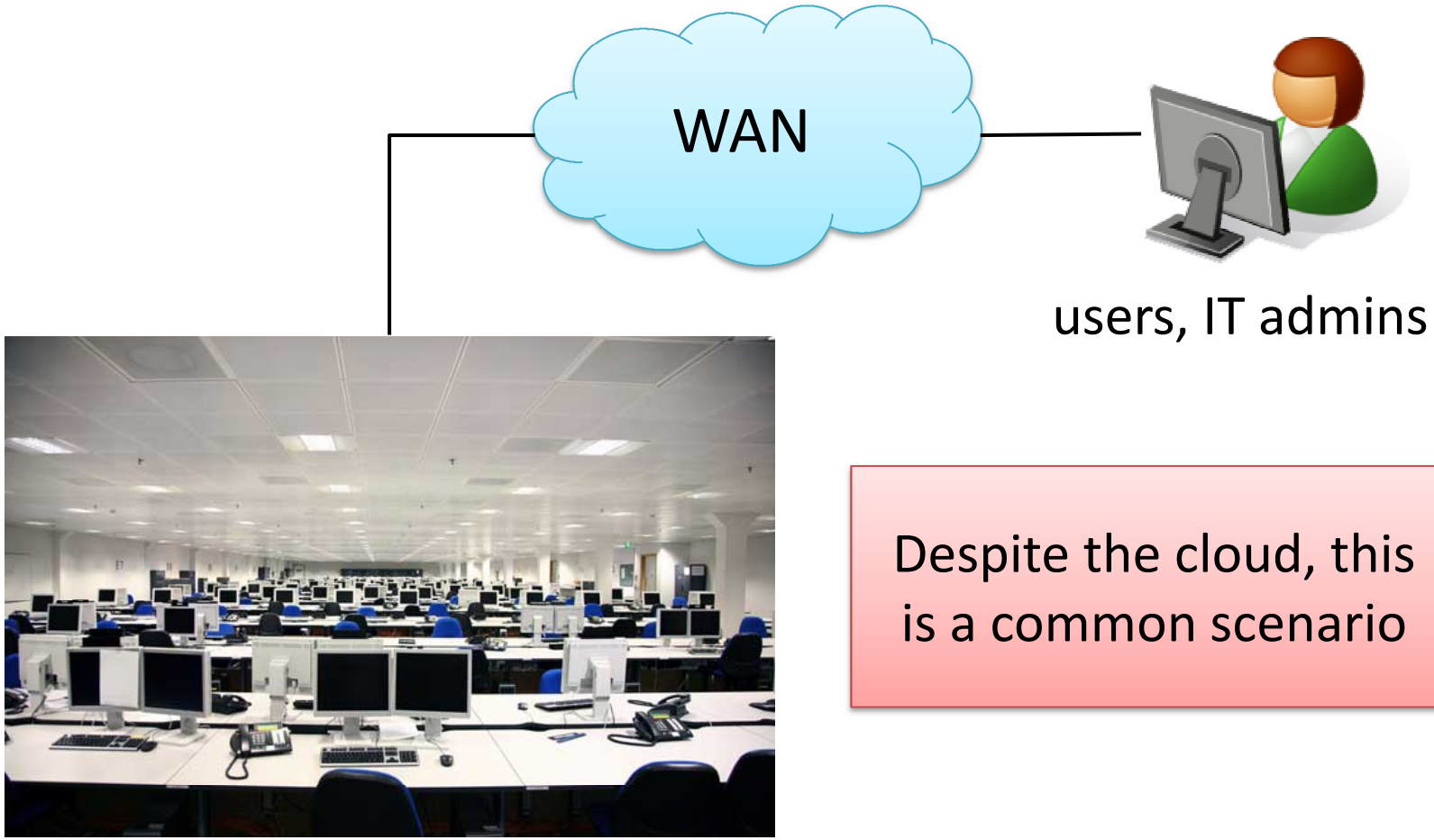
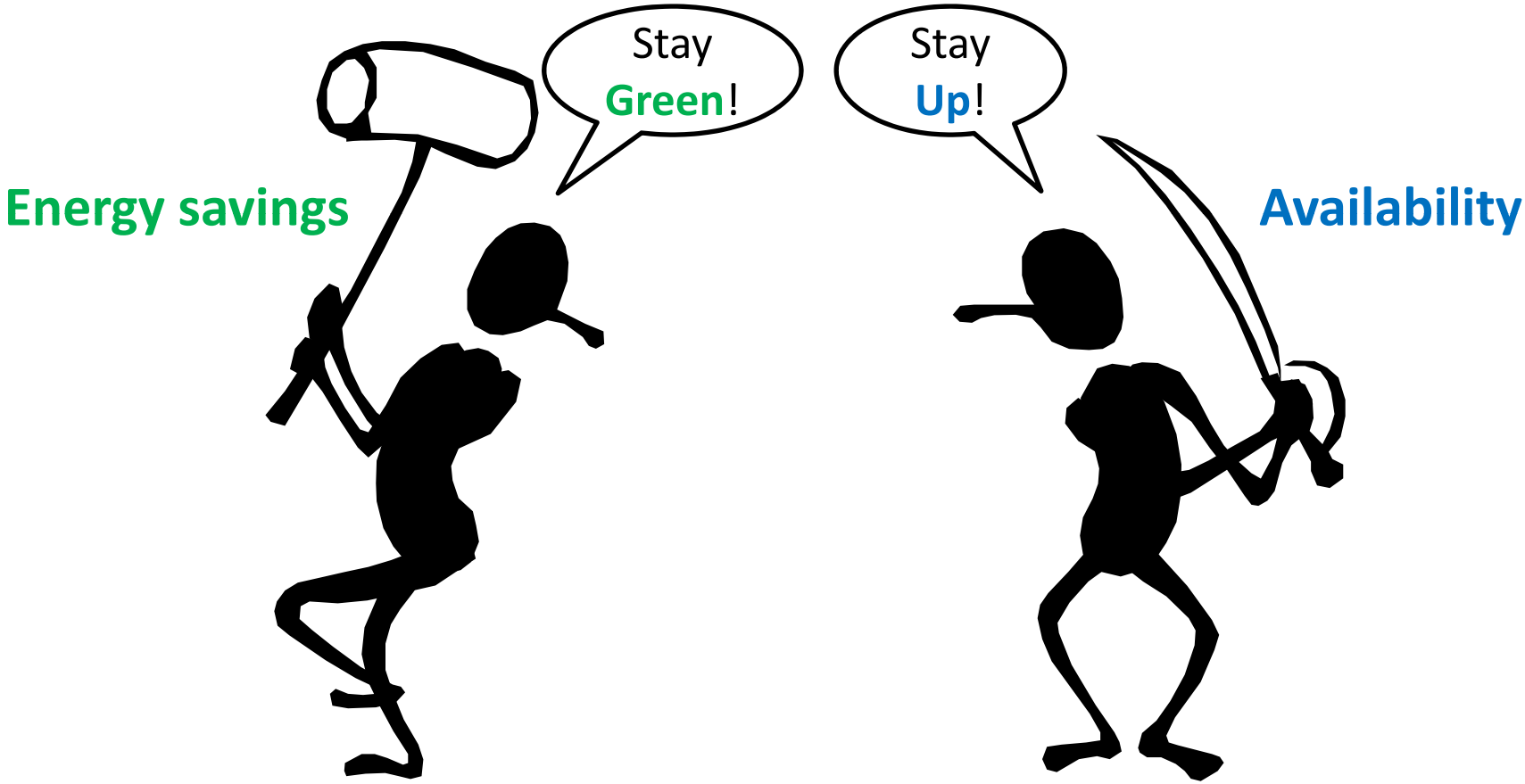


Despite the cloud, this is a common scenario

Enterprise networks



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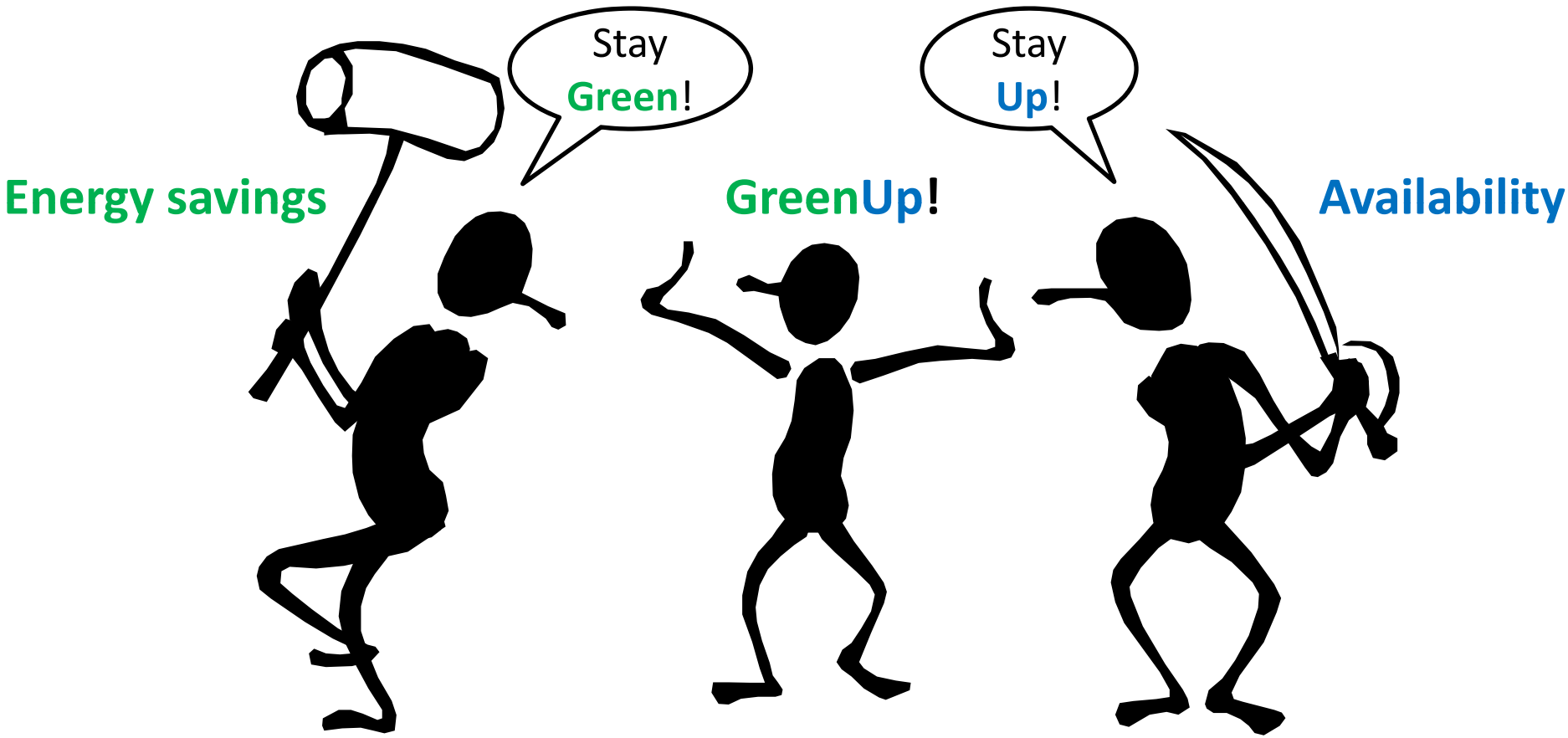
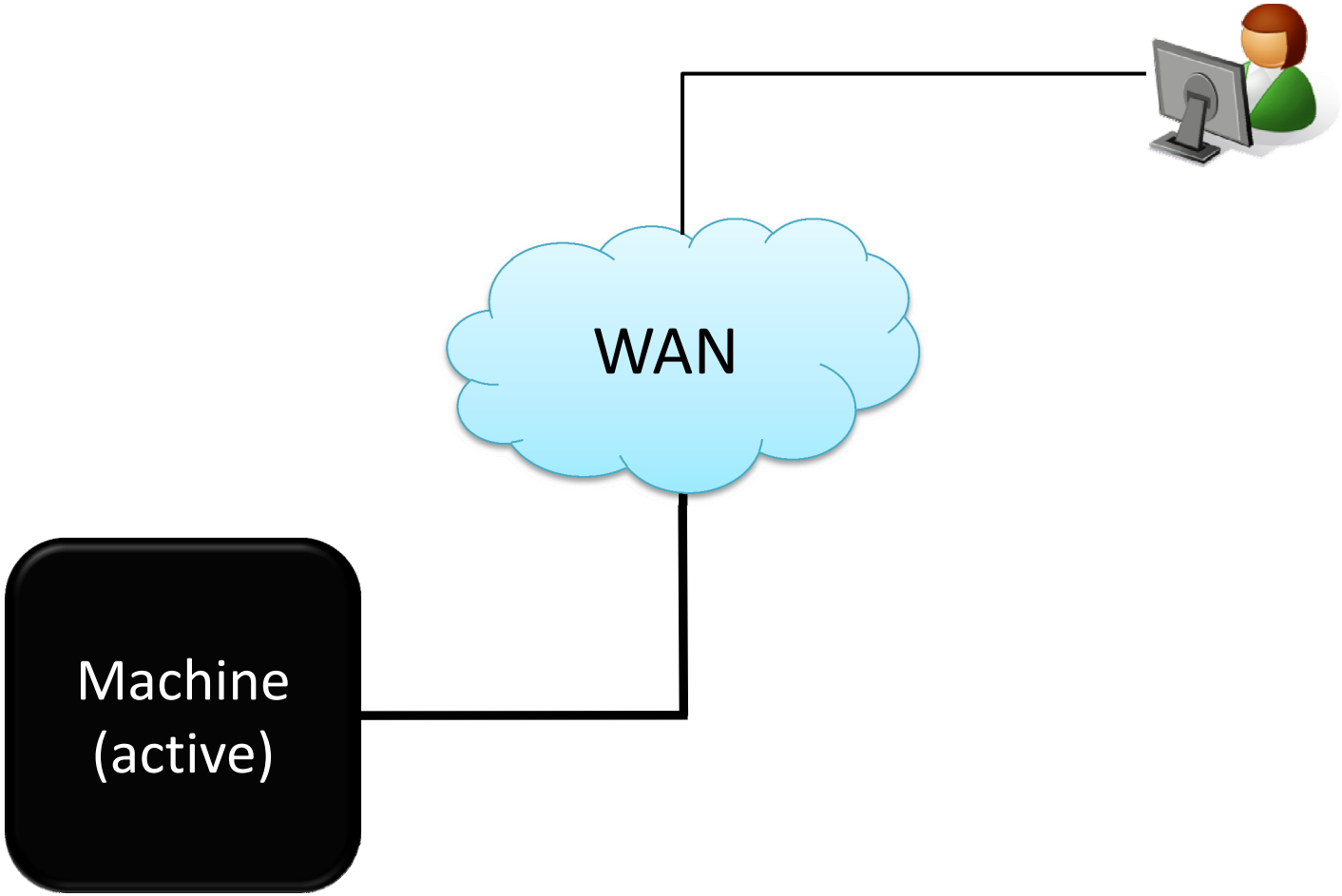


Sleep proxy



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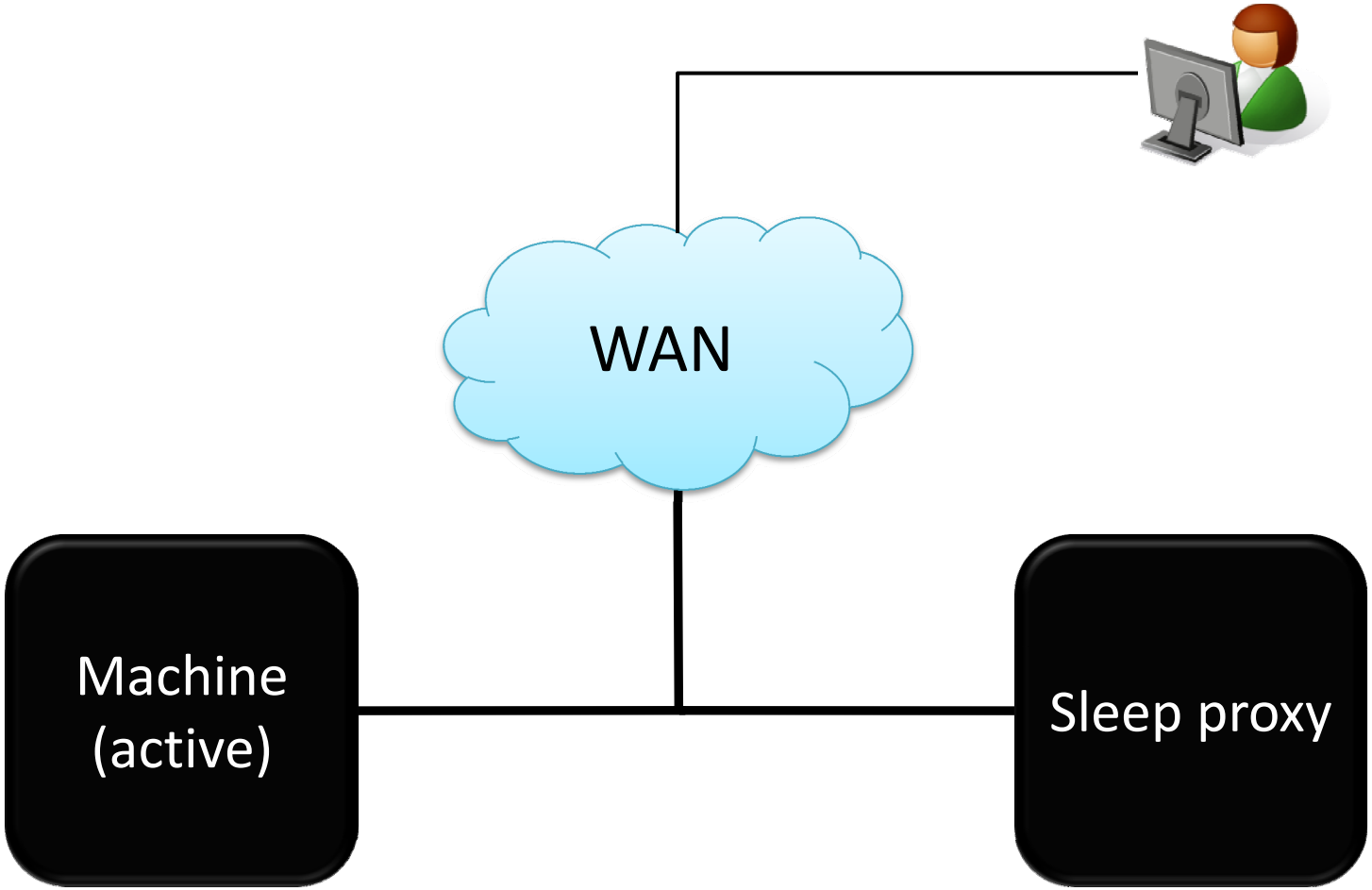

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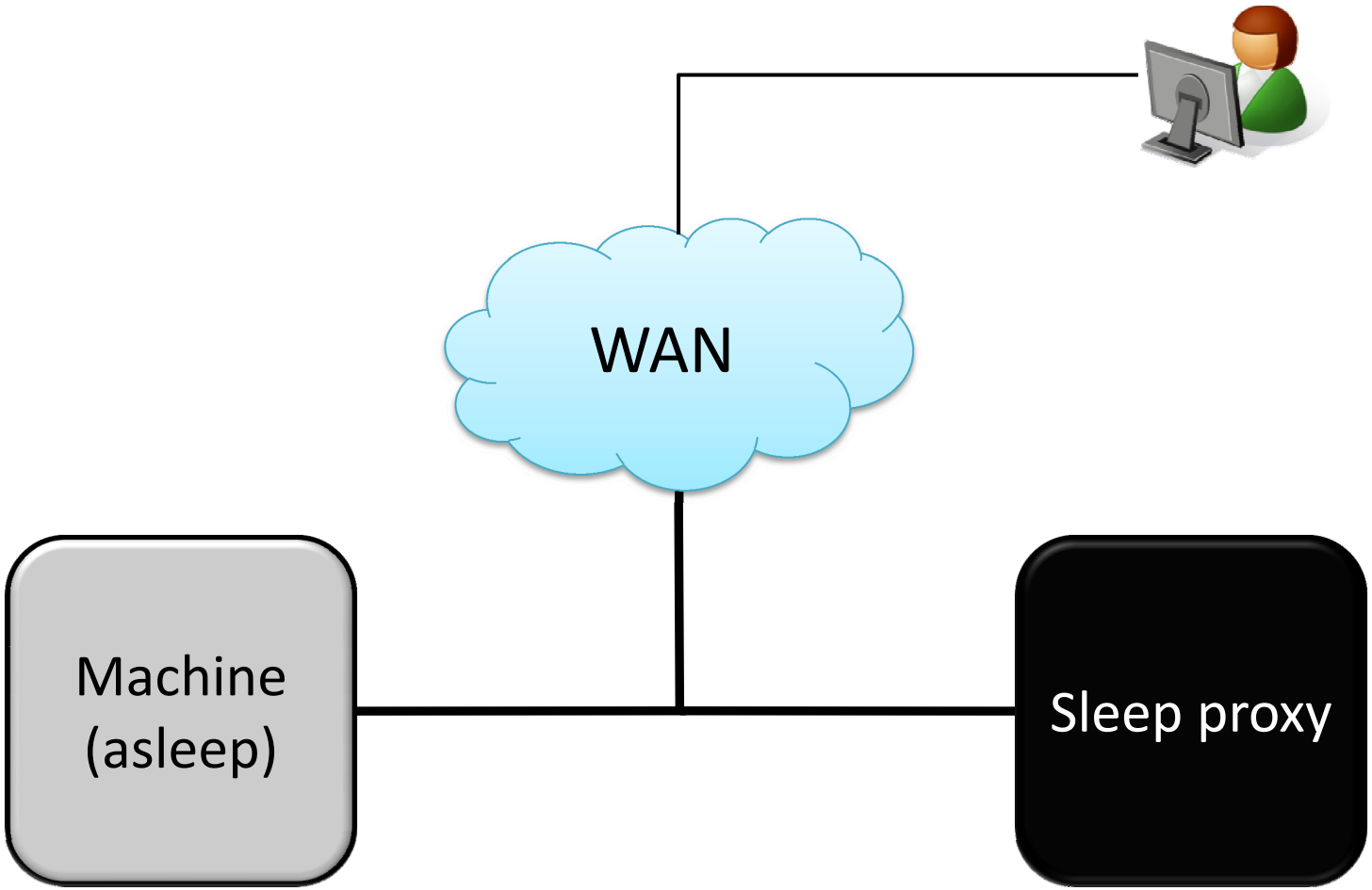

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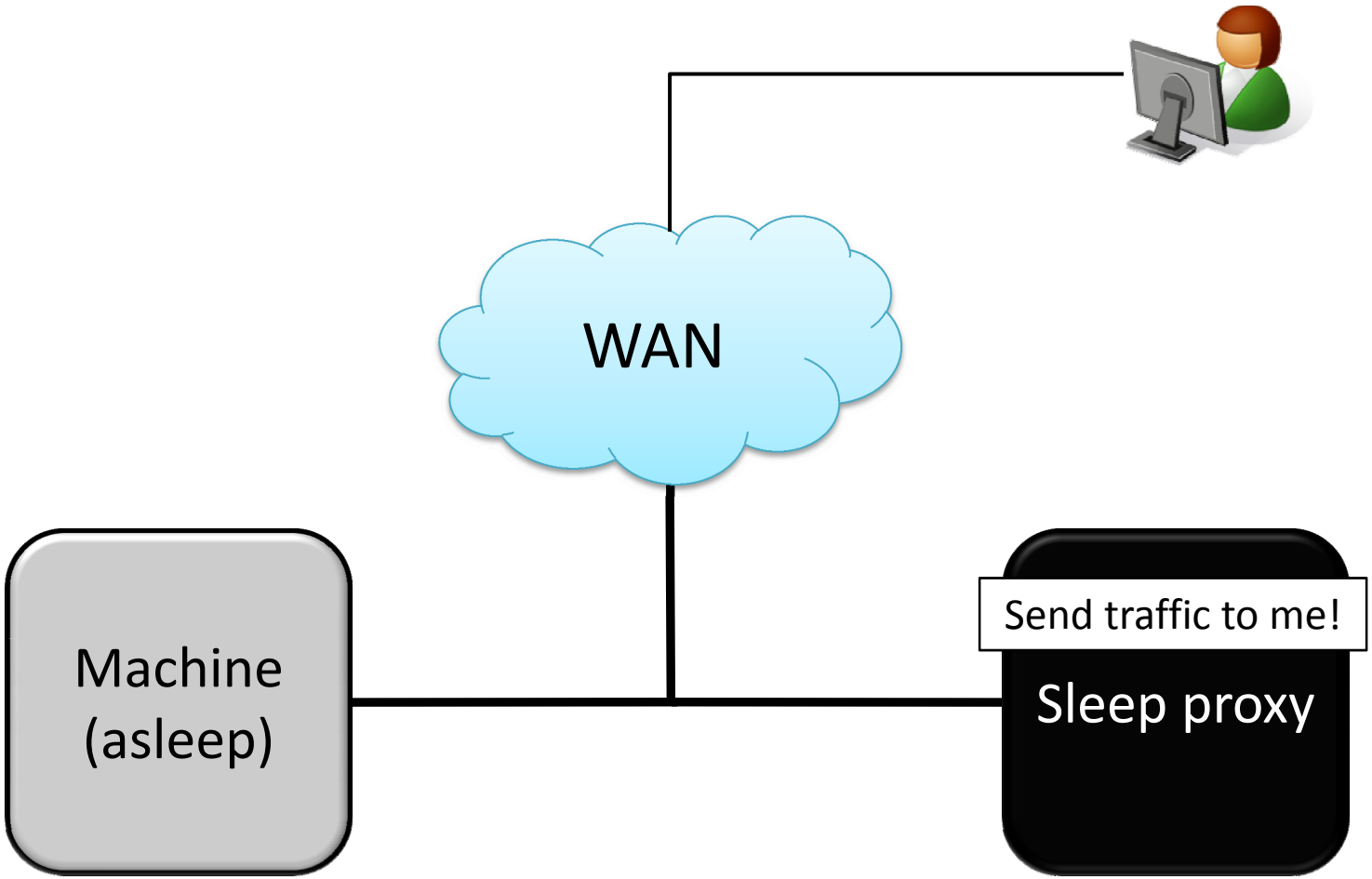

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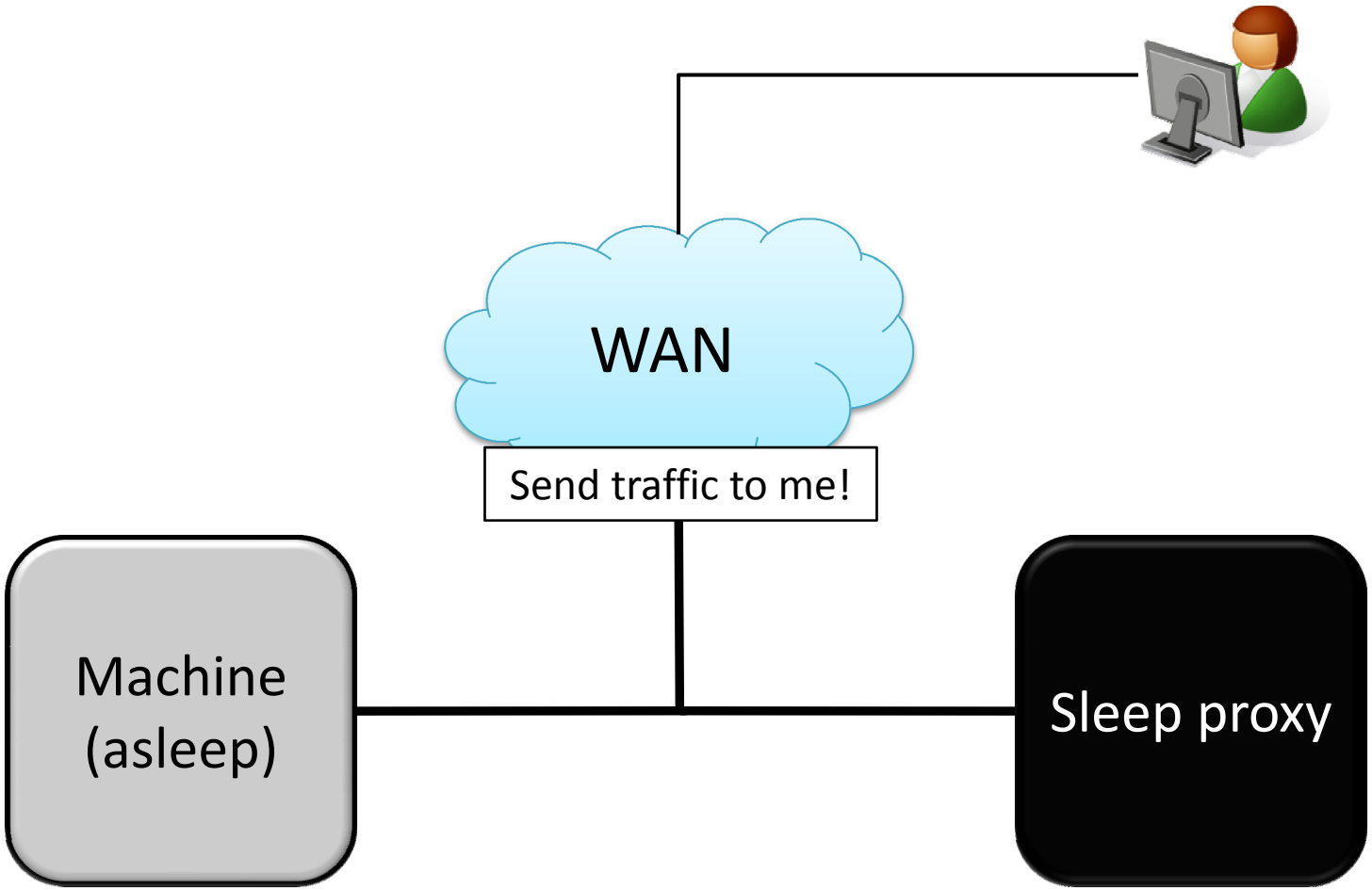

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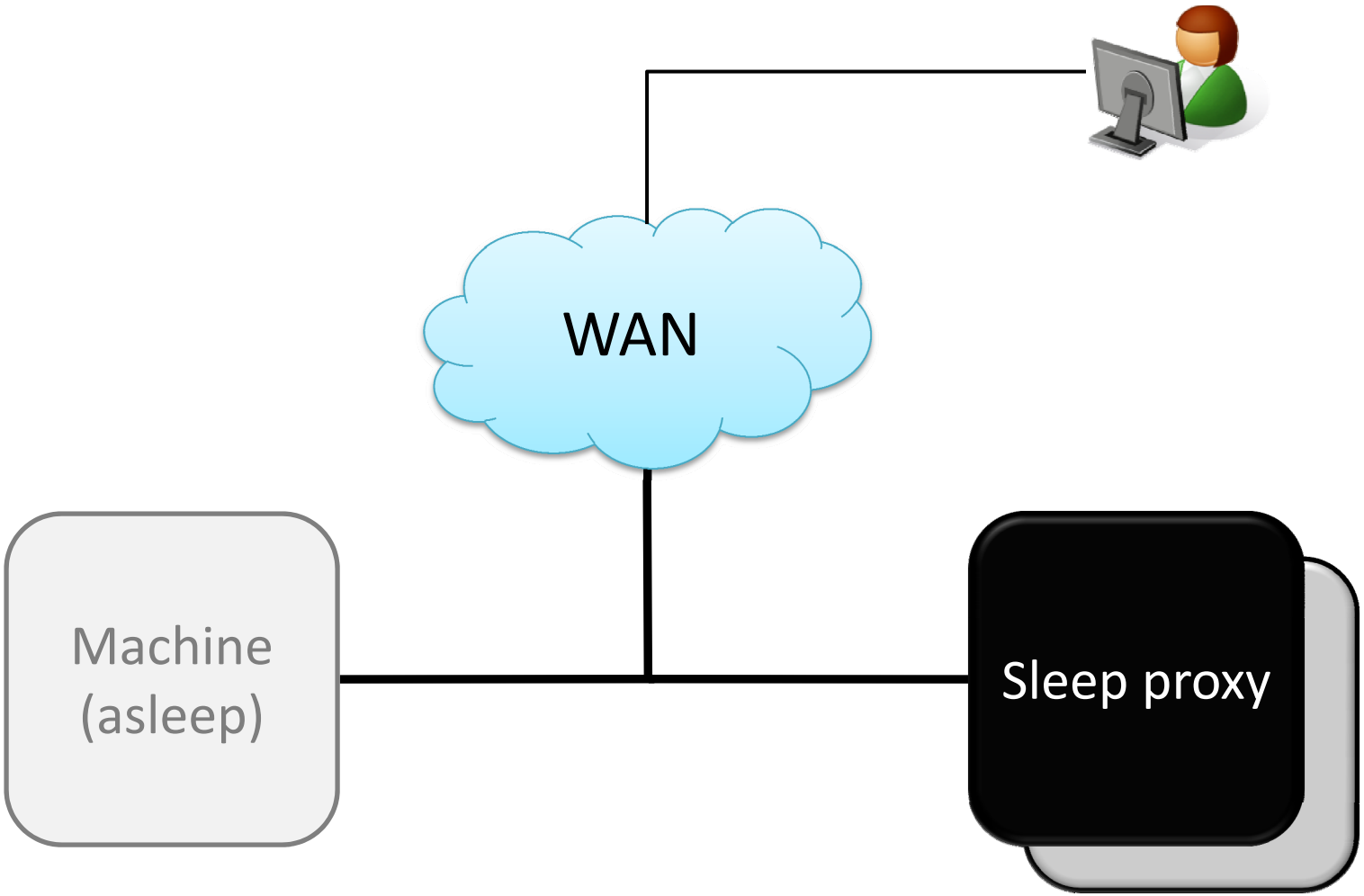

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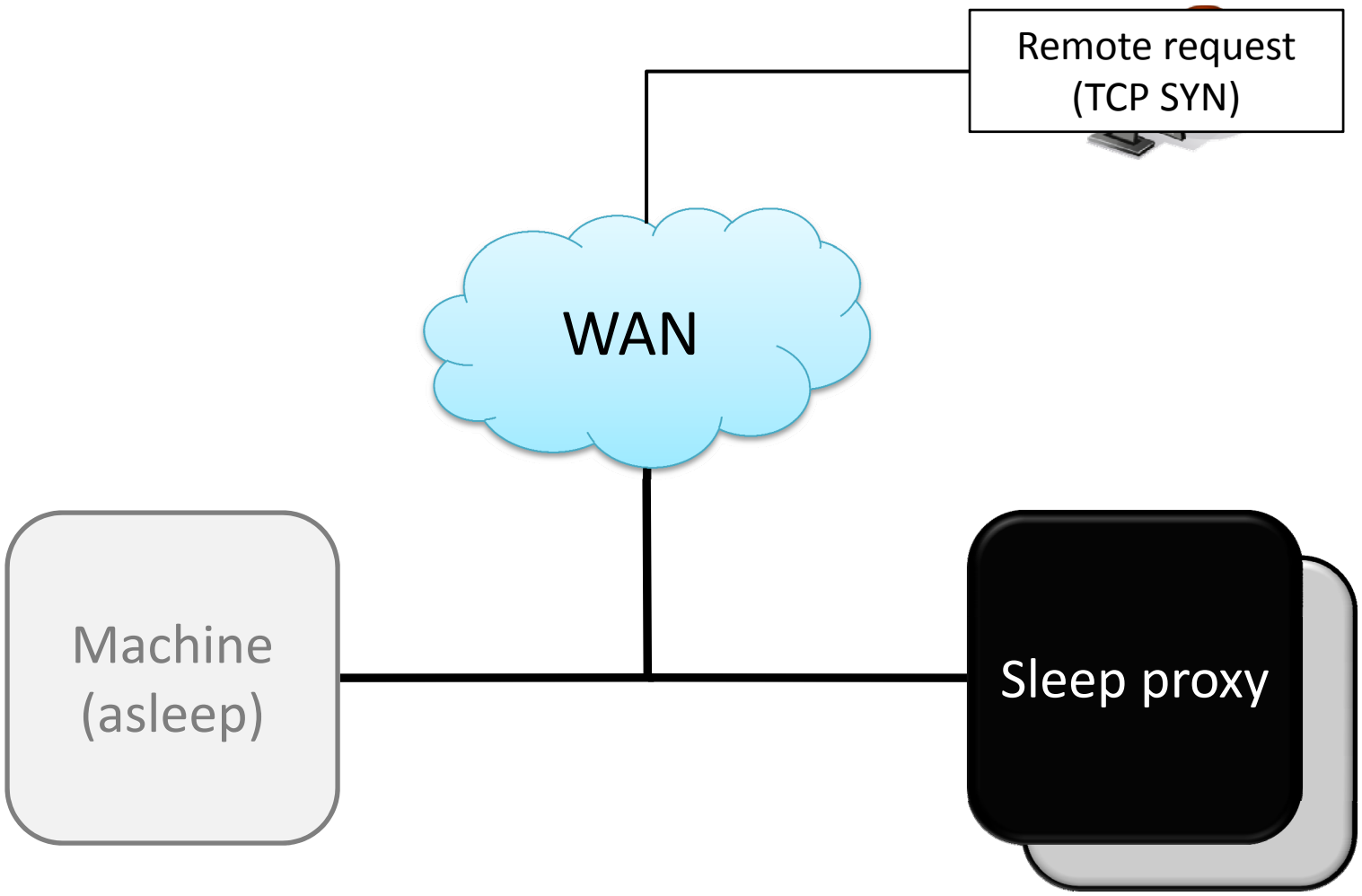

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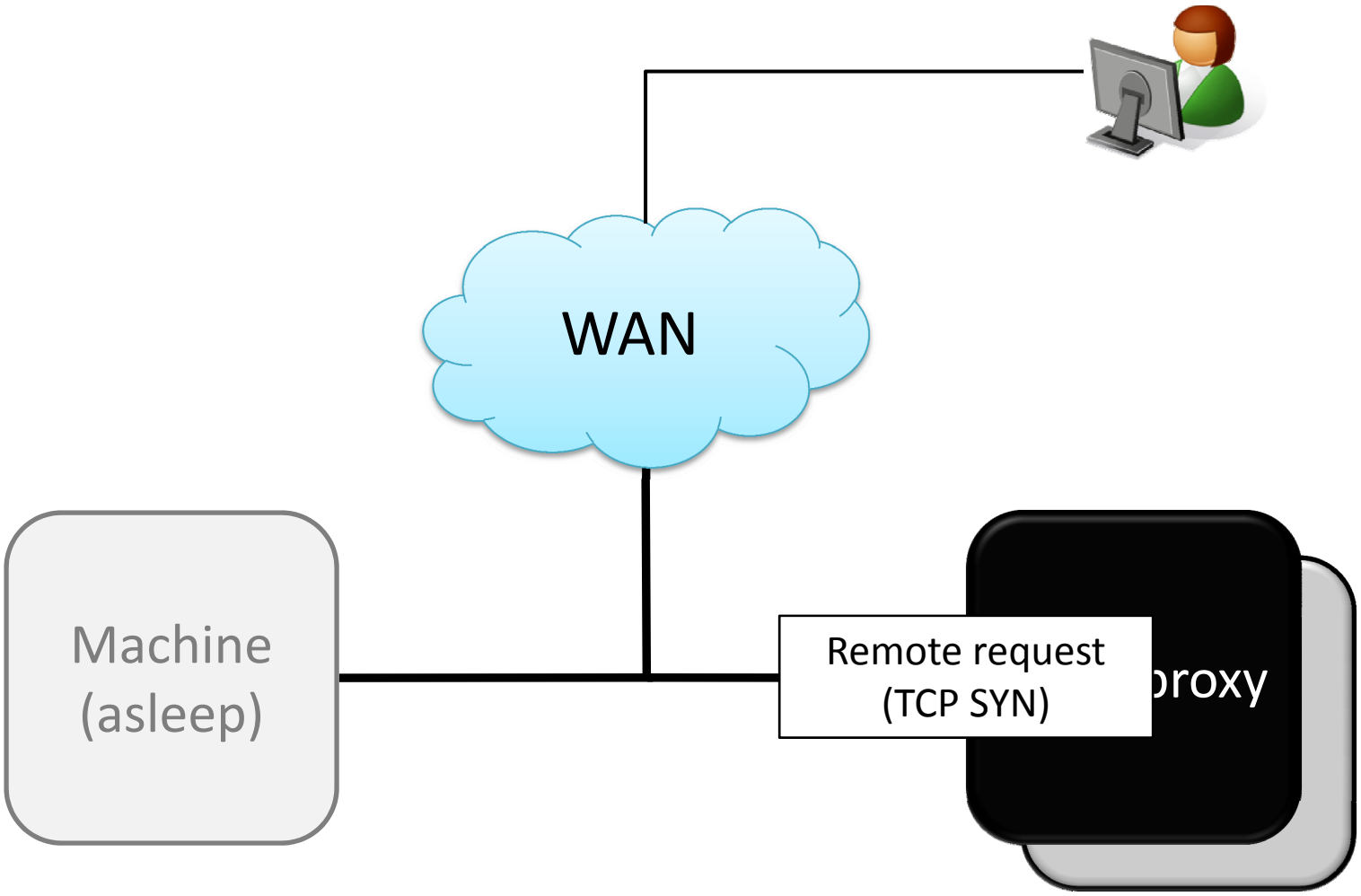

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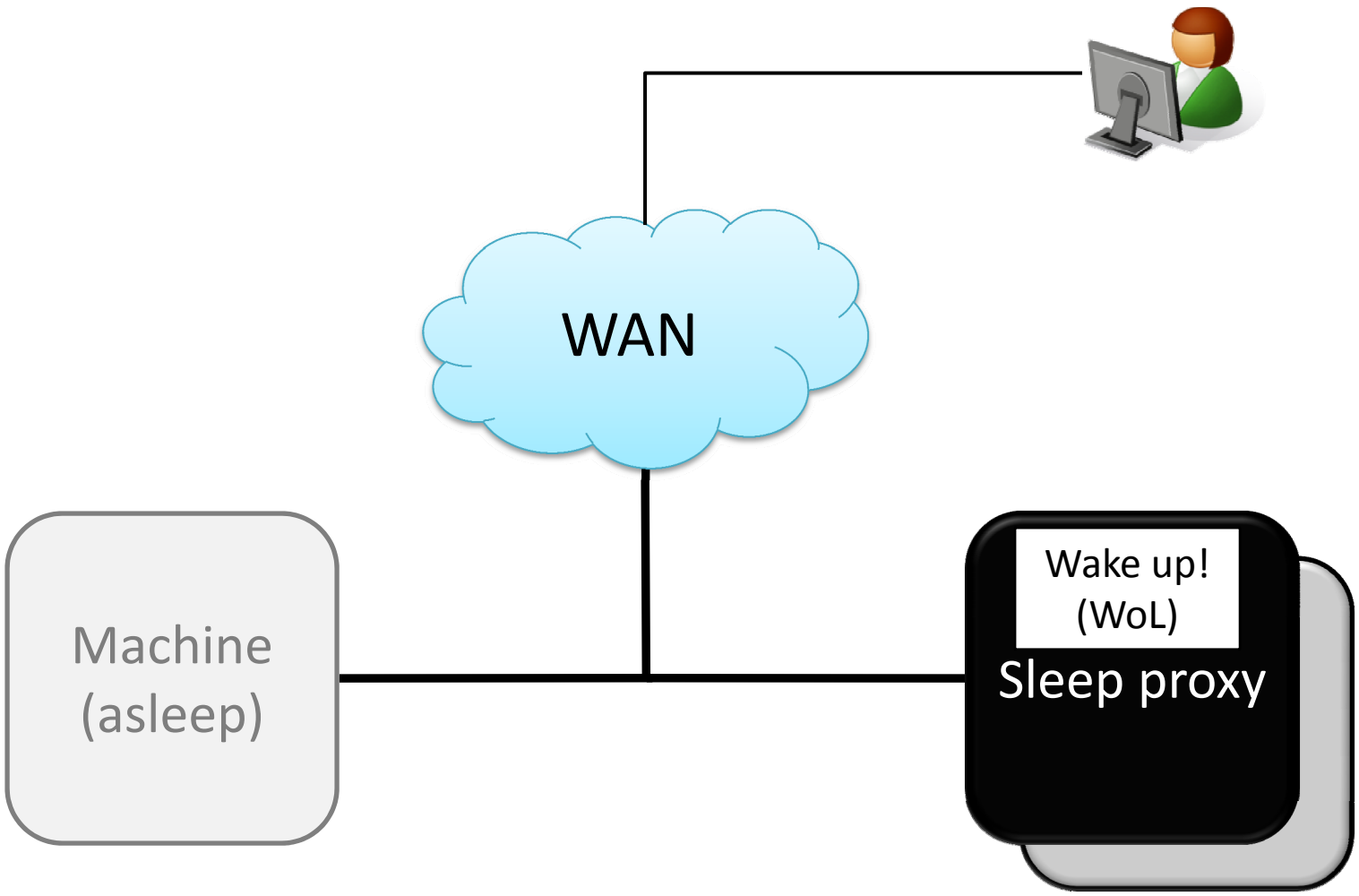

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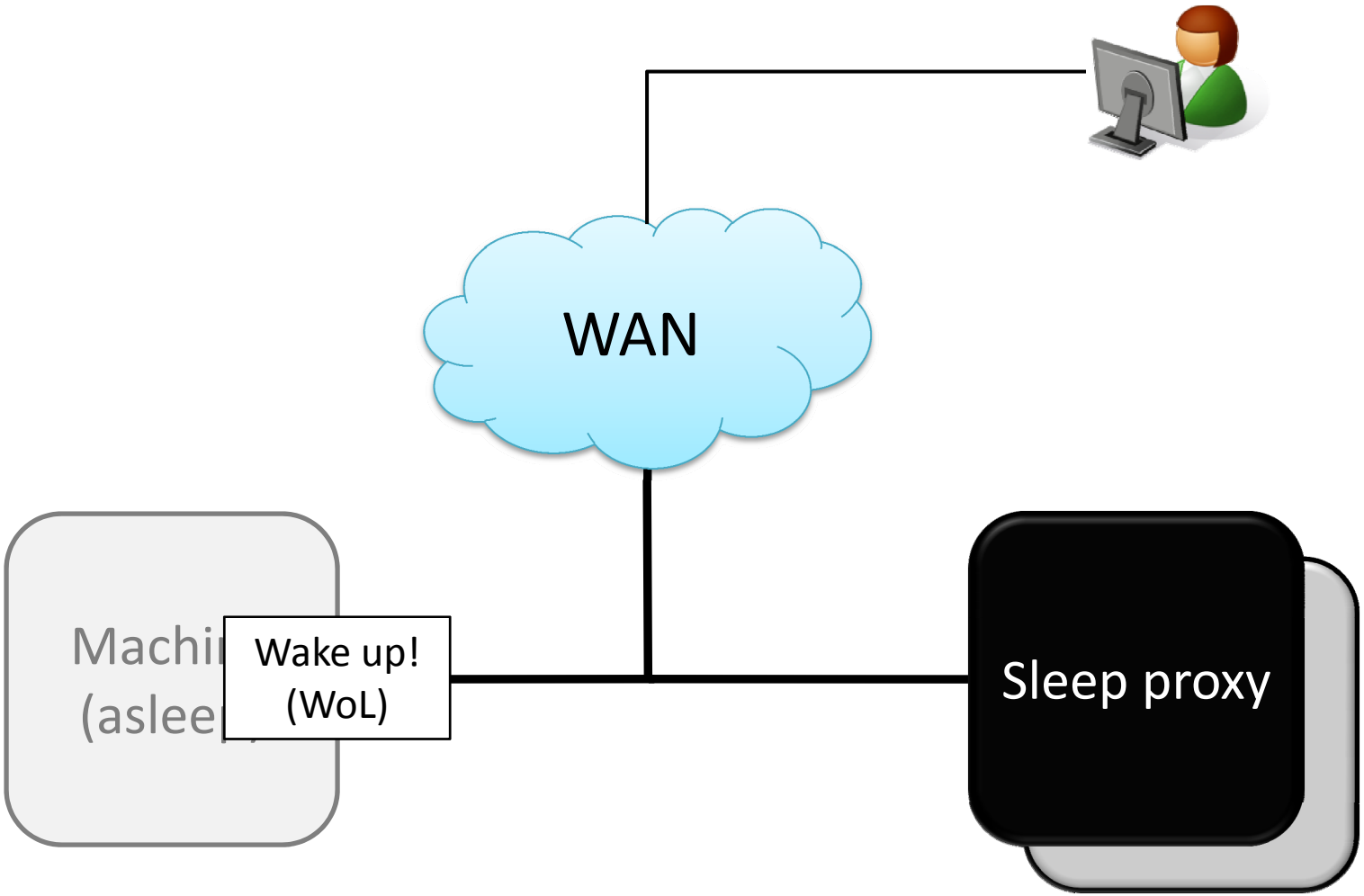

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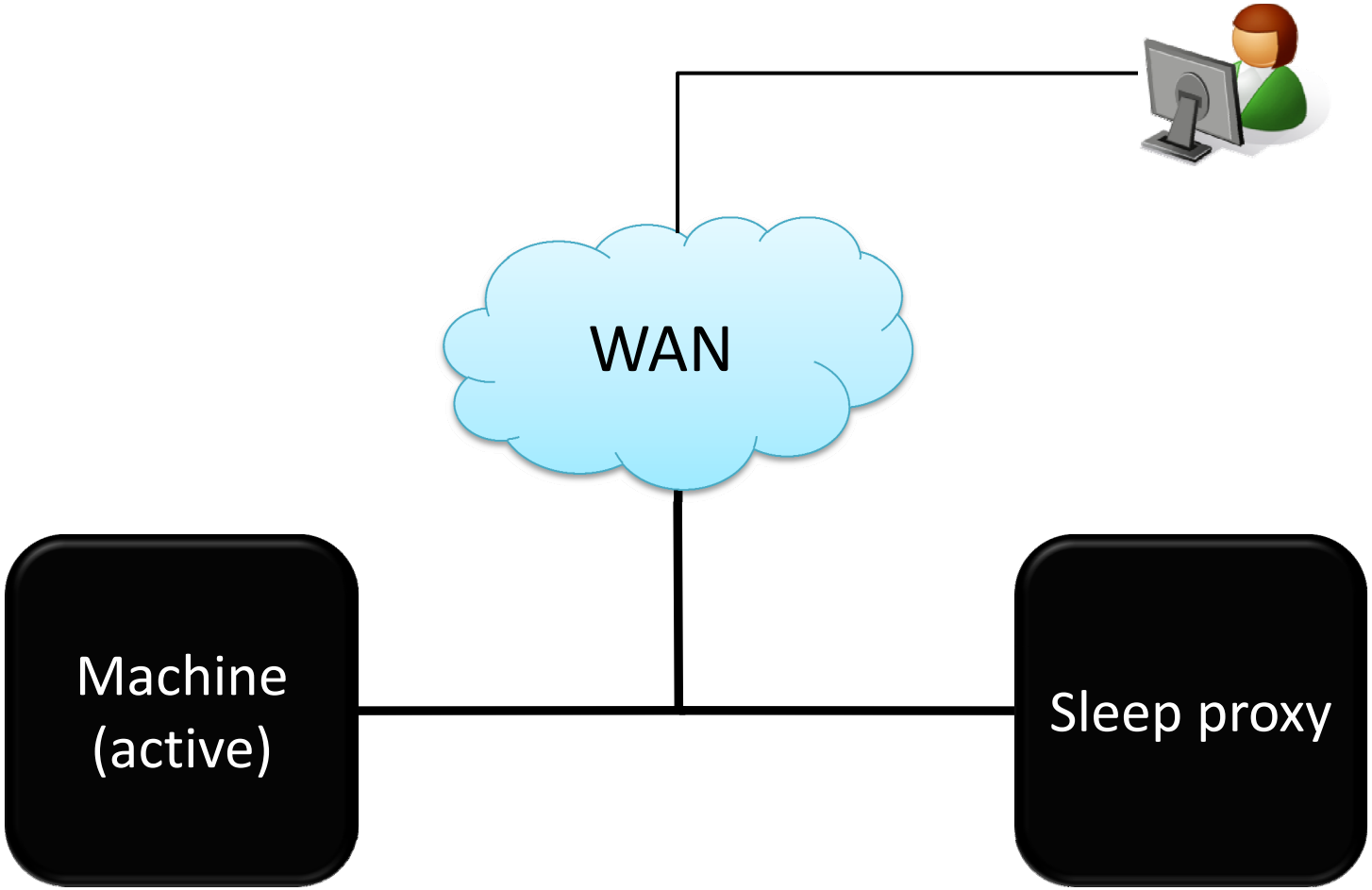

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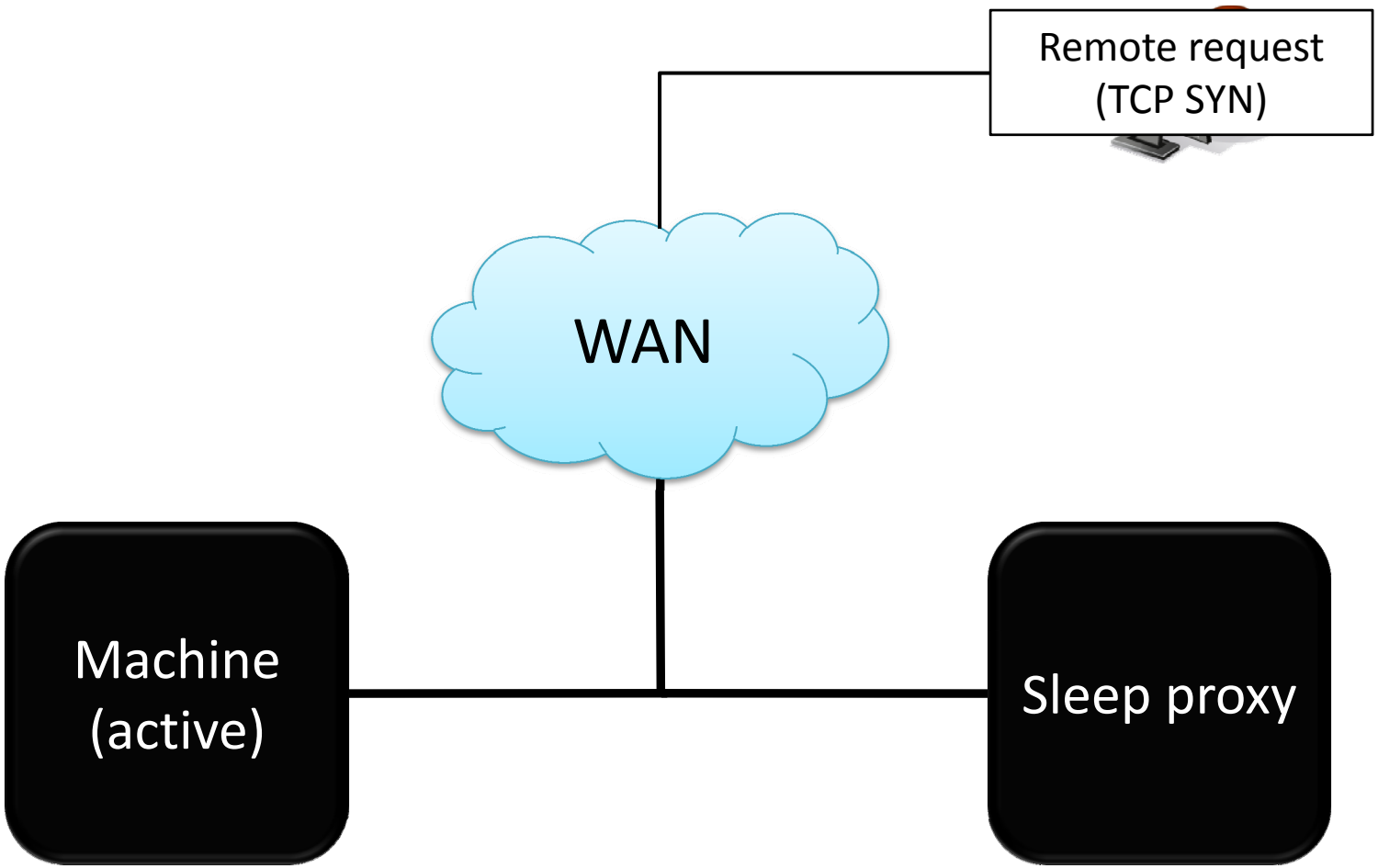

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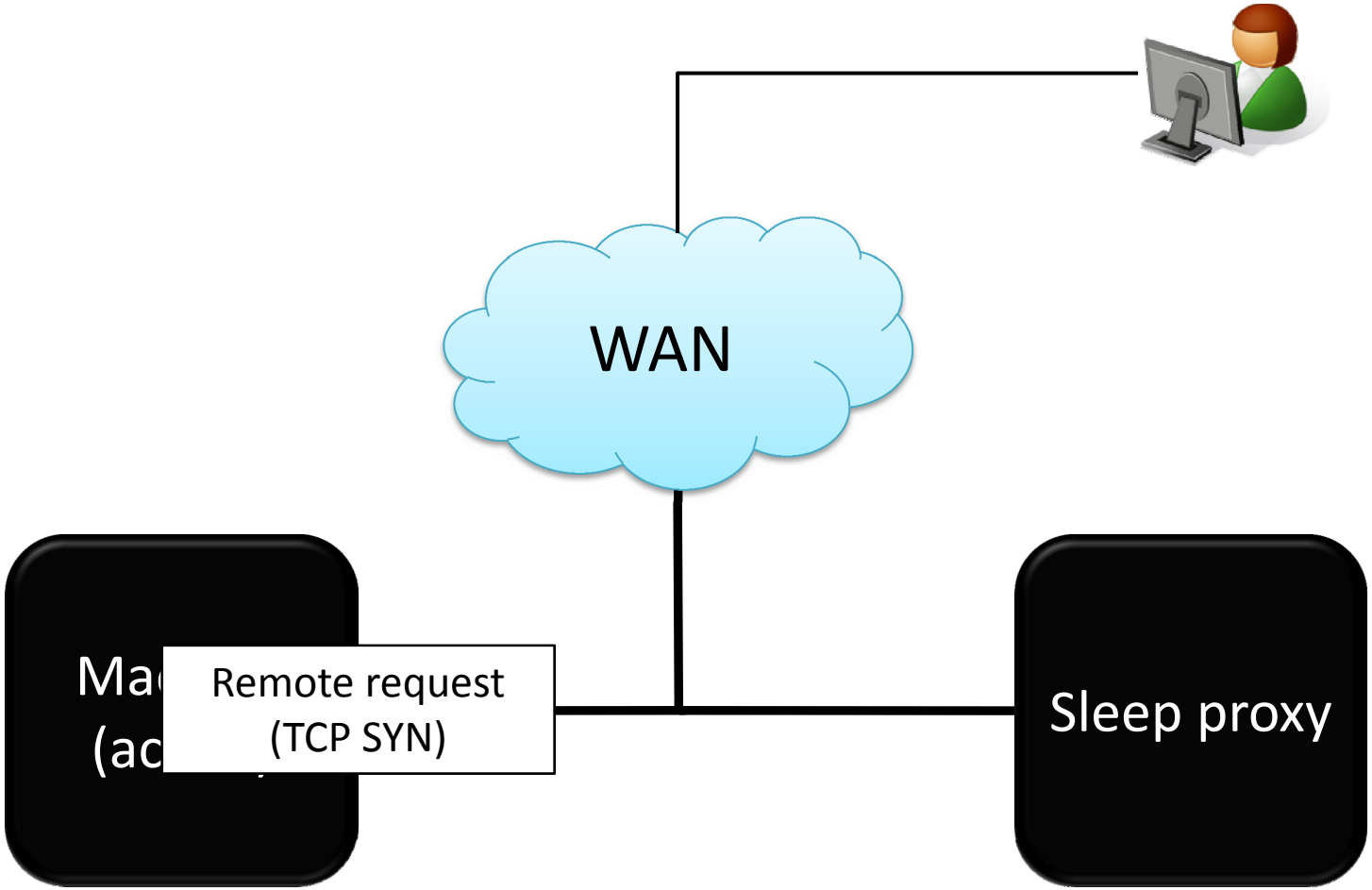

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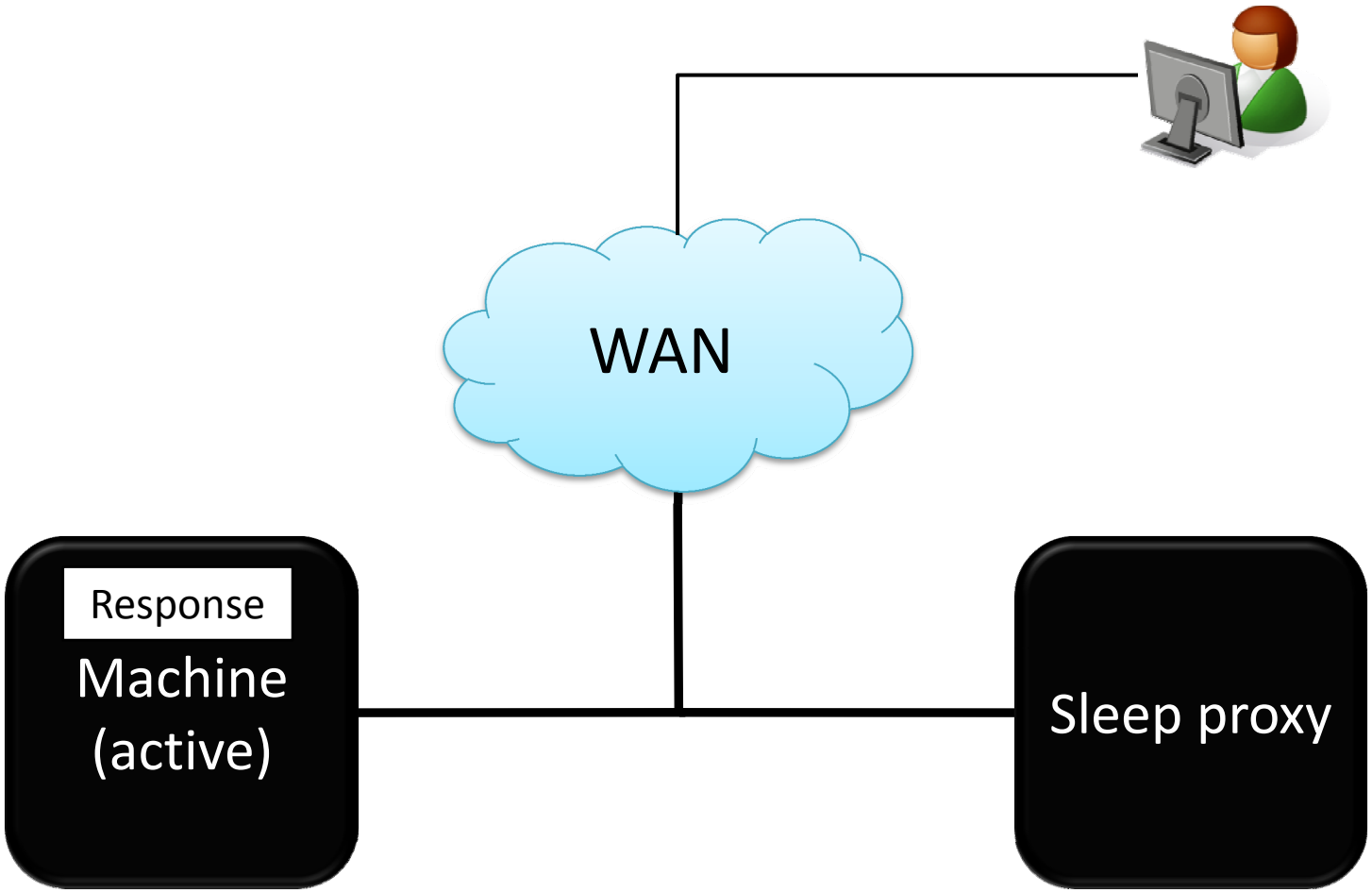

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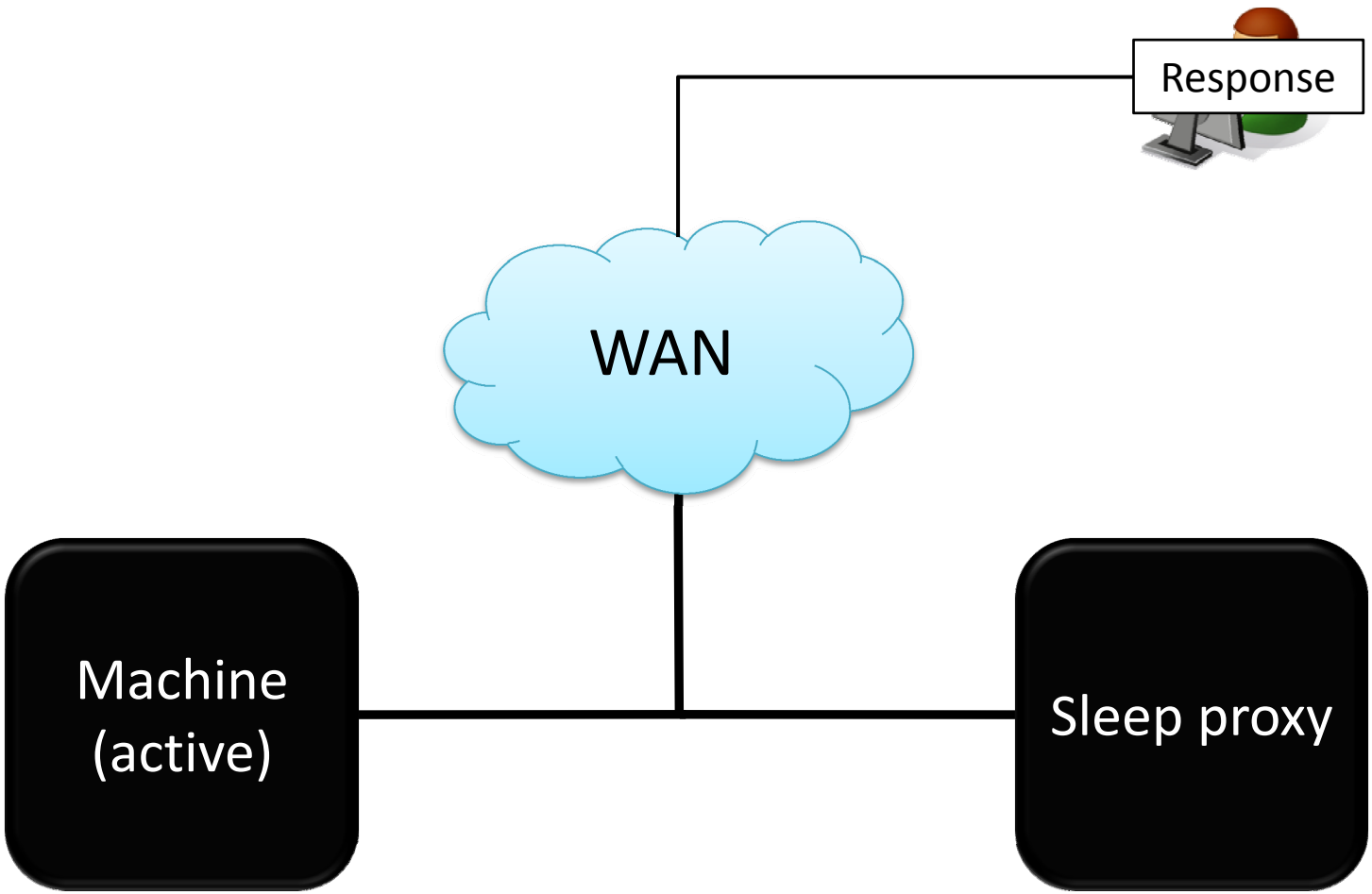

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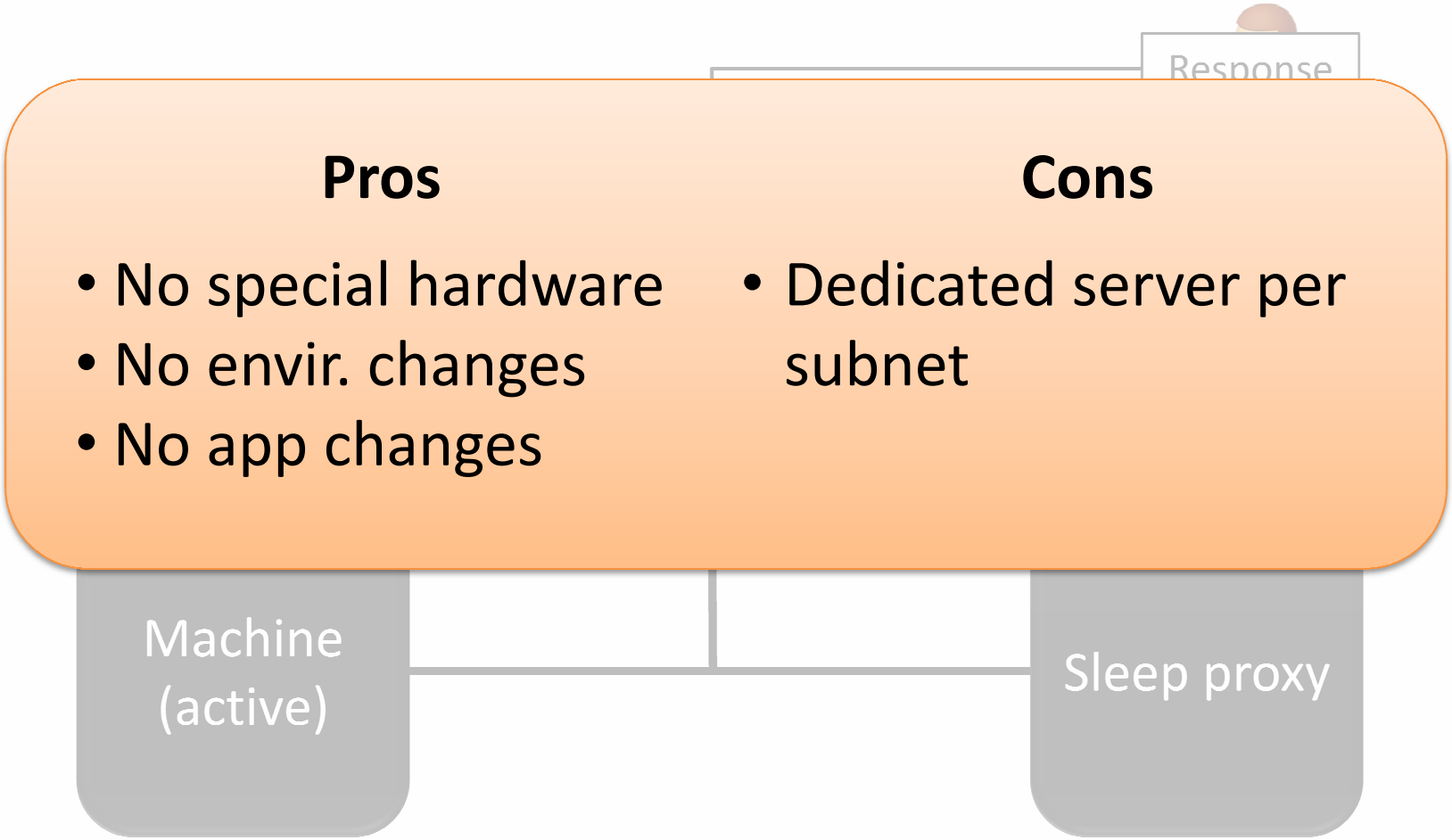
Response
Pros
• No special hardware
• No envir. changes
• No app changes
Cons
• Dedicated server per subnet
Machine (active)
Sleep proxy

Dedicated servers are a **problem**

- High deployment and management cost
- Single point of failure

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- High deployment and management cost
- Single point of failure
- High availability becomes expensive!

GreenUp: A decentralized, minimal software-only sleep proxy

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Any machine can act as a proxy (manager) for sleeping machines on the subnet

Outline

1. How does GreenUp work?
2. What can I learn from GreenUp?

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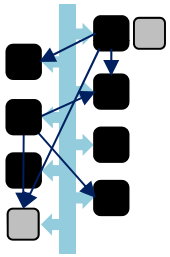

Distributed management

Machine	State
…	…
…	…
…	…

Subnet state coordination

Guardians

Outline

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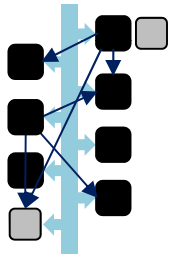


Distributed management

Machine	State
…	…
…	…
…	…

Subnet state coordination

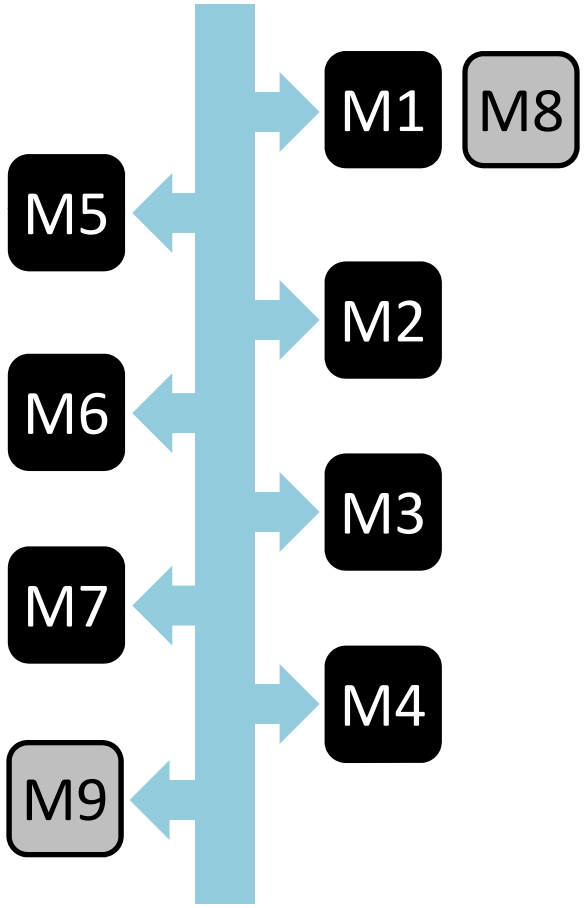
Guardians

3. How effective is GreenUp?
   - Evaluation on ~**100** user machines, currently deployed on ~**1,100** machines

GreenUp’s environment

- Subnet domains
- Load-sensitive, unreliable machines
- Single administrative domain
- Availability most important

Running example (not to scale)



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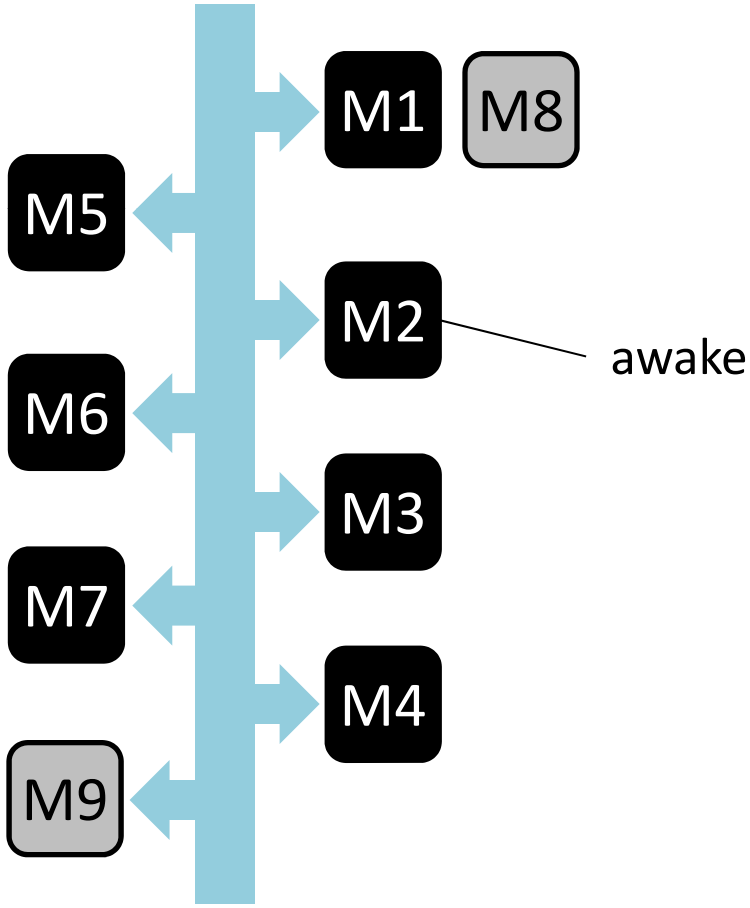

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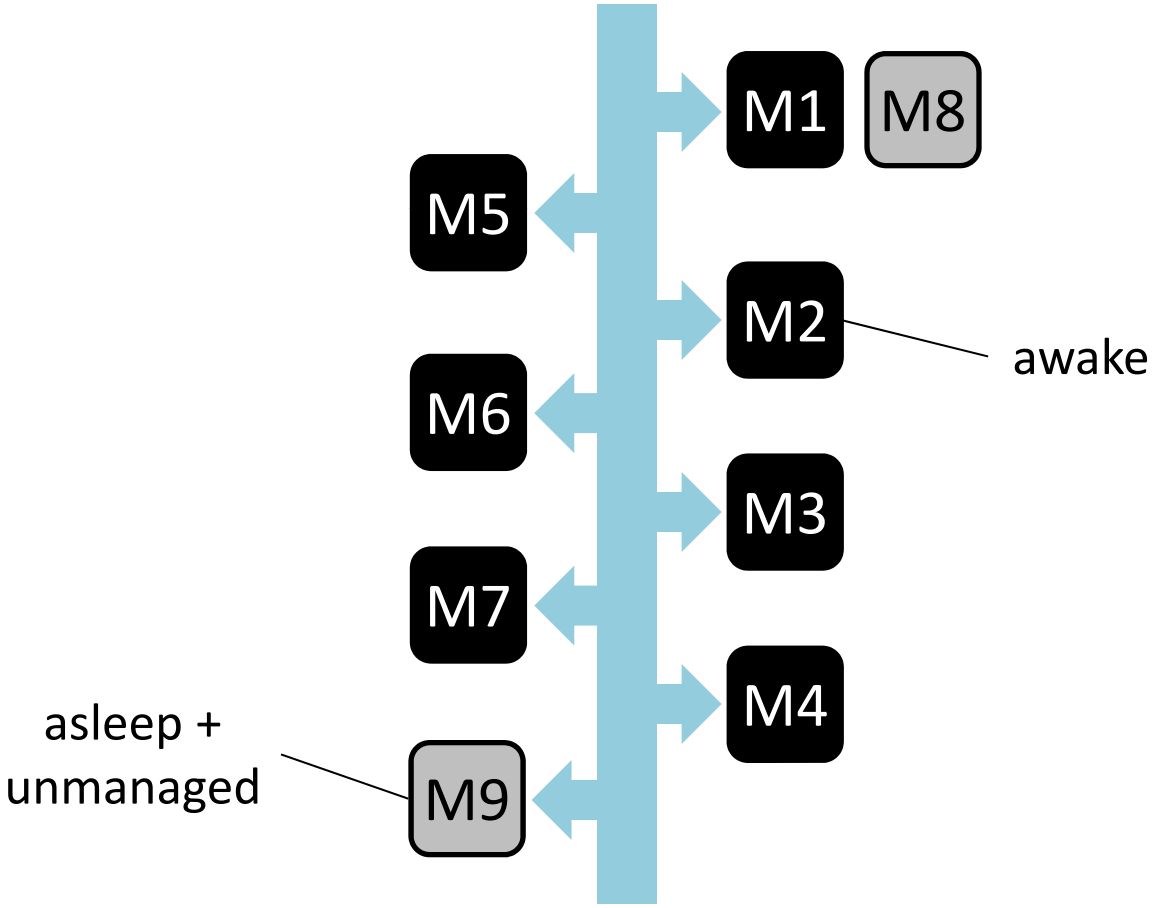

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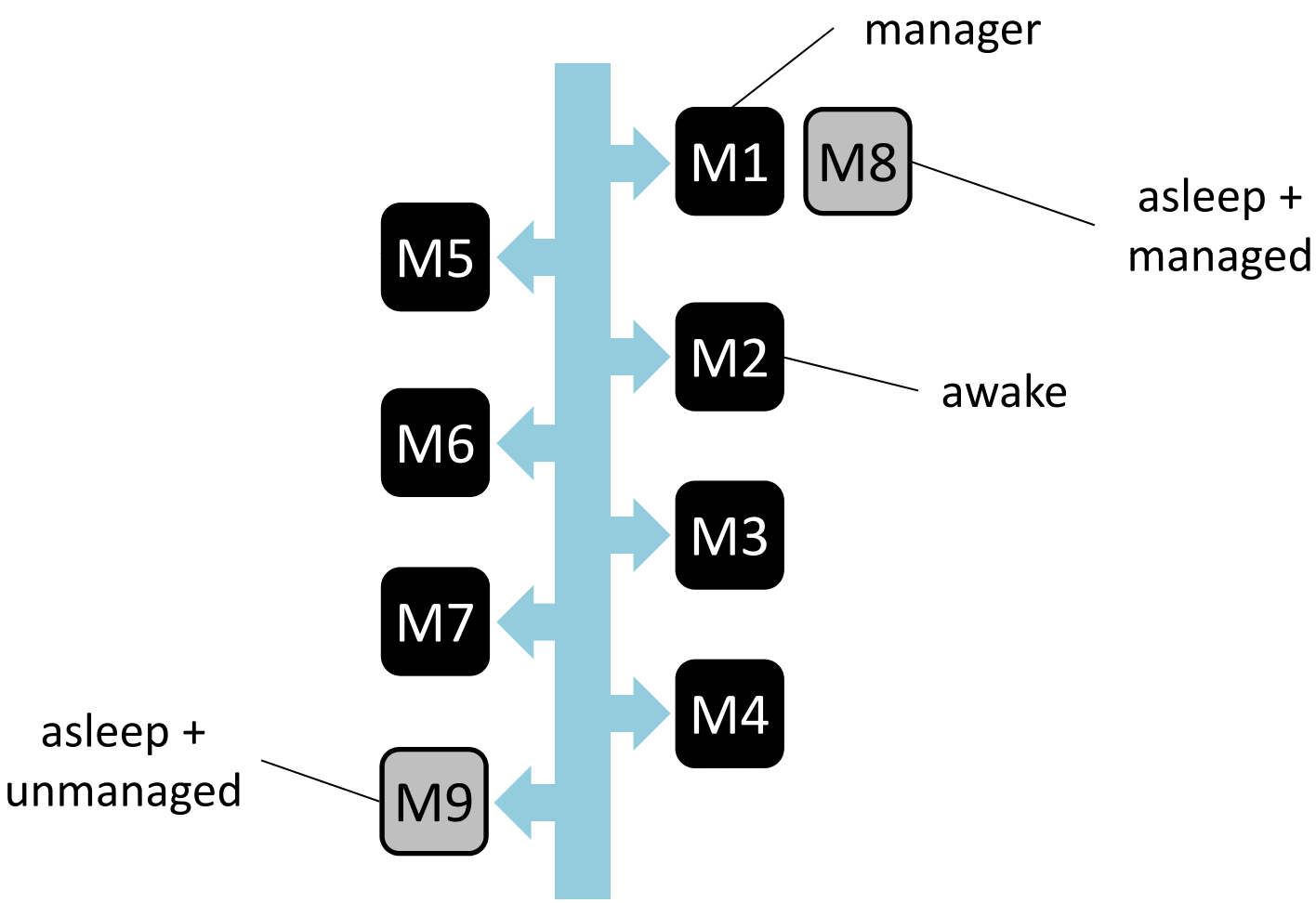
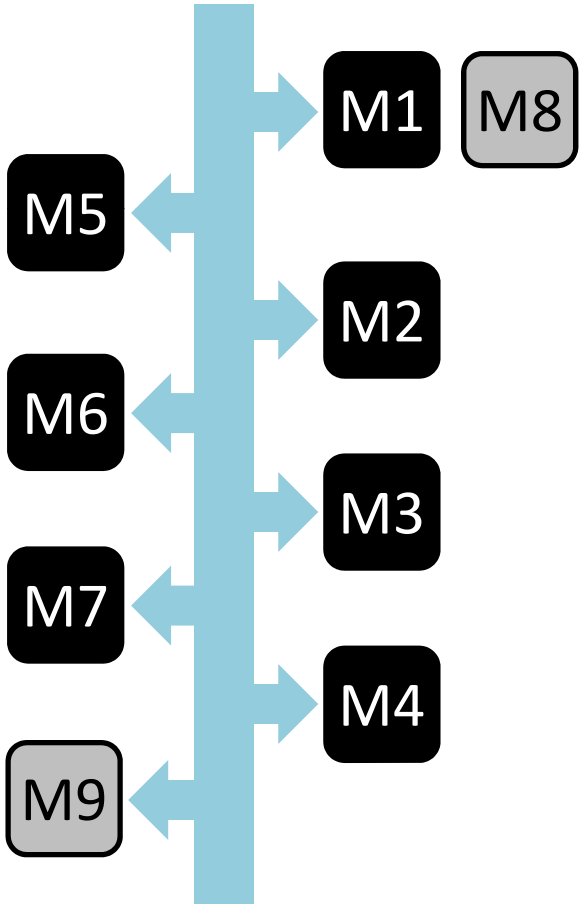


Distributed management: Who manages M9?



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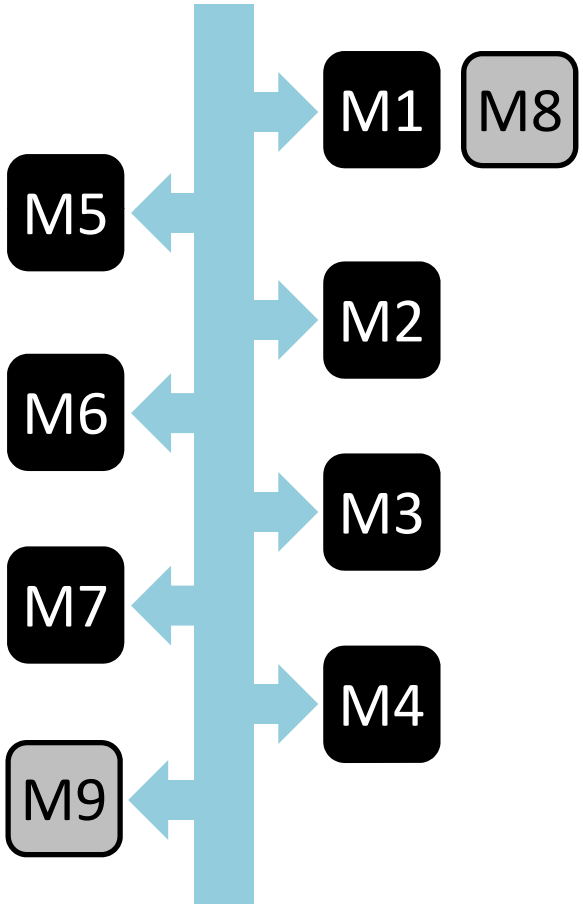

- Wait for notification?

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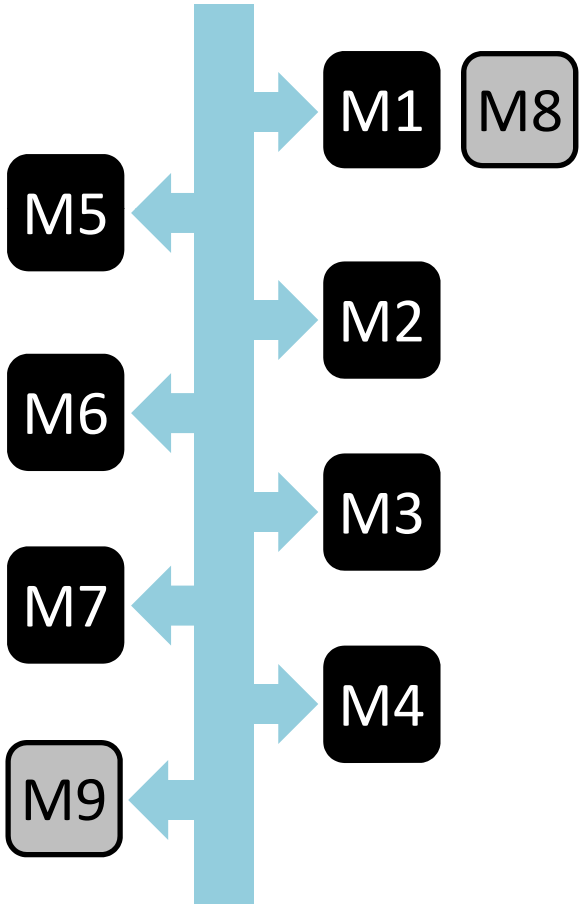

- Wait for notification?
  - No guarantees before sleep
  - M1 failure abandons M8

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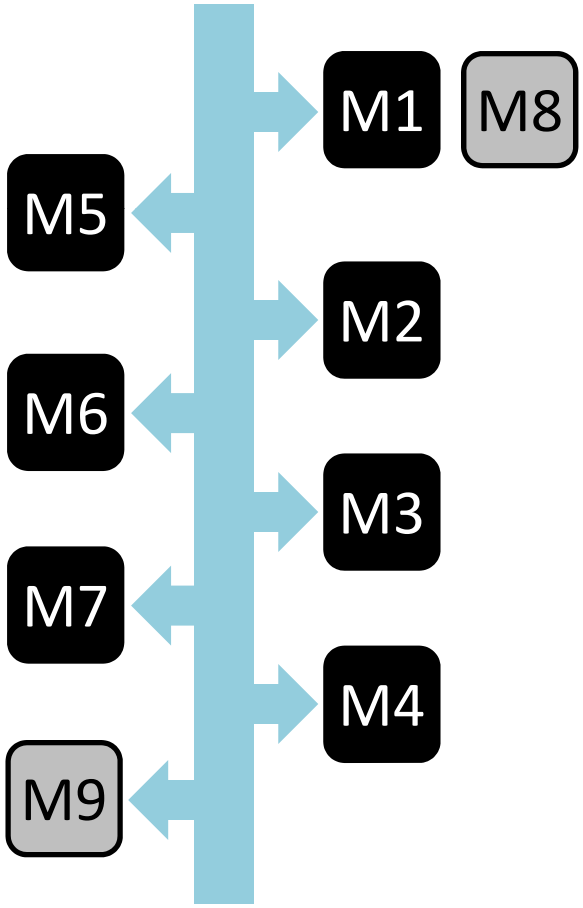

- Wait for notification?
  - No guarantees before sleep
  - M1 failure abandons M8
- Probe randomly, repeat since machines unreliable
- Load-sensitive machines, so distribute probing
  - Robust to manager issues

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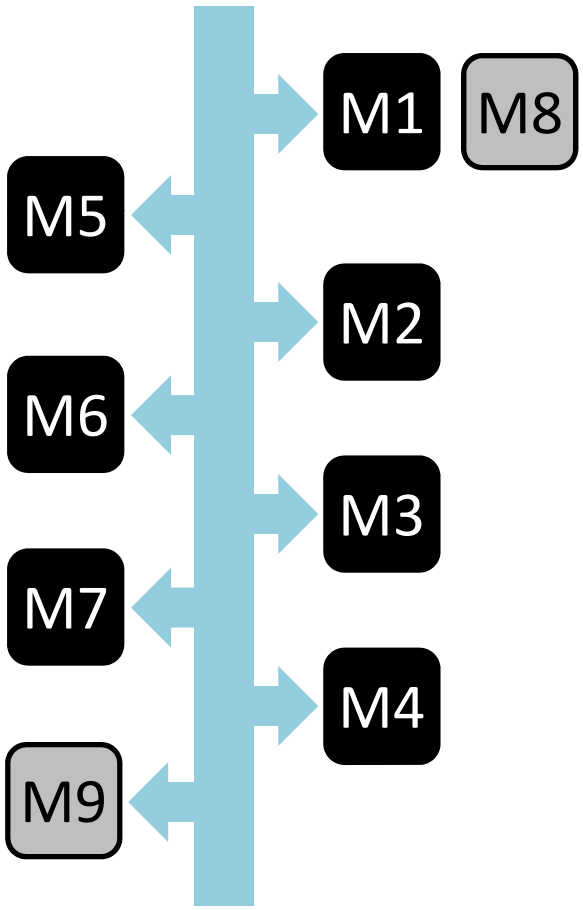

total # machines

$$\frac{n}{\#\text{ awake machines}}$$

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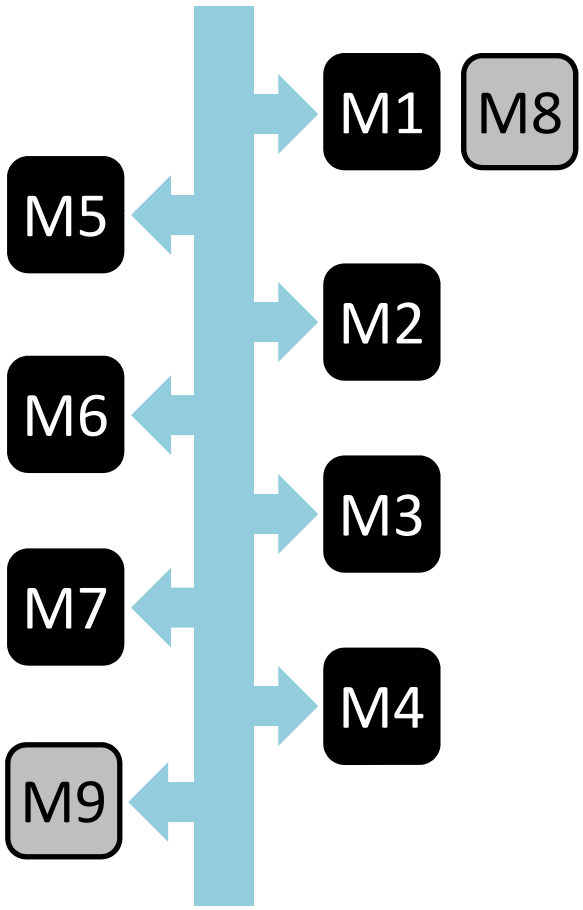

total # machines

managed by *i*

$$\frac{n - m_i}{\#\ \text{awake machines}}$$

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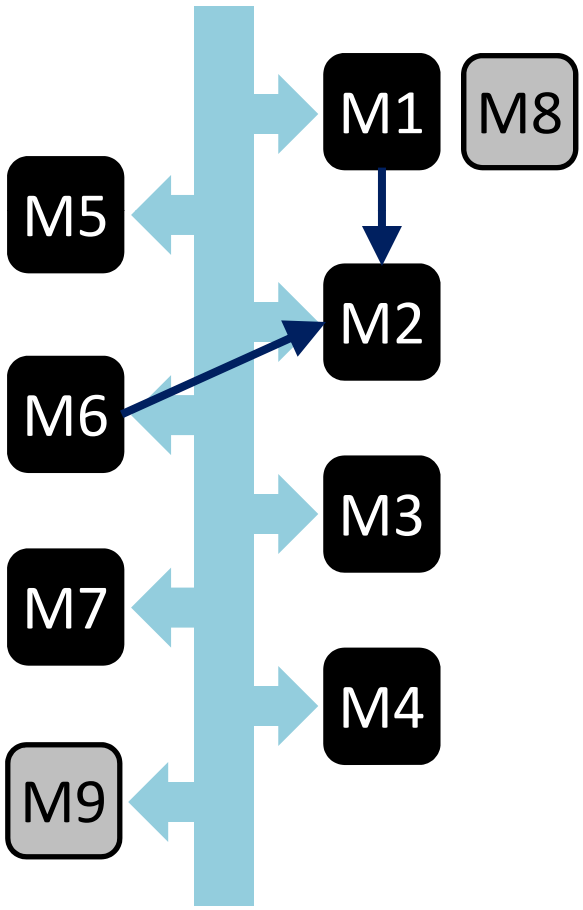

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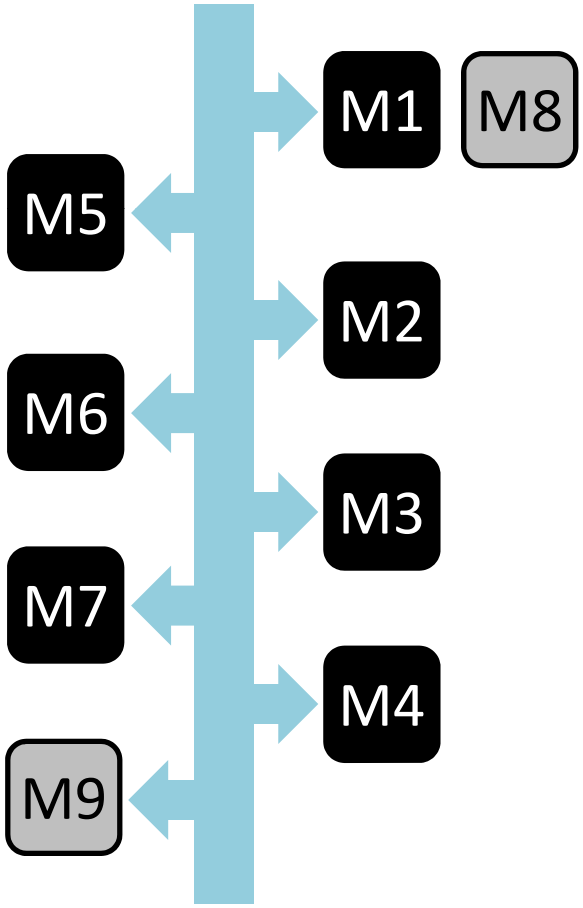

$$\frac{(n - m_i)\ln\left(\frac{1}{1-p}\right)}{\#\text{ awake machines}}$$

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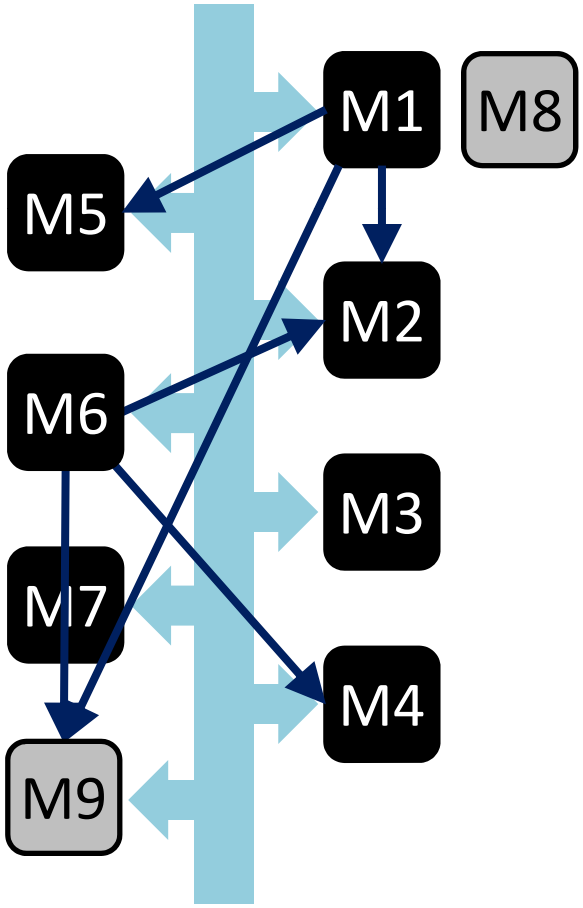

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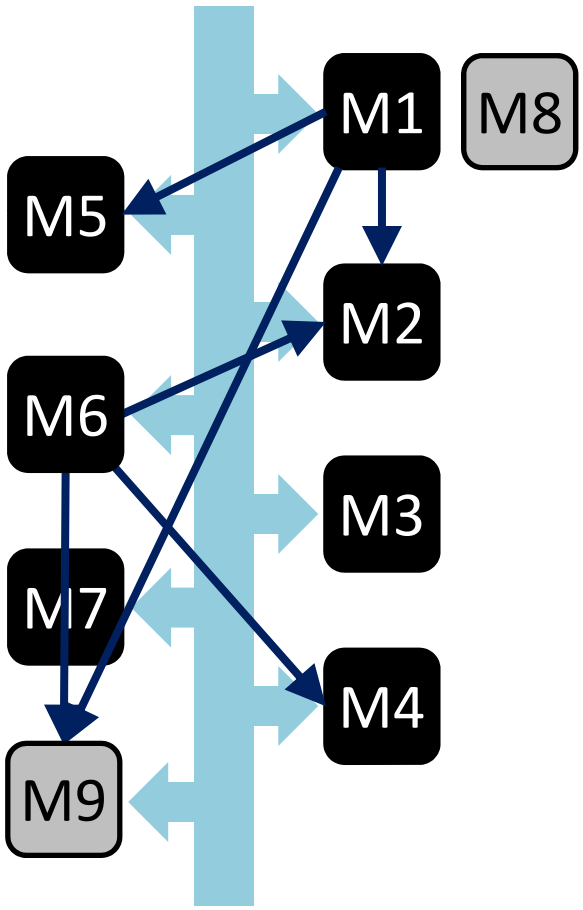
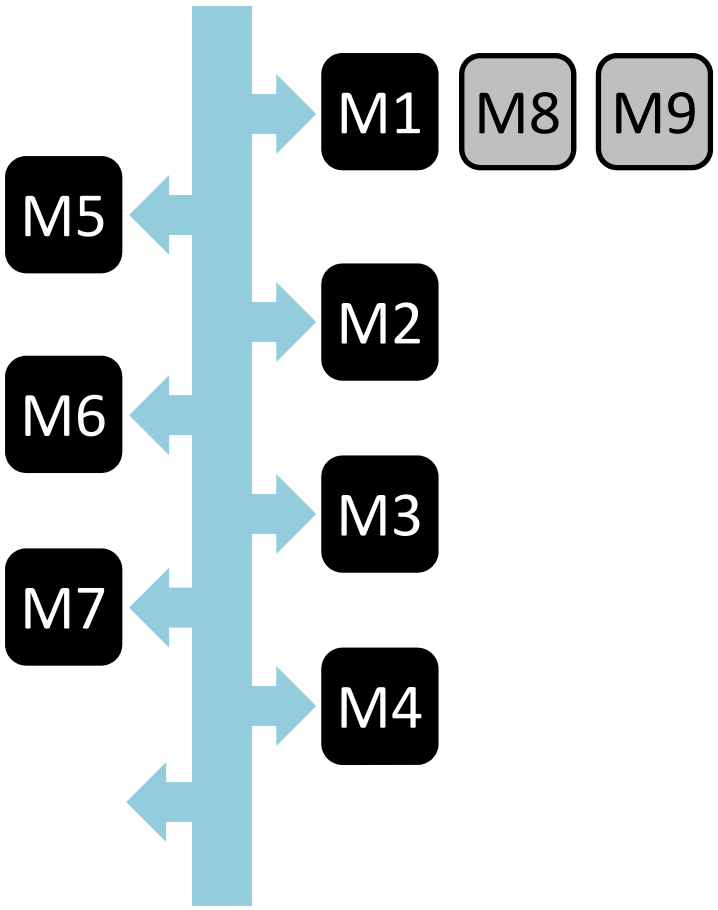


p = Pr(machine probed)

$$\frac{(n - m_i)\ln\left(\frac{1}{1-p}\right)}{\#\text{ awake machines}}$$

- Coupon collector analysis

Distributed management: Who manages M9?



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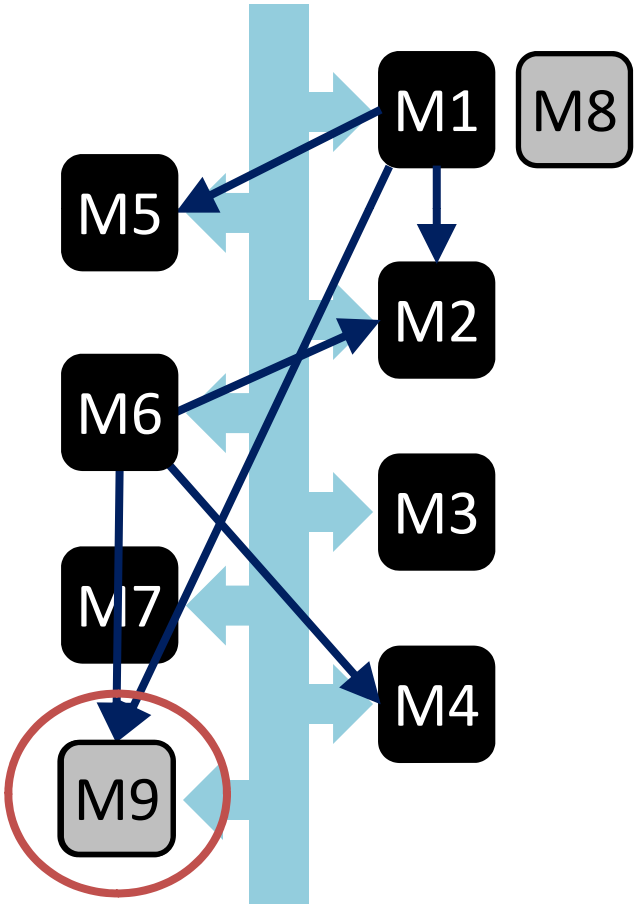
Multiple managers



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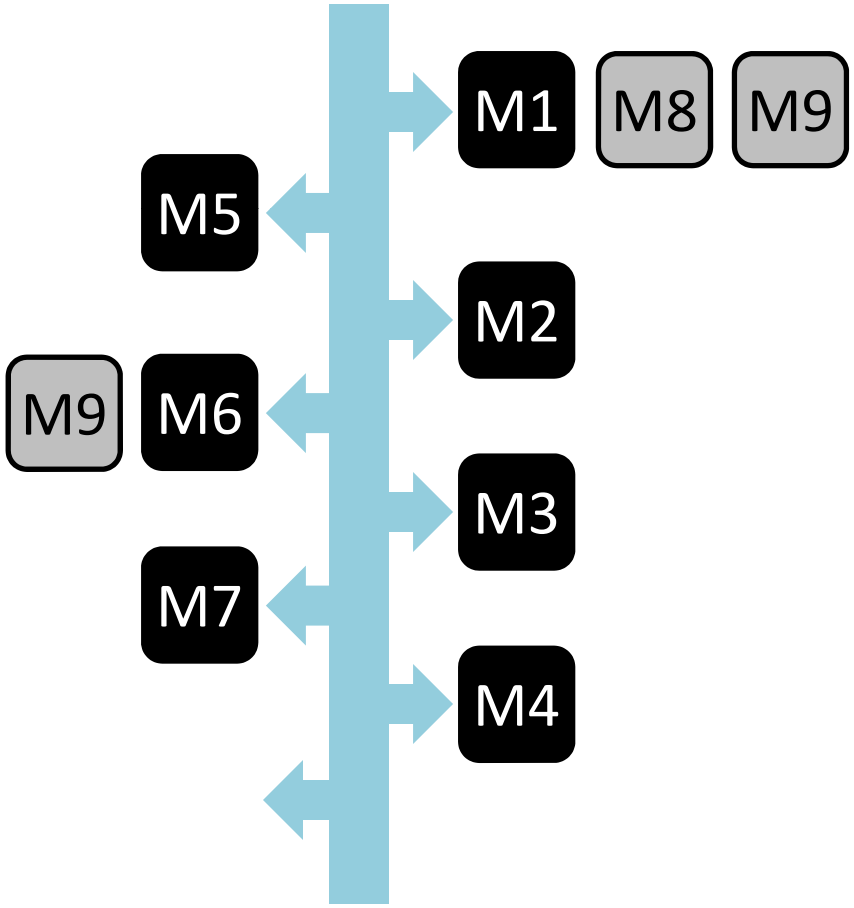

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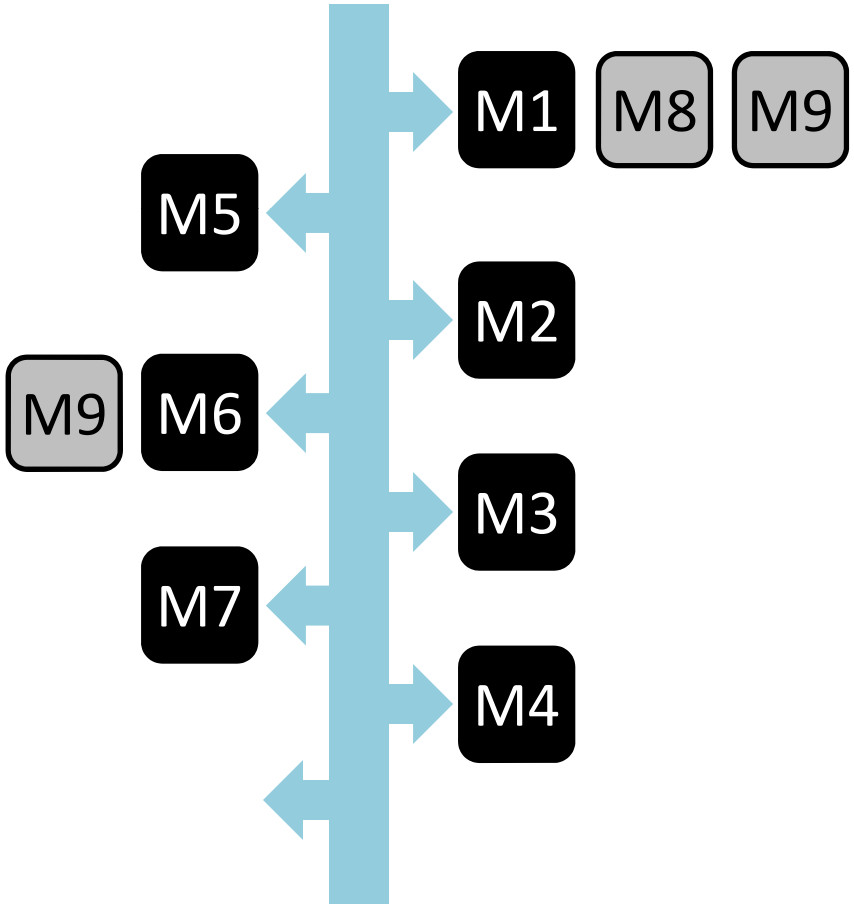

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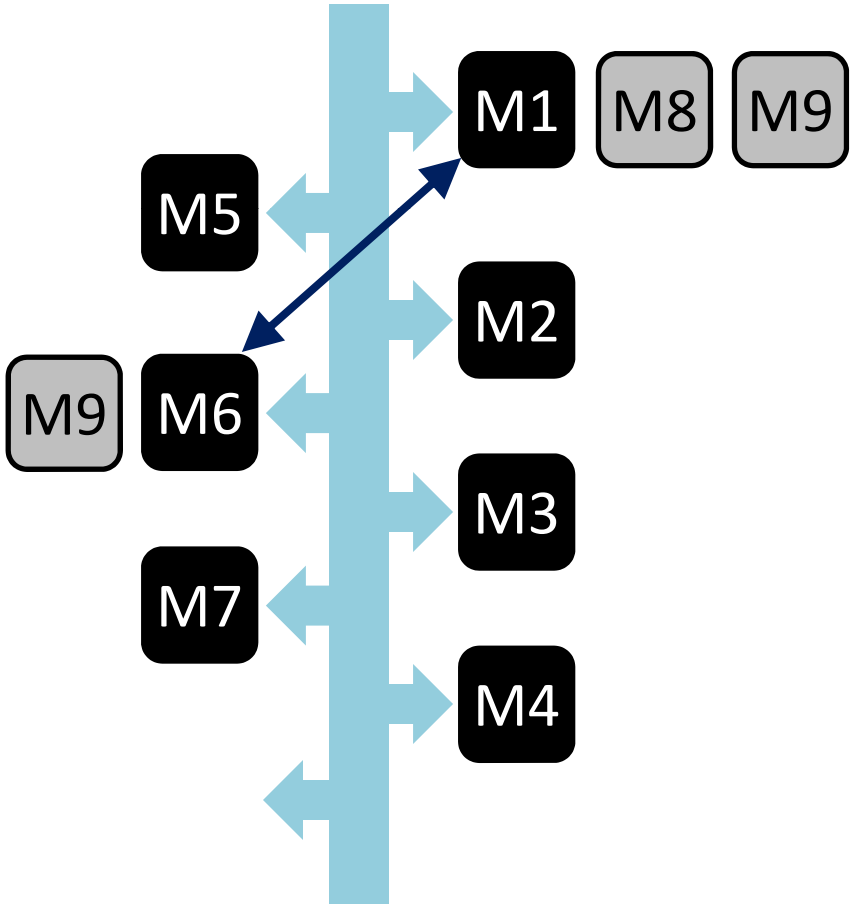

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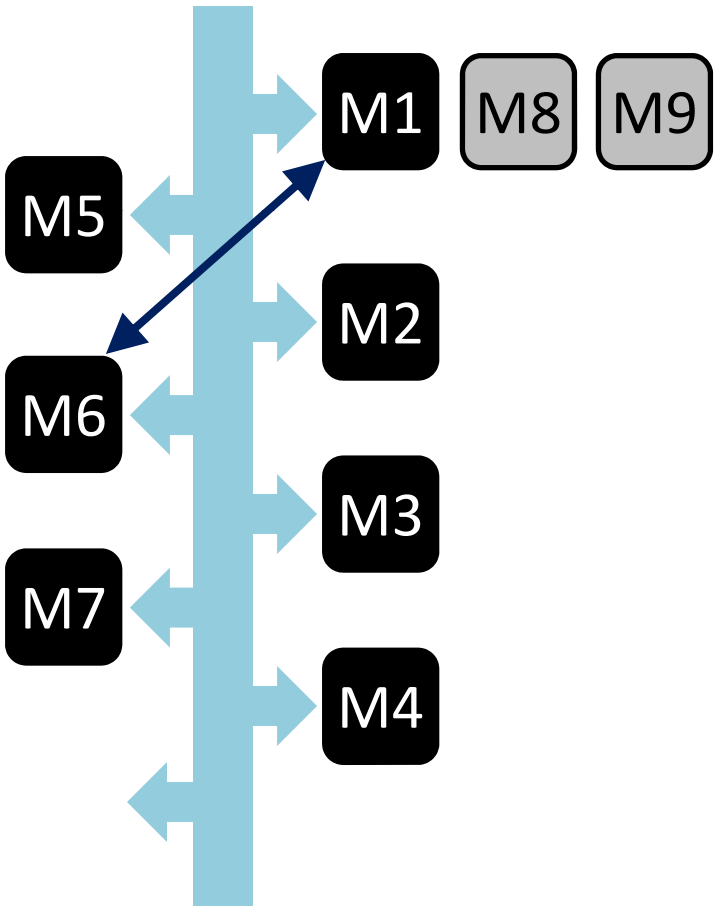
- Availability most important
- Simple resolution protocol

Multiple managers



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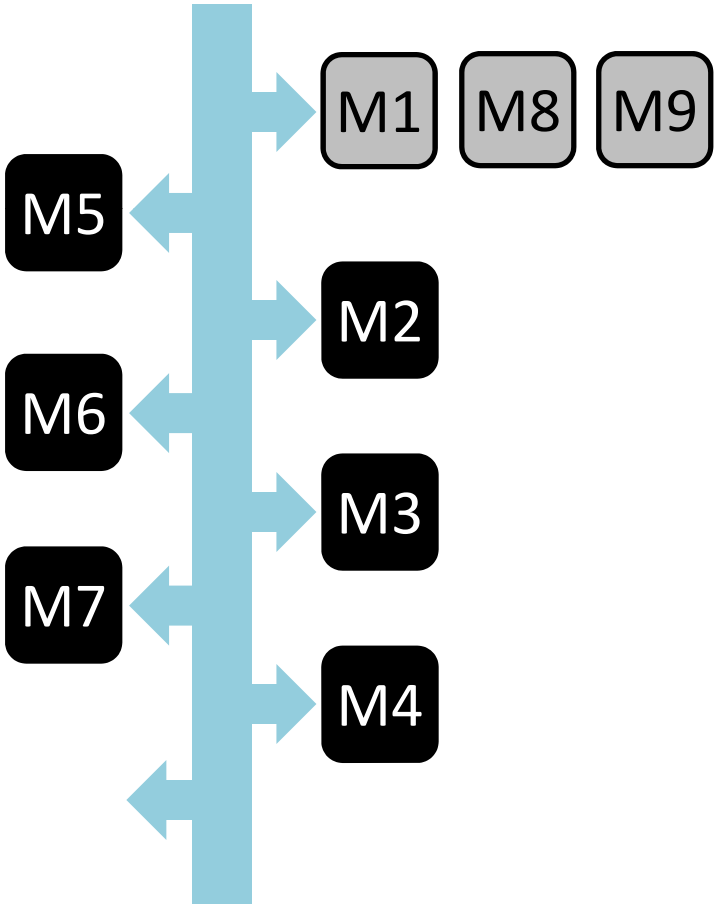
Load balance



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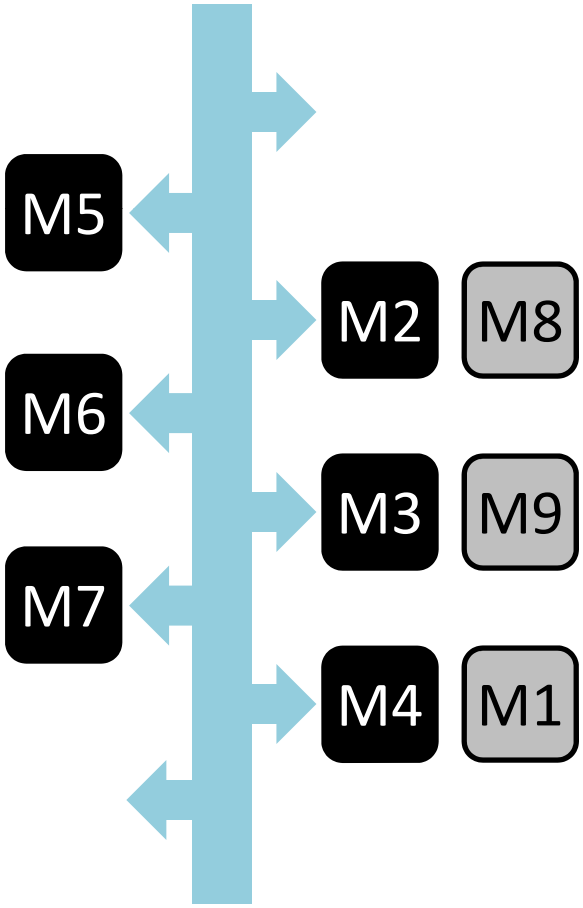

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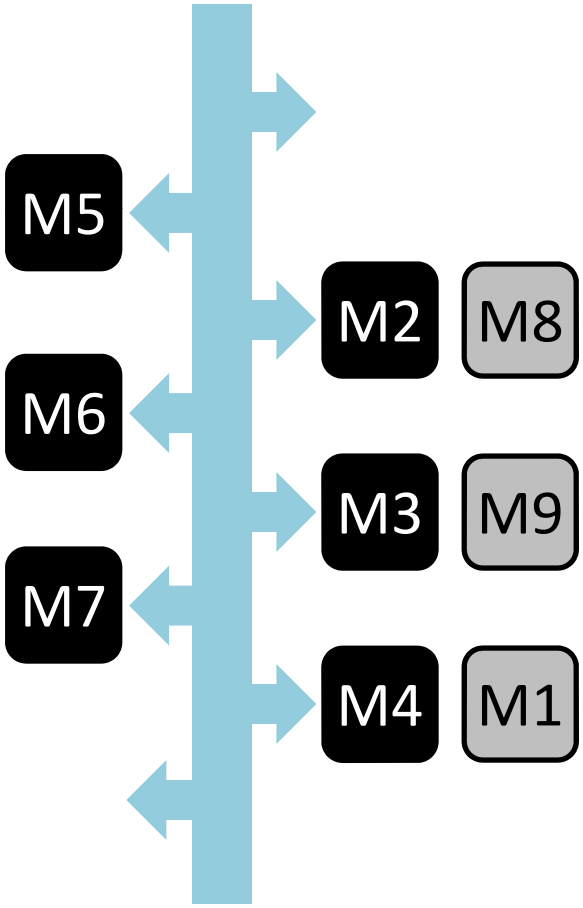


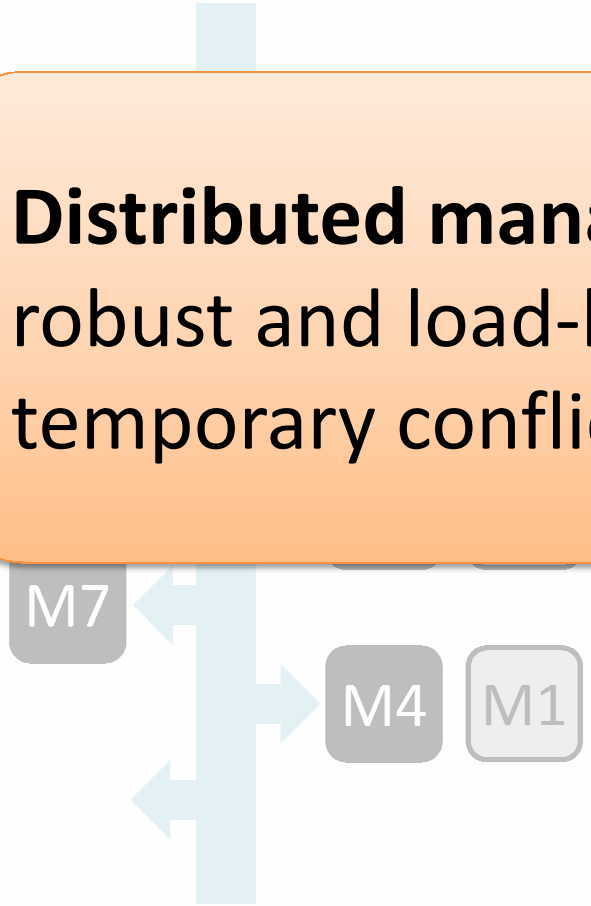
- Induction analysis: equivalent to balls-in-bins!

$$\frac{\ln(n/2)}{\ln\ln(n/2)}$$ after $n/2$ sleeps

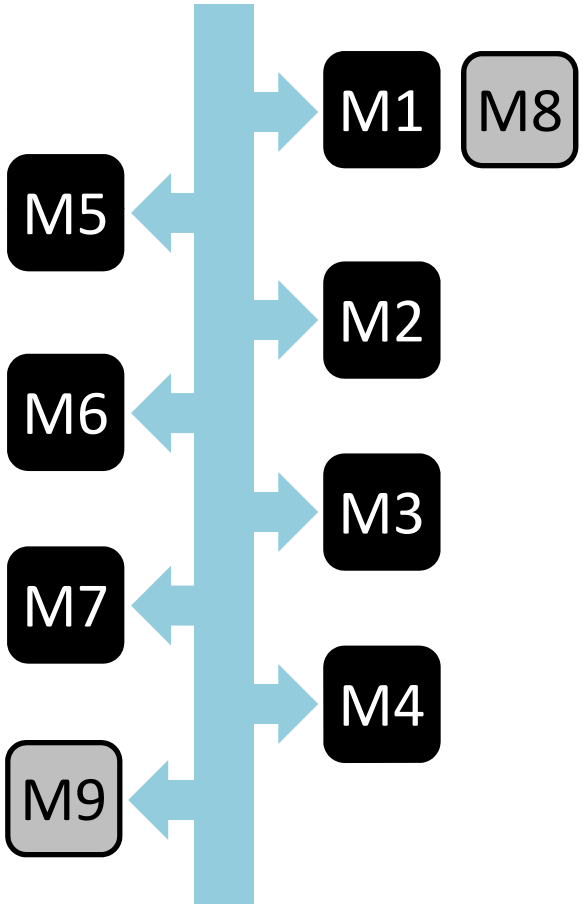
Load balance

- Induction analysis:

Distributed management elects leaders in a robust and load-balanced way, assuming temporary conflicts are tolerable.



Subnet state coordination



- Distributed management relies on global state
  - Who to probe?
  - How to manage?

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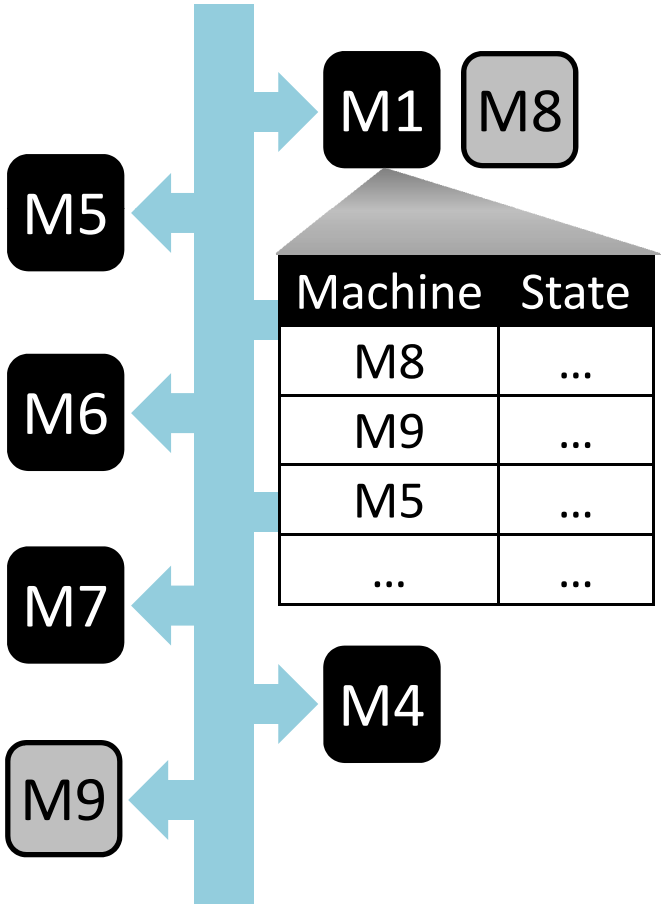

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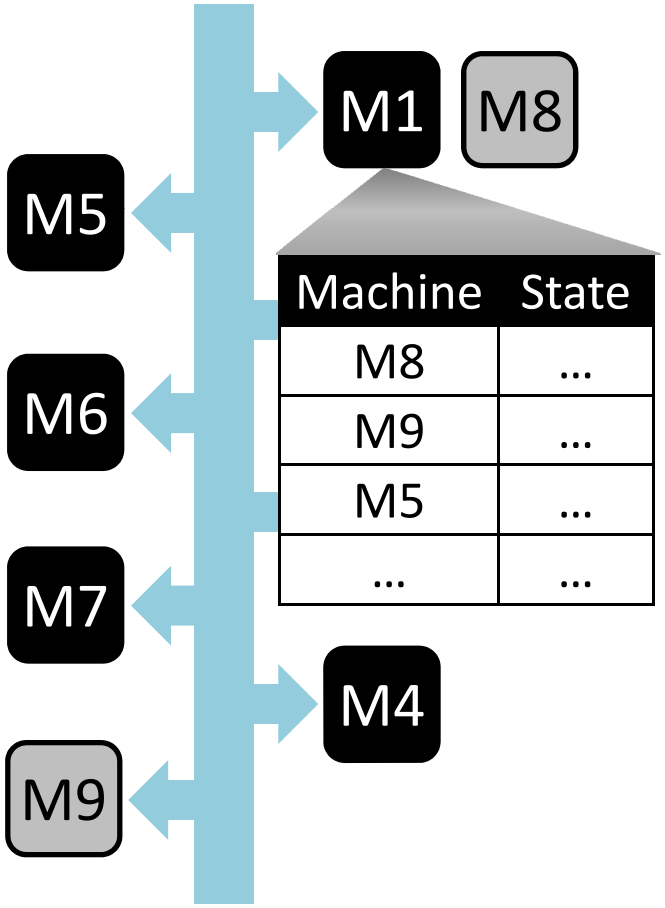
- IP address, MAC address
- TCP listen ports

Subnet state coordination



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  - Unreliable machines, correlated behavior
  - Strong consistency overkill

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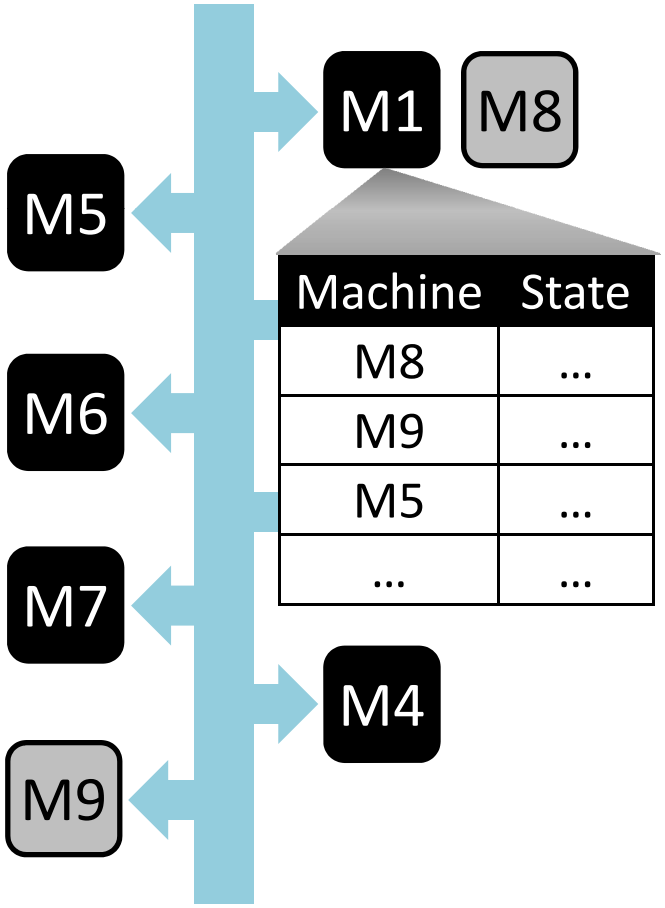

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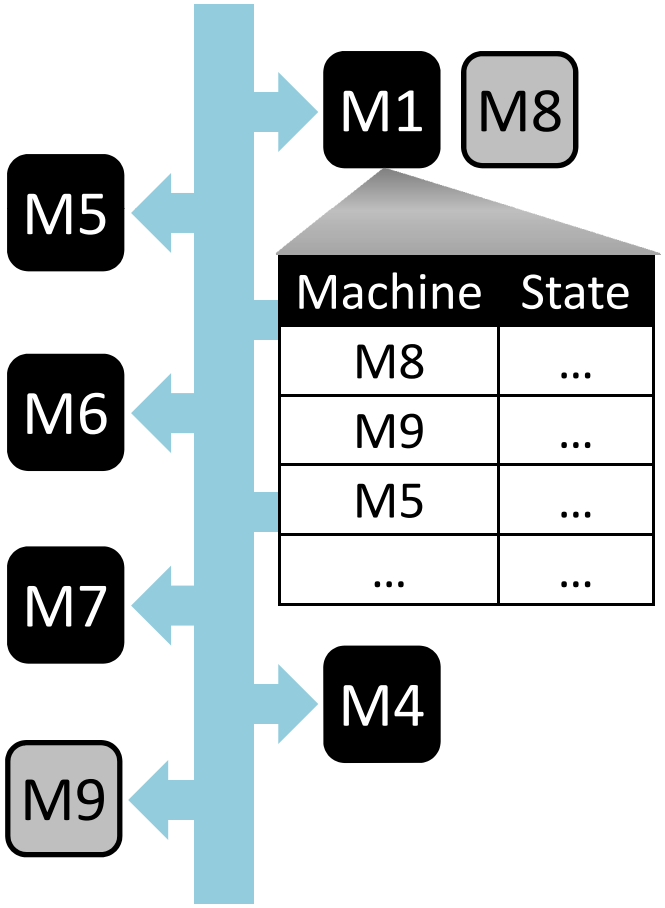
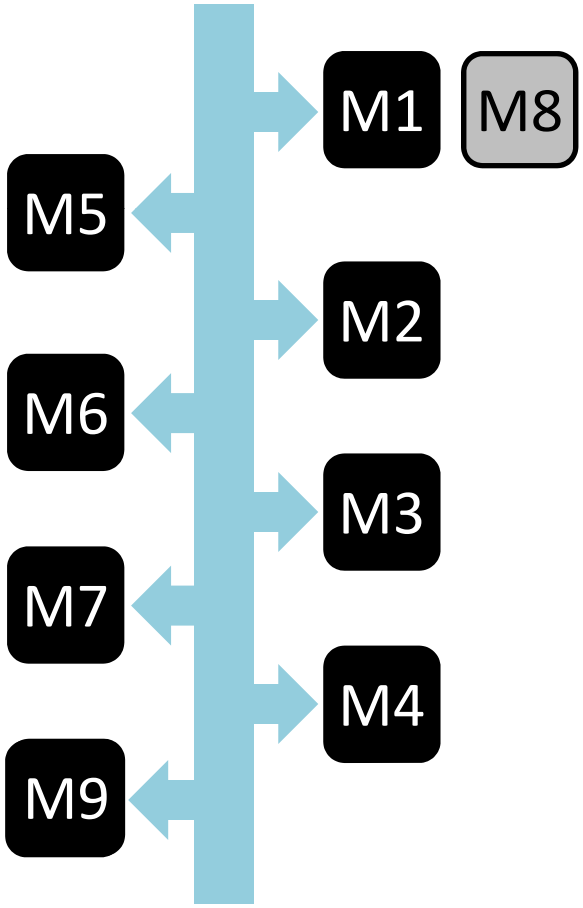
- External database?
  - Lose instant deployability

Subnet state coordination



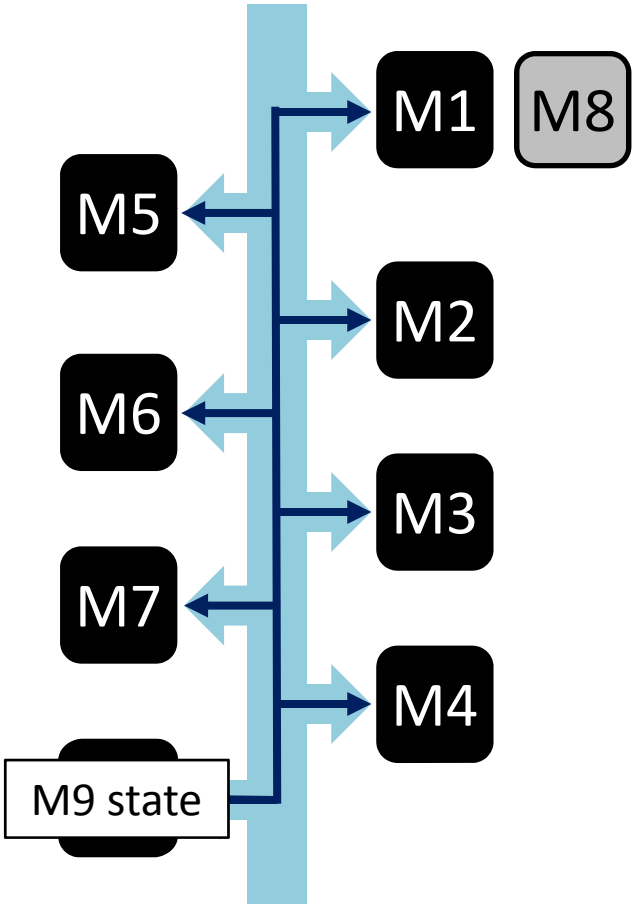
- Replicated state machine?
  - Unreliable machines, correlated behavior
  - Strong consistency overkill
- External database?
  - Lose instant deployability
- Exploit subnet and weaker consistency

Subnet state coordination



1. Periodic broadcast while awake

Subnet state coordination



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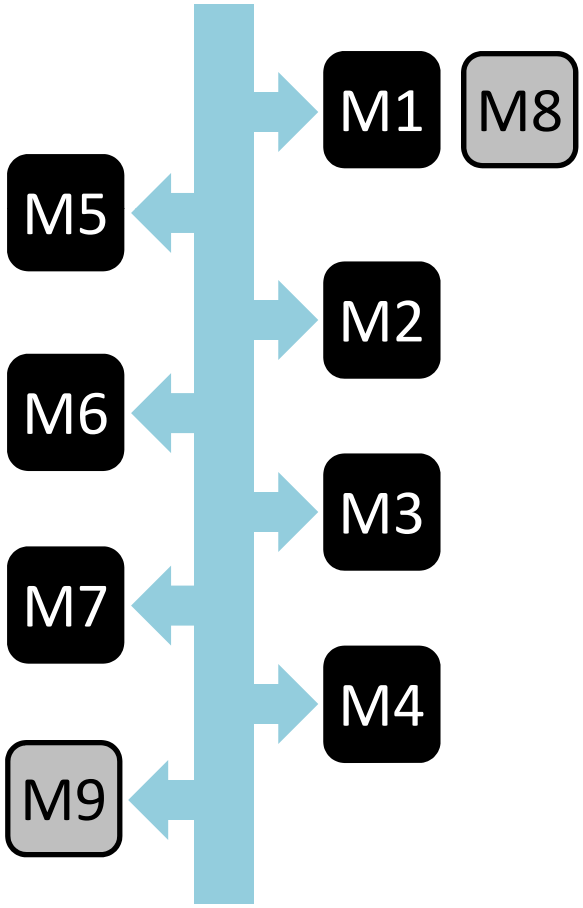

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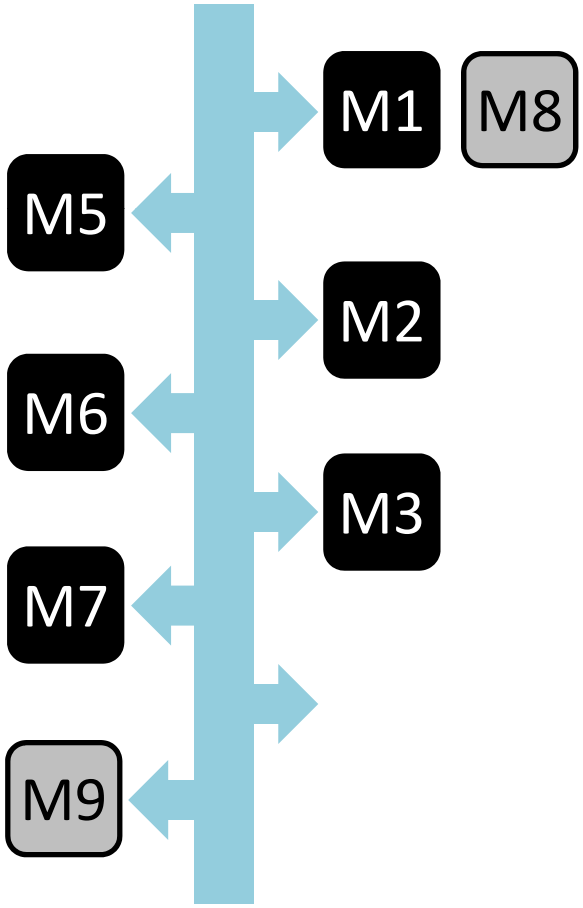

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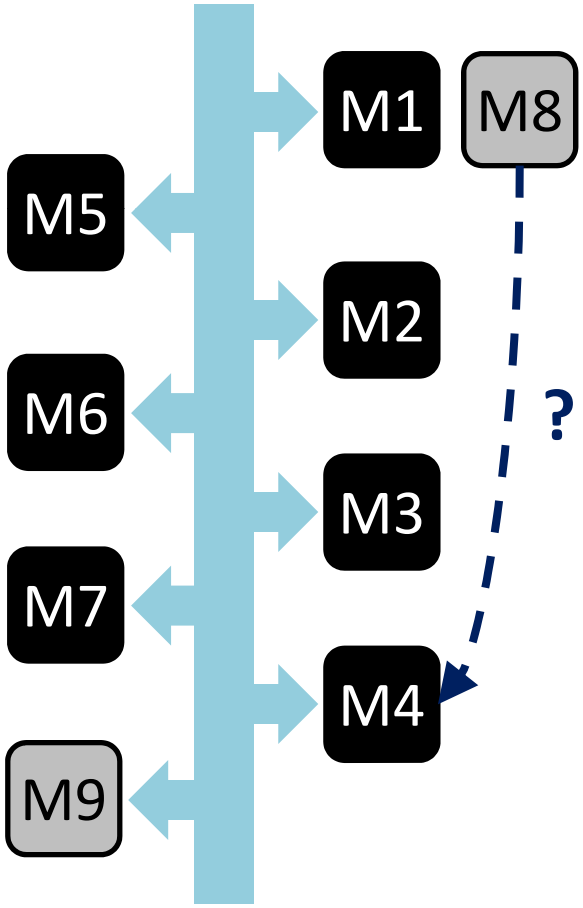

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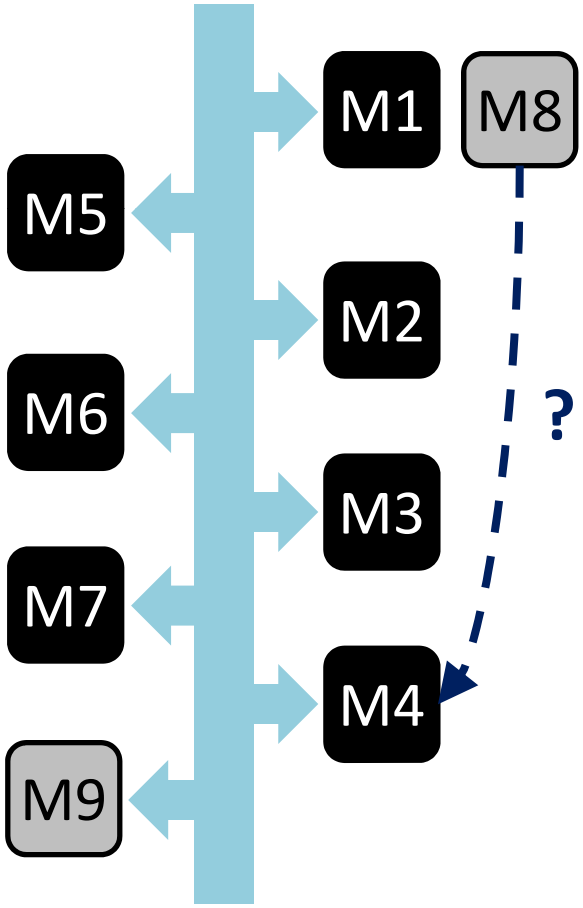

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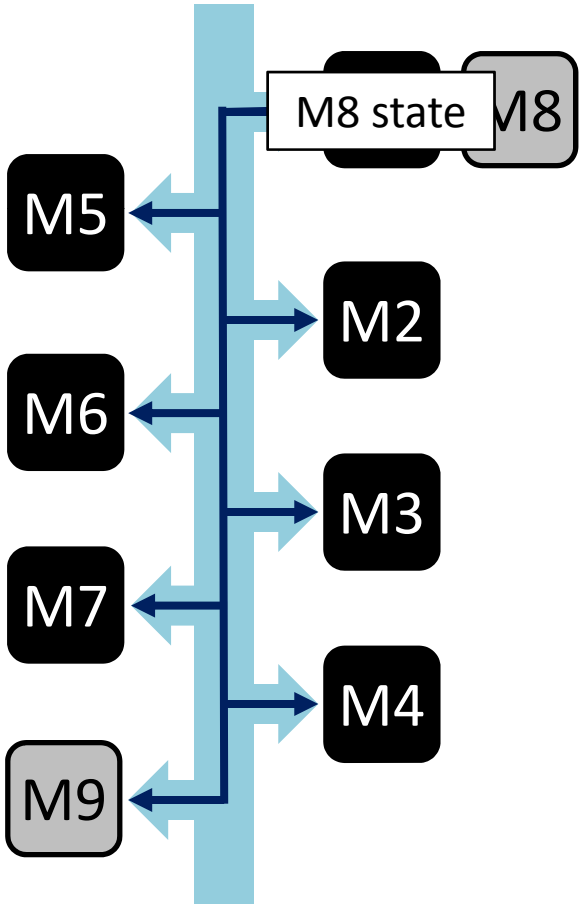

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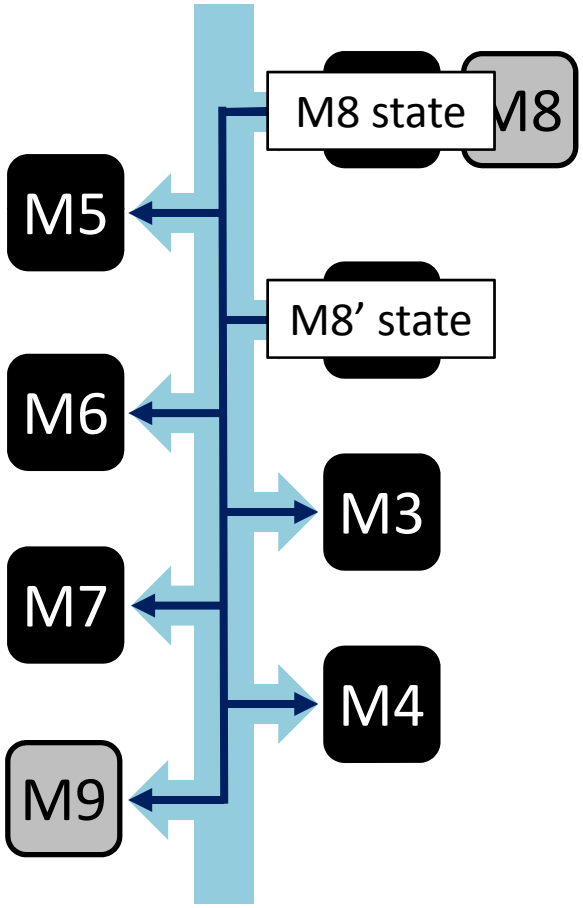

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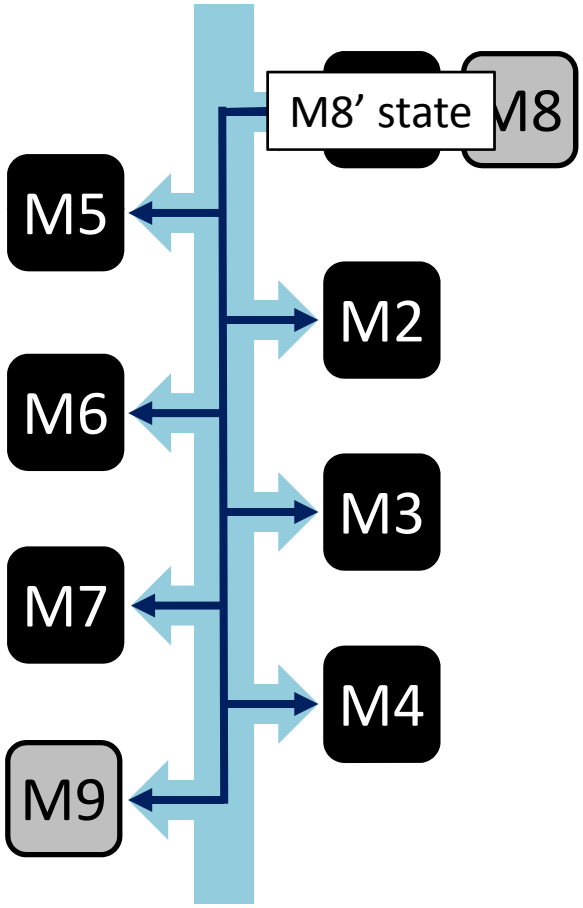

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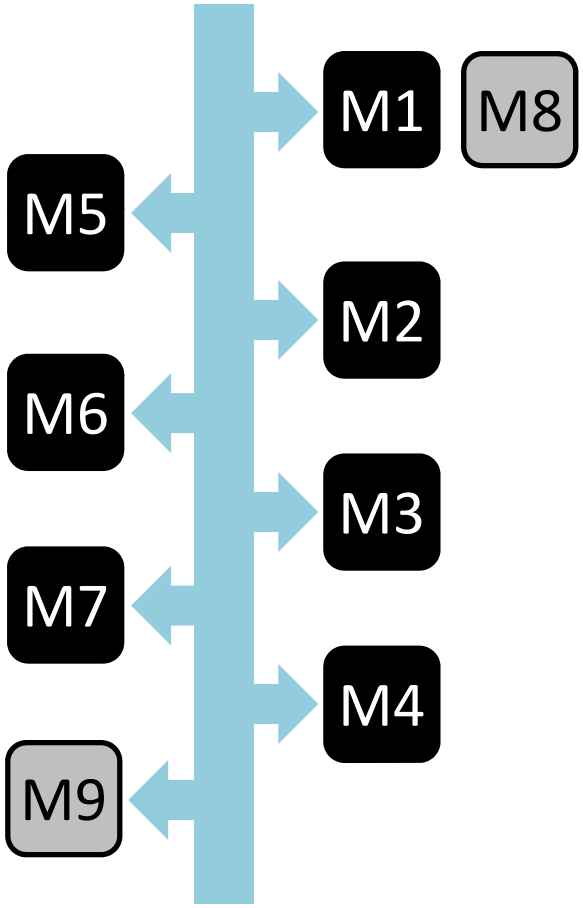
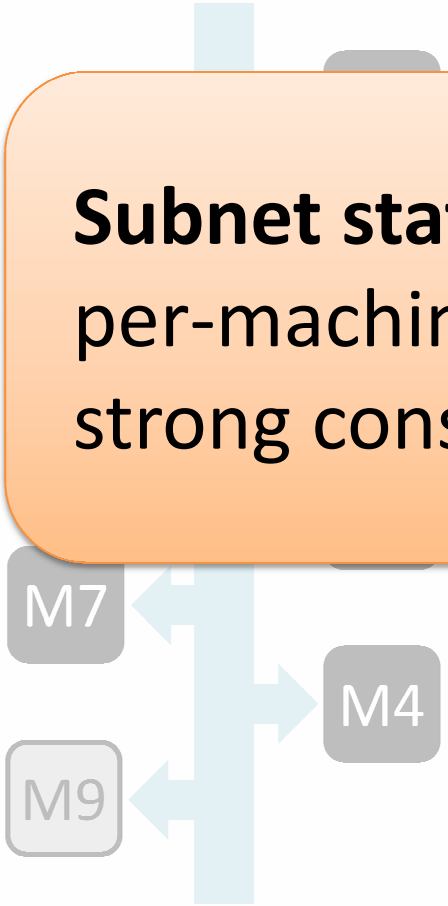


1. Periodic broadcast while awake
2. Rebroadcast by managers while asleep
3. Daily roll call to garbage-collect state

Subnet state coordination



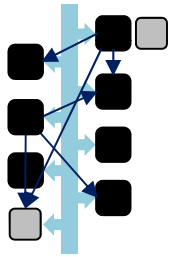
Subnet state coordination distributes per-machine state on a subnet when strong consistency is not required.

eep

3. Daily roll call to garbage-collect state

Outline

1. How does GreenUp work?
2. What can I learn from GreenUp?



Distributed management

Machine	State
…	…
…	…
…	…

Subnet state coordination

Guardians

3. How effective is GreenUp?
   - Evaluation on ~**100** user machines, currently deployed on ~**1,100** machines

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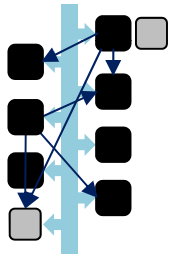

Distributed management

- Protects against simultaneous sleep
- Caps the max load

Guardians

coordination

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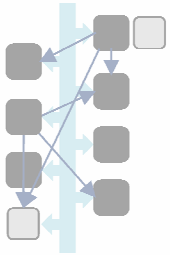


Distributed management

Machine	State
…	…
…	…
…	…

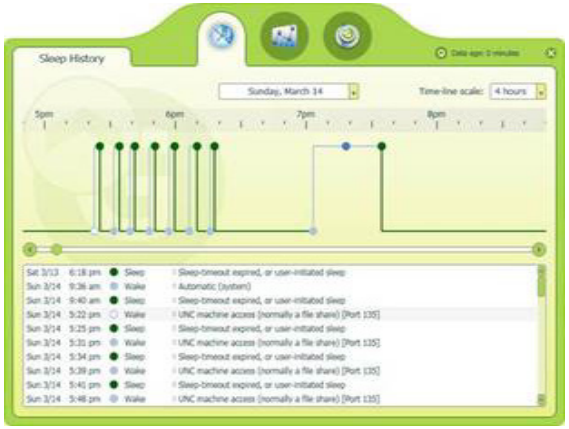
Subnet state coordination

Guardians

3. How effective is GreenUp?
   - Evaluation on ~**100** user machines, currently deployed on ~**1,100** machines

Deployment in Microsoft

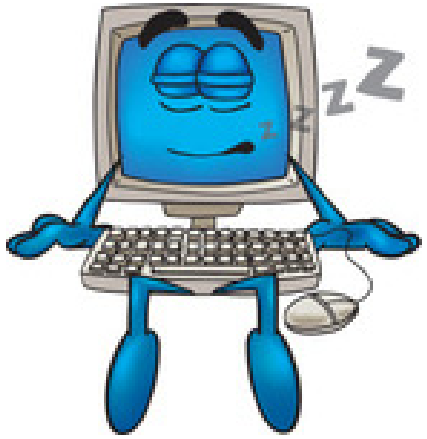
- C# code
  - Interfaces with packet sniffer/network driver
- Client GUI for users and easy deployment
- Pilot on ~1,100 machines



Evaluation

- Logs from 101 Windows 7 machines, Feb. – Sep. 2011
- Questions:
  - Does GreenUp consistently wake machines when accessed?
  - Does it do so in time to meet user patience?
  - Can GreenUp scale to large subnets?

GreenUp wakes machines reliably



GreenUp wakes machines reliably

- Connect to machines using Samba (TCP port 139)
- 11 different days (weekends, evenings):
  - 496 already awake, 278 woken, 5 unwakeable
  - Most failures due to WoL
- 99.4% success rate

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WoL is availability bottleneck!

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  - Wakeup delay
  - User retry logic

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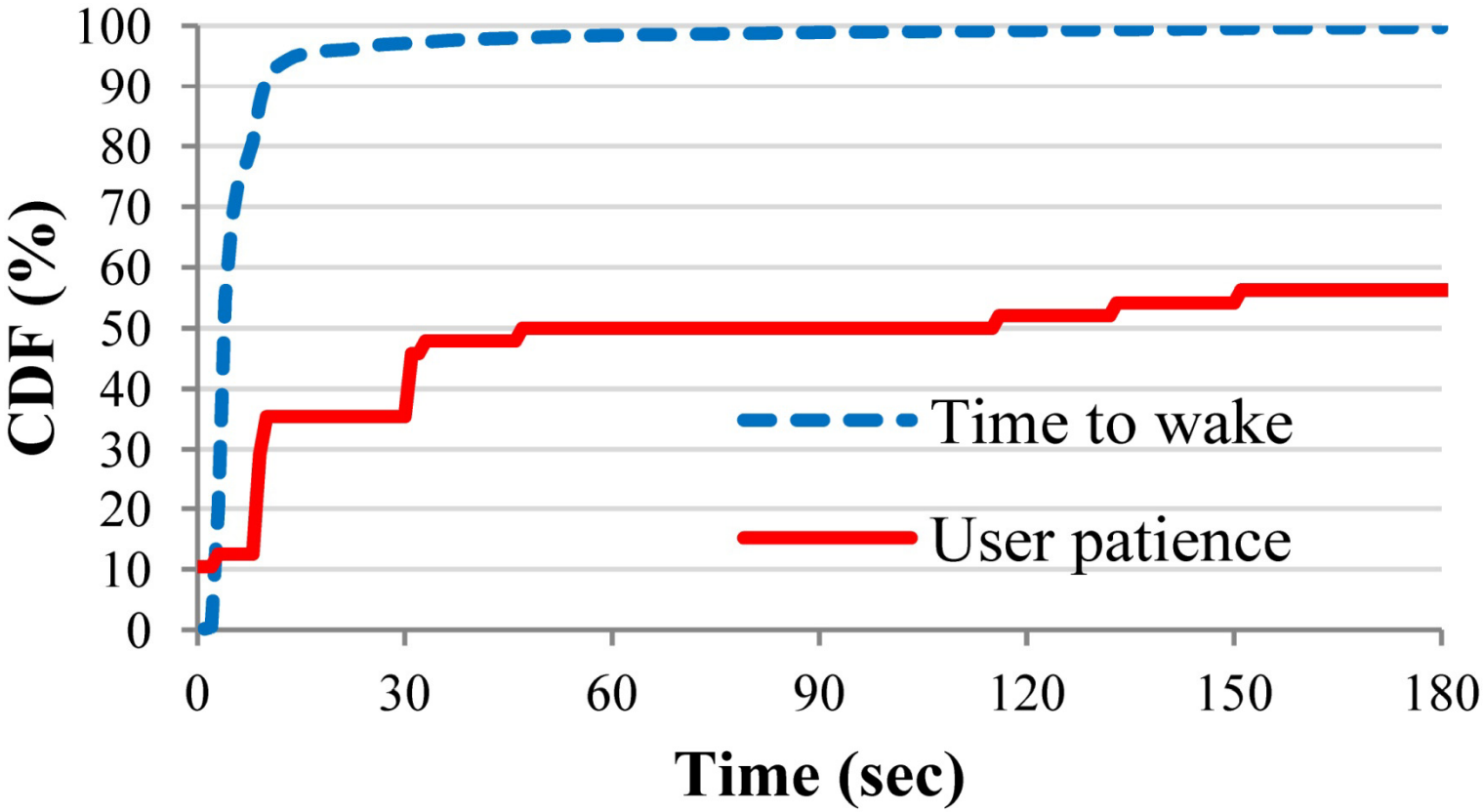
- GreenUp relies on *some* user patience
  - Wakeup delay
  - User retry logic
- Side-effect of WoL failure: manager logs how long user waits
  - 48 events

GreenUp wakes machines quickly



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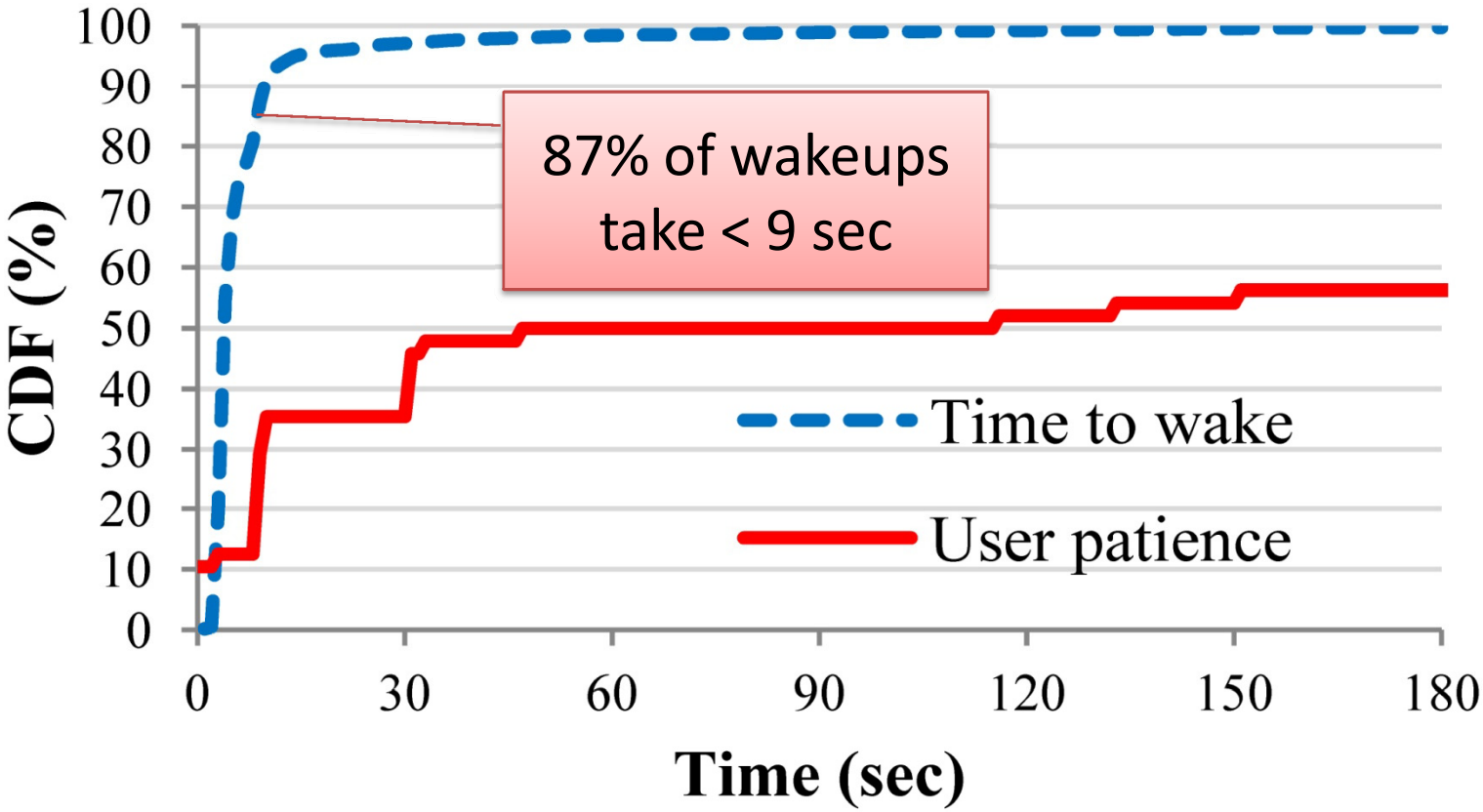

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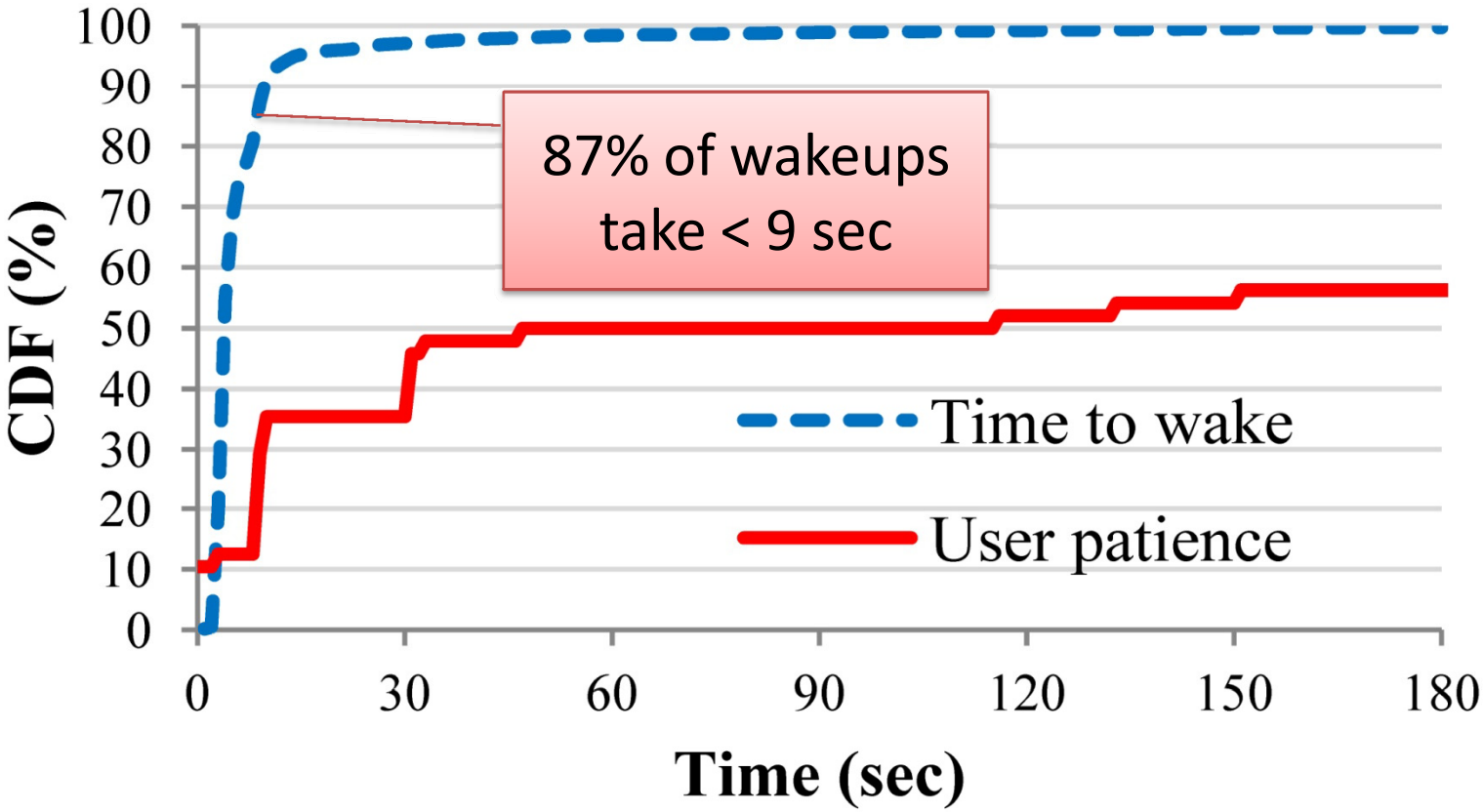

- Convolving: GreenUp wakes machines before user gives up 85% of the time

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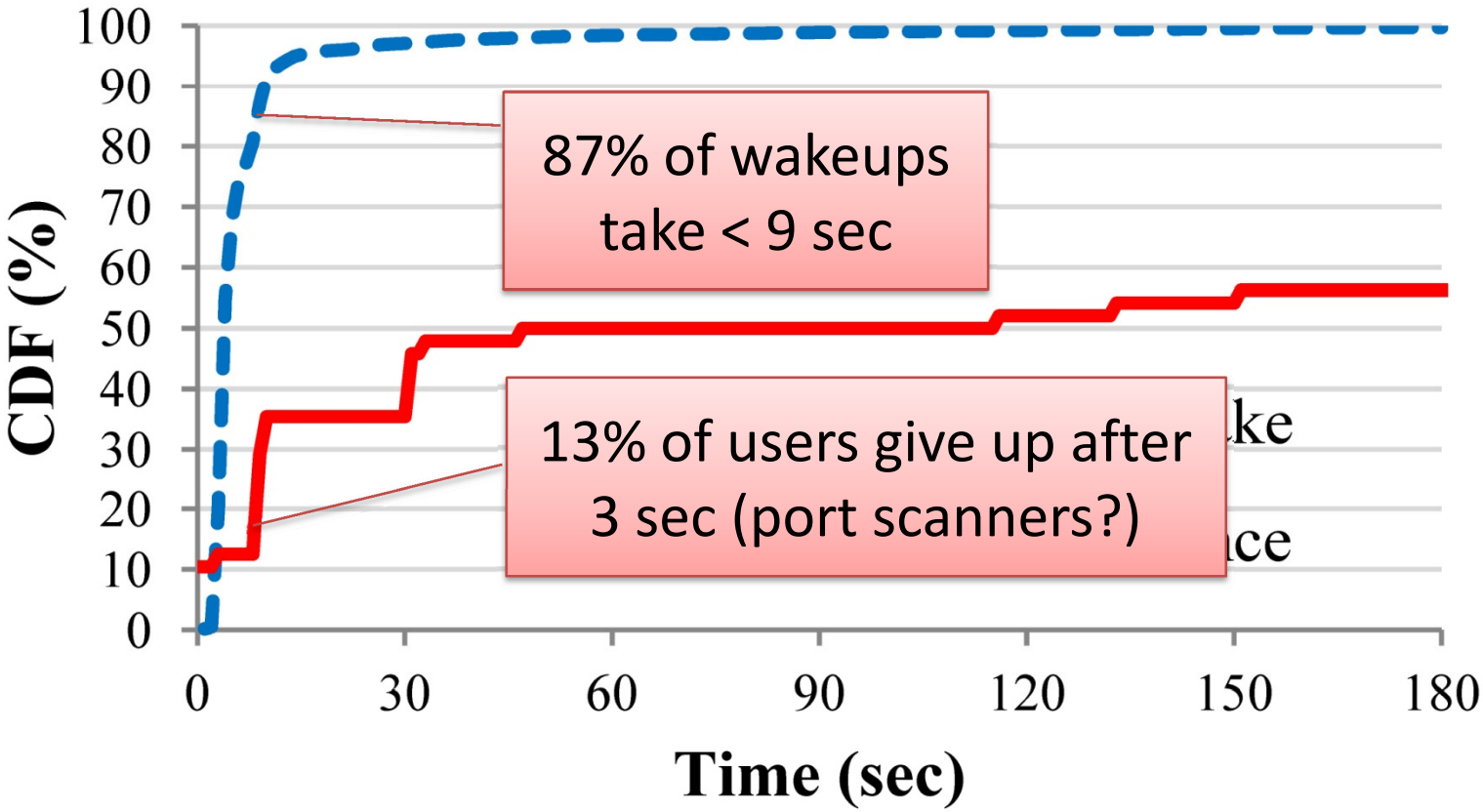
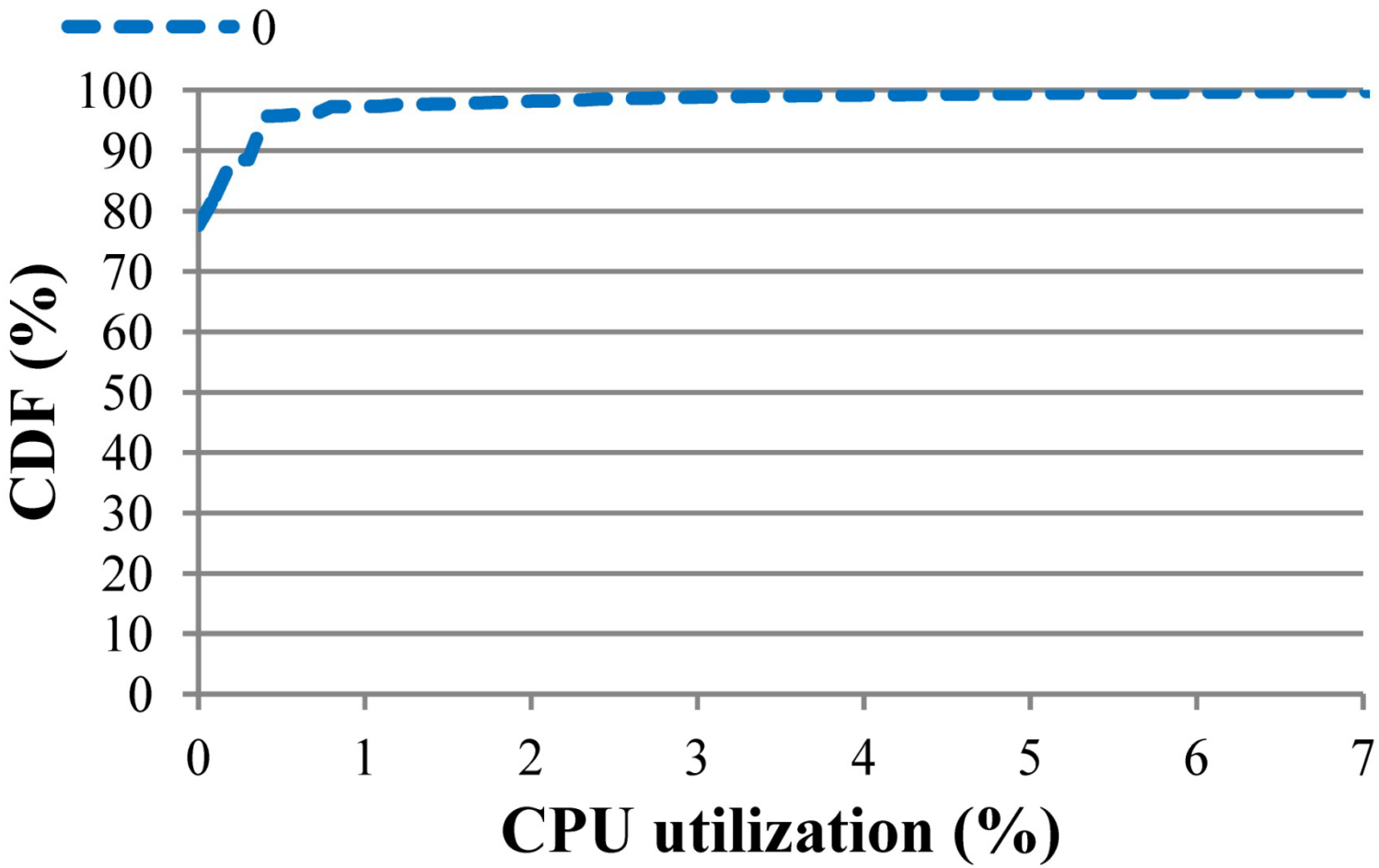


- Convolving: GreenUp wakes machines before user gives up 85% of the time

GreenUp scales to large subnets

- Sources of manager load
  - Intercept traffic for asleep machines
  - Broadcast state
  - Probe/respond to probes

GreenUp scales to large subnets



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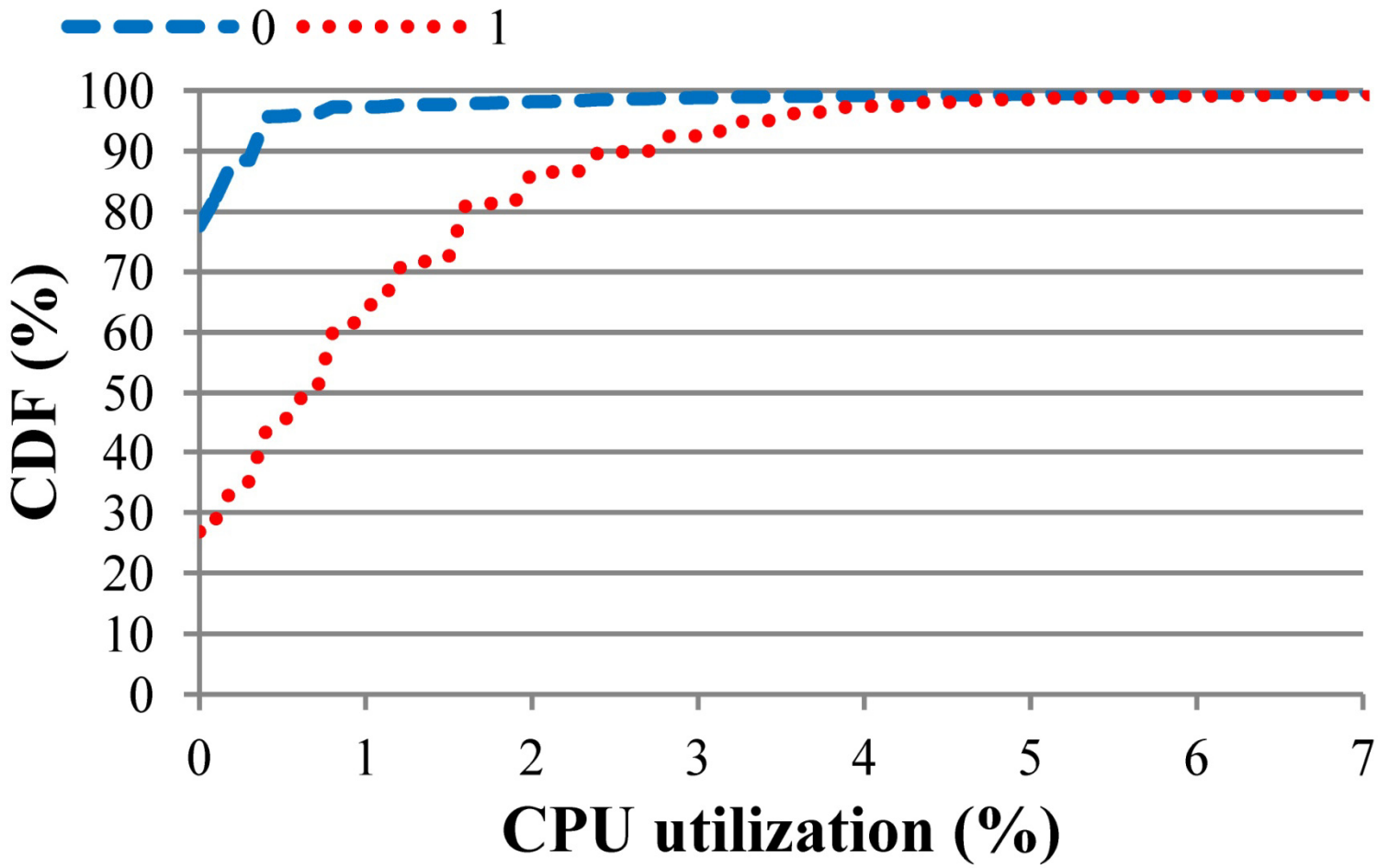

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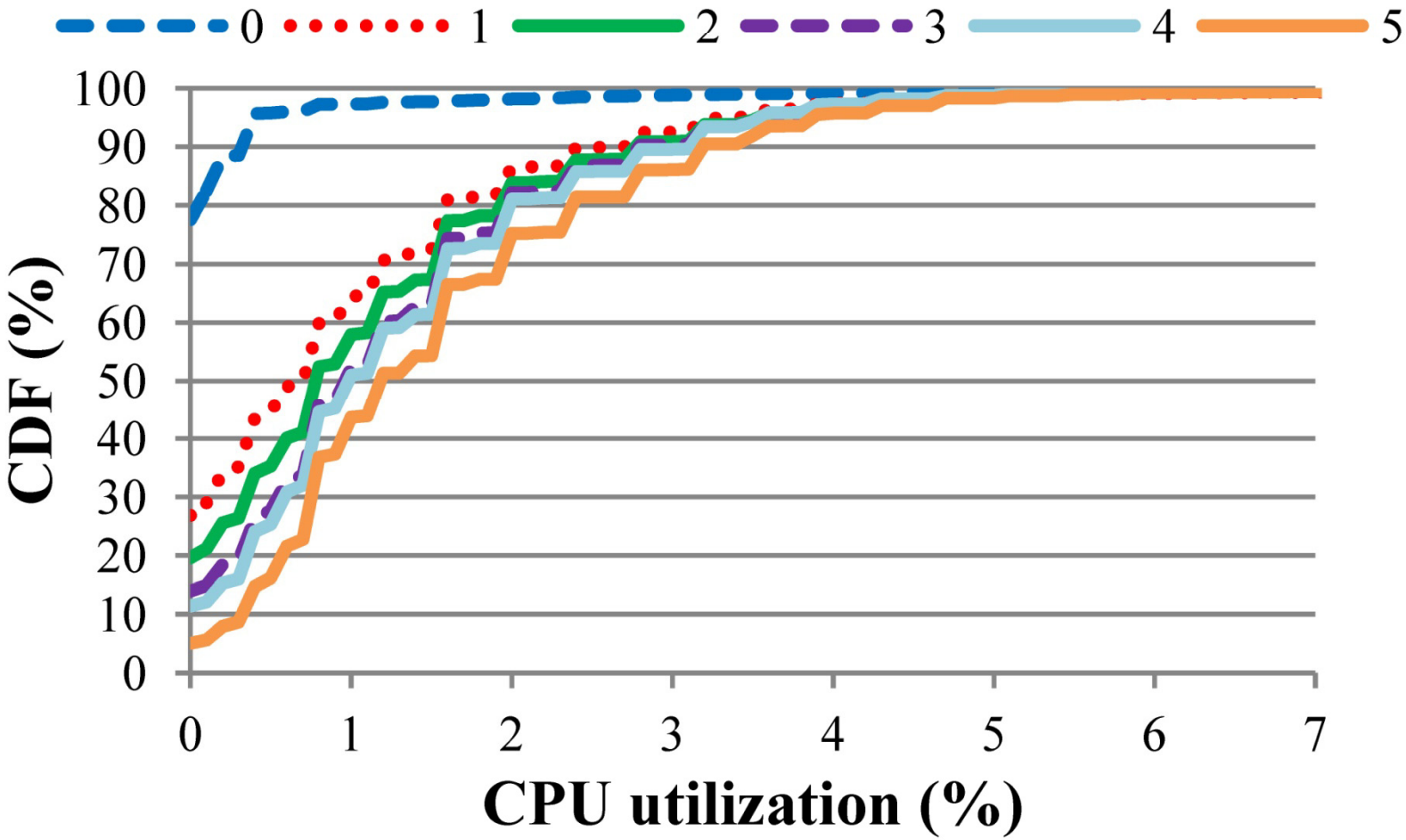

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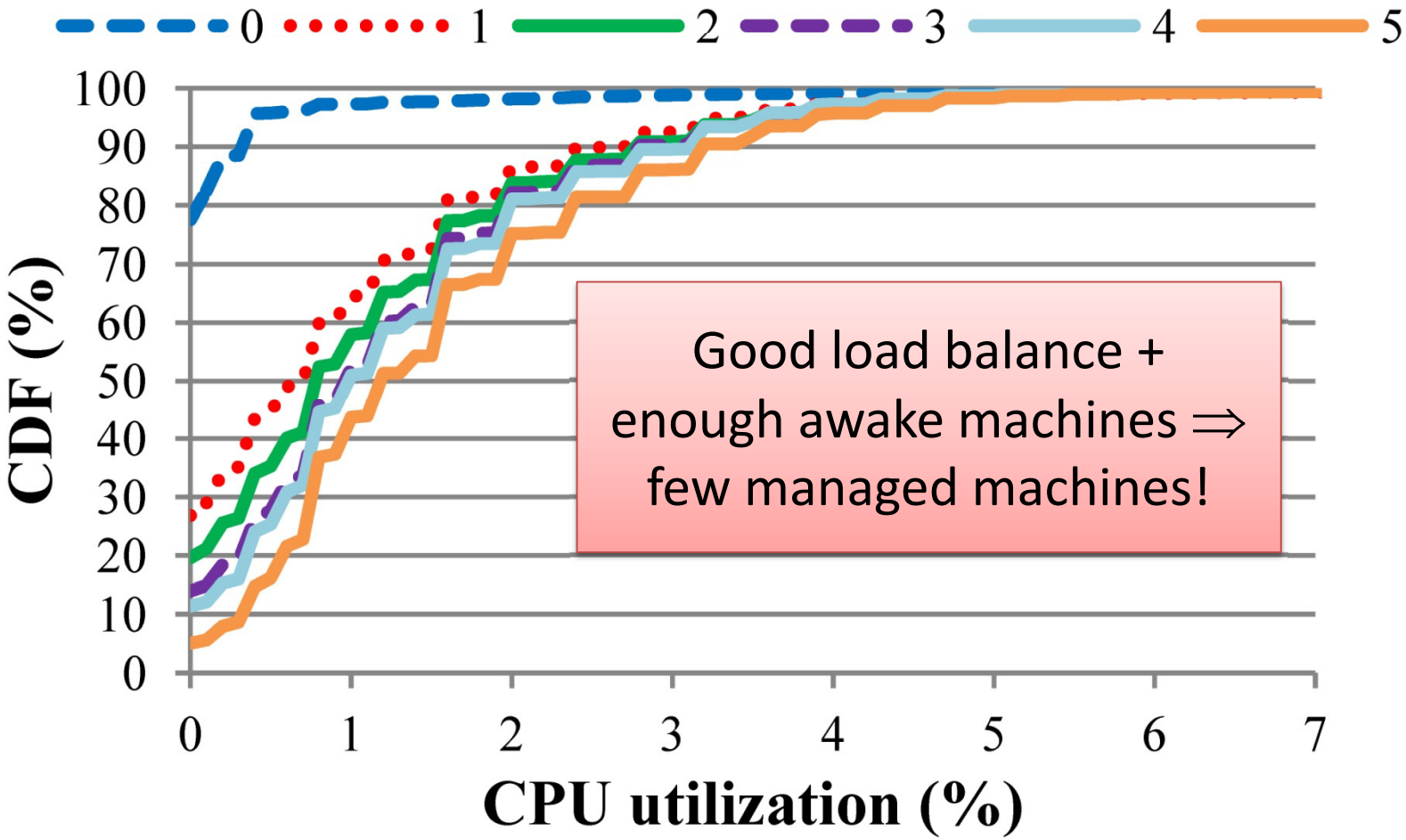

GreenUp scales to large subnets

- Simulated probing load on 2.4-GHz, dual-core Windows 7 machine w/ 4GB memory and 1Gb/s NIC:

# of managed machines	CPU utilization
100	12%
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- Guardians ensure max load is 100

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- Energy savings depends on sleep time

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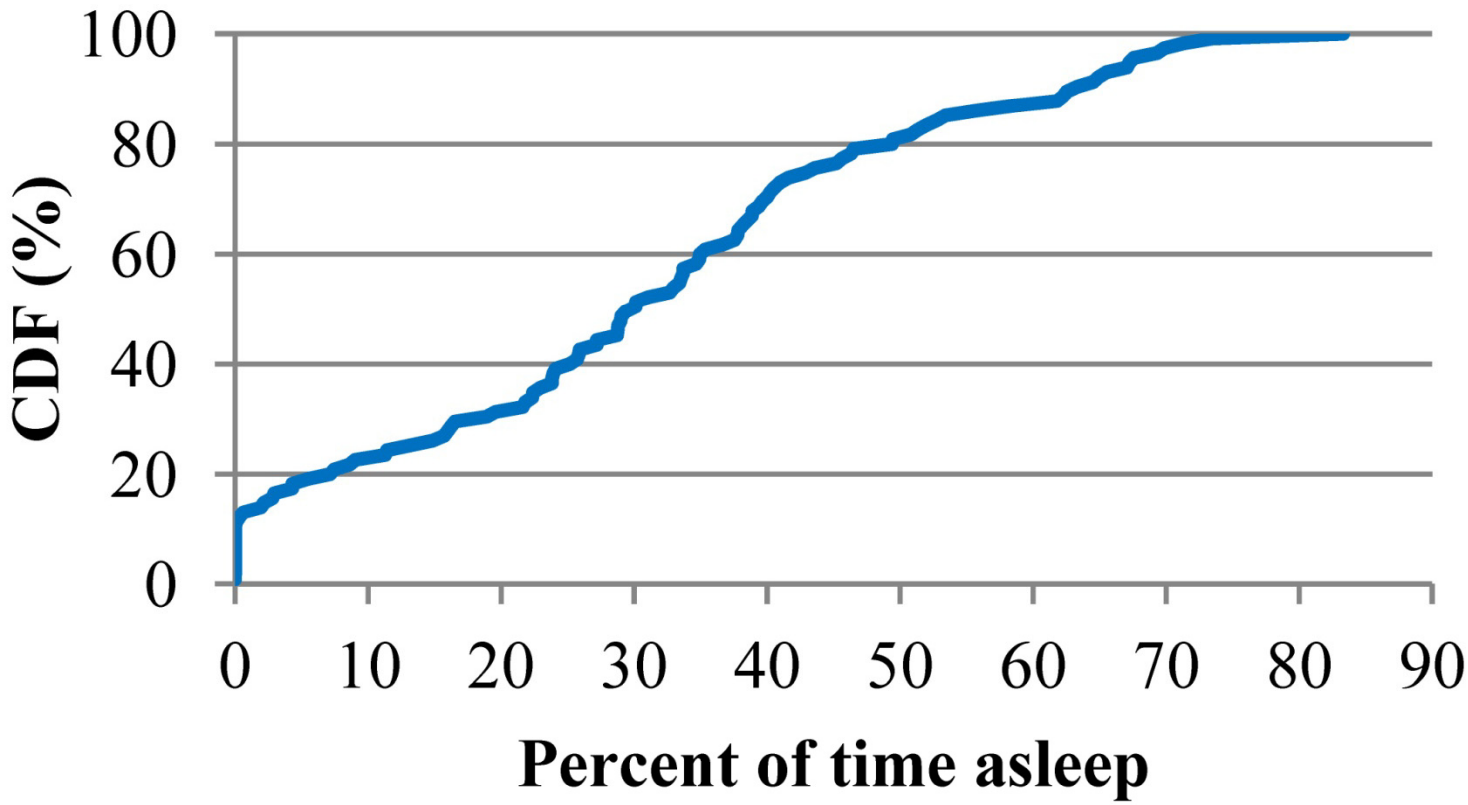

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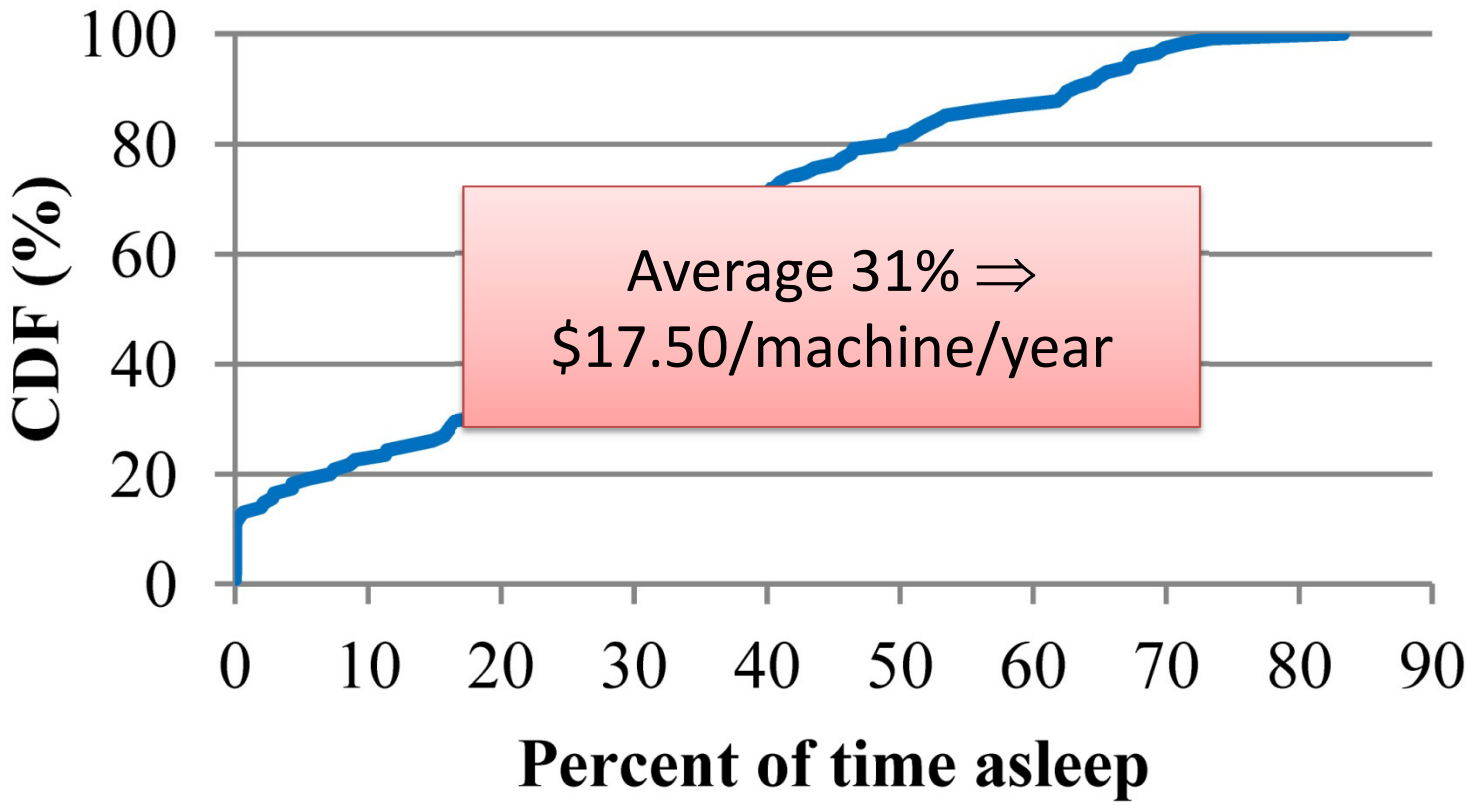
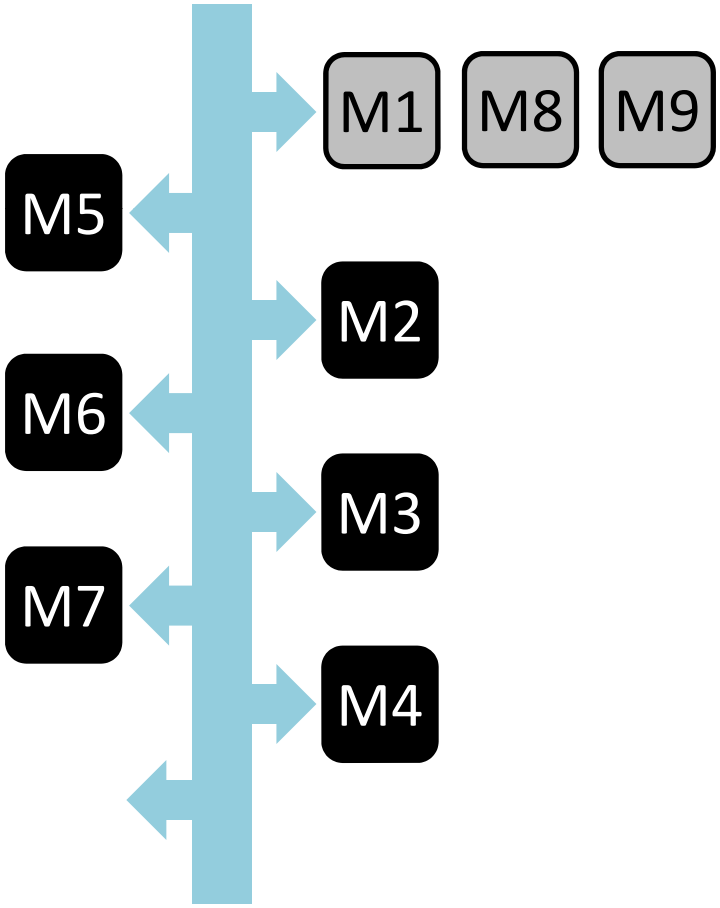


Does GreenUp save more energy?

- Energy savings depends on sleep time
- IT enforces sleep policy at Microsoft, so hard to tell

Extension: Higher availability via explicit load hand-off



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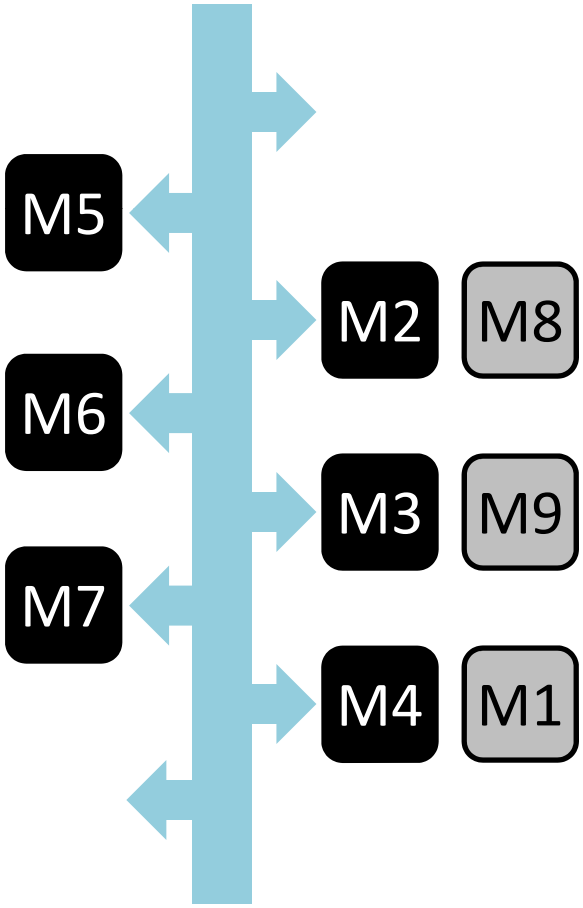

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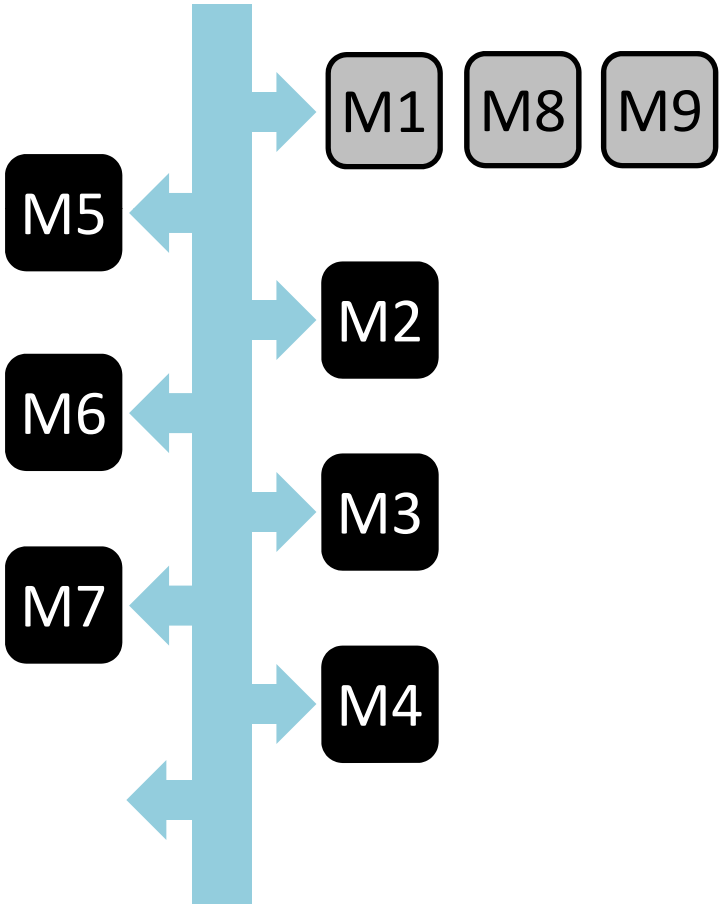

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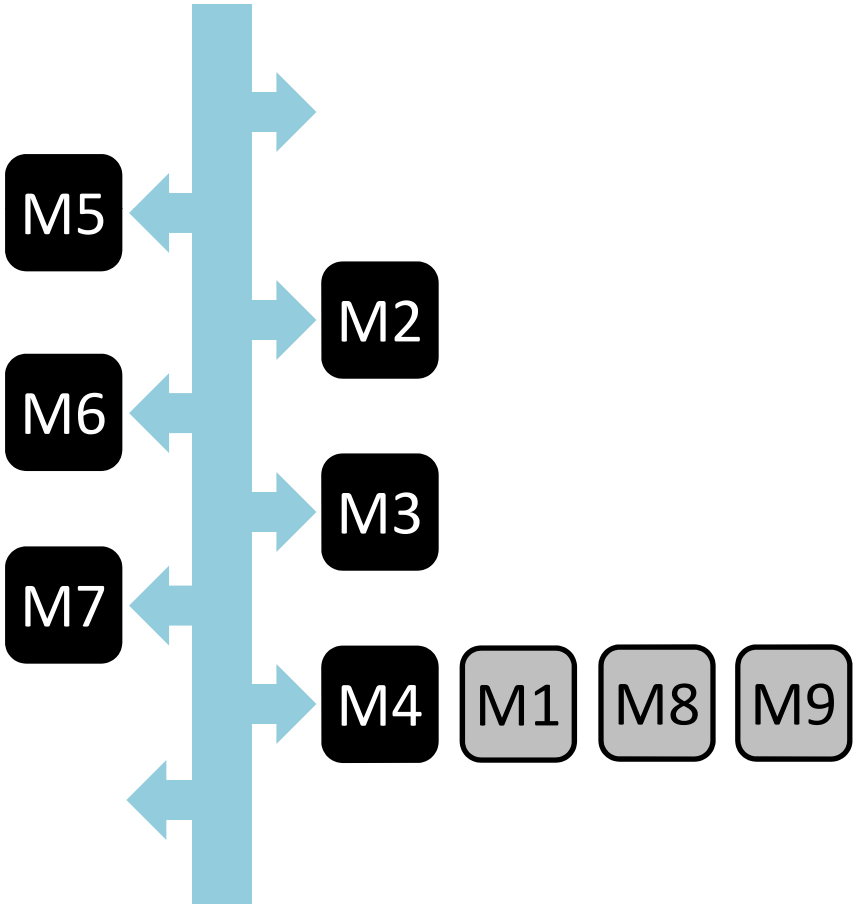

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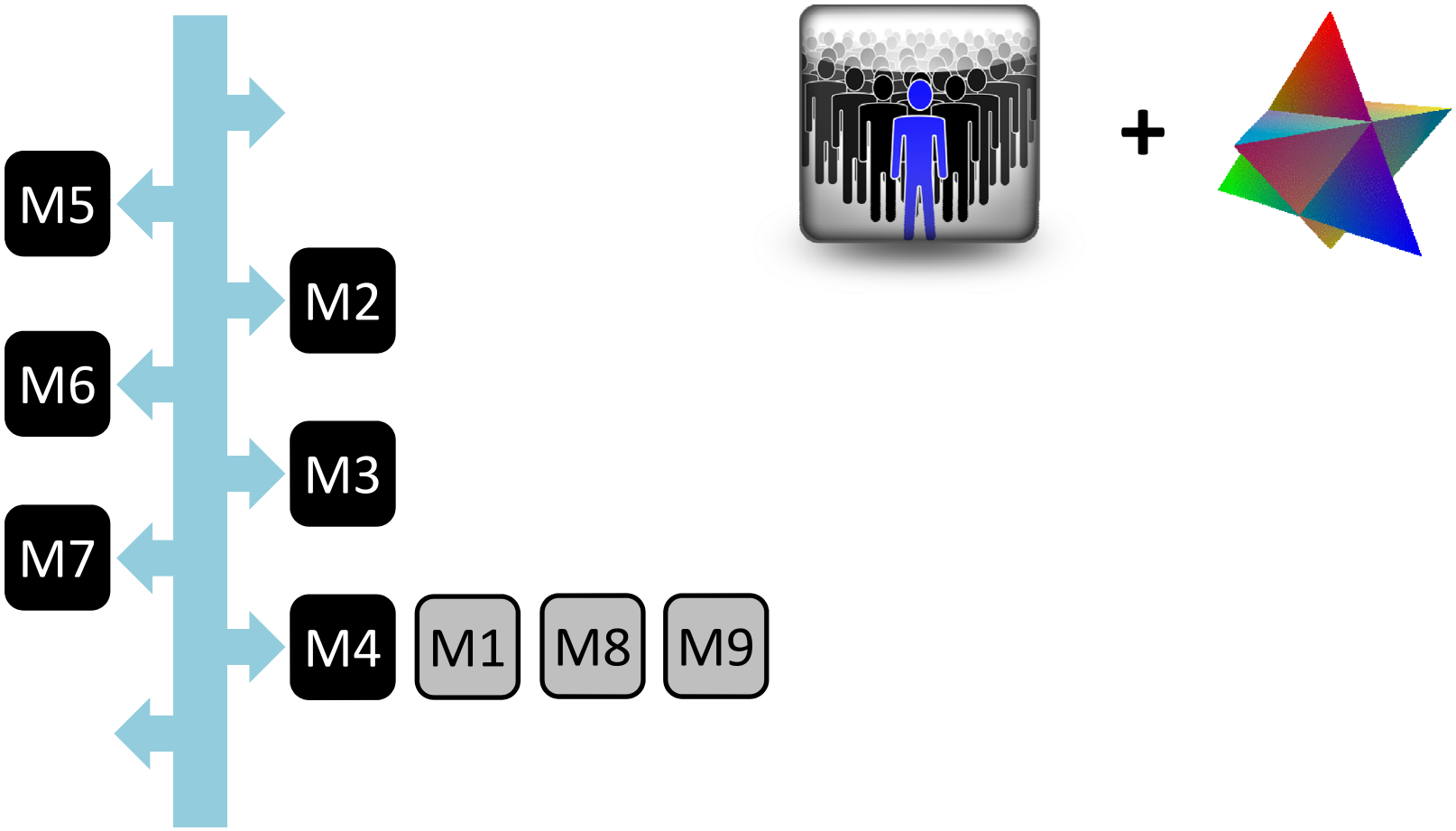

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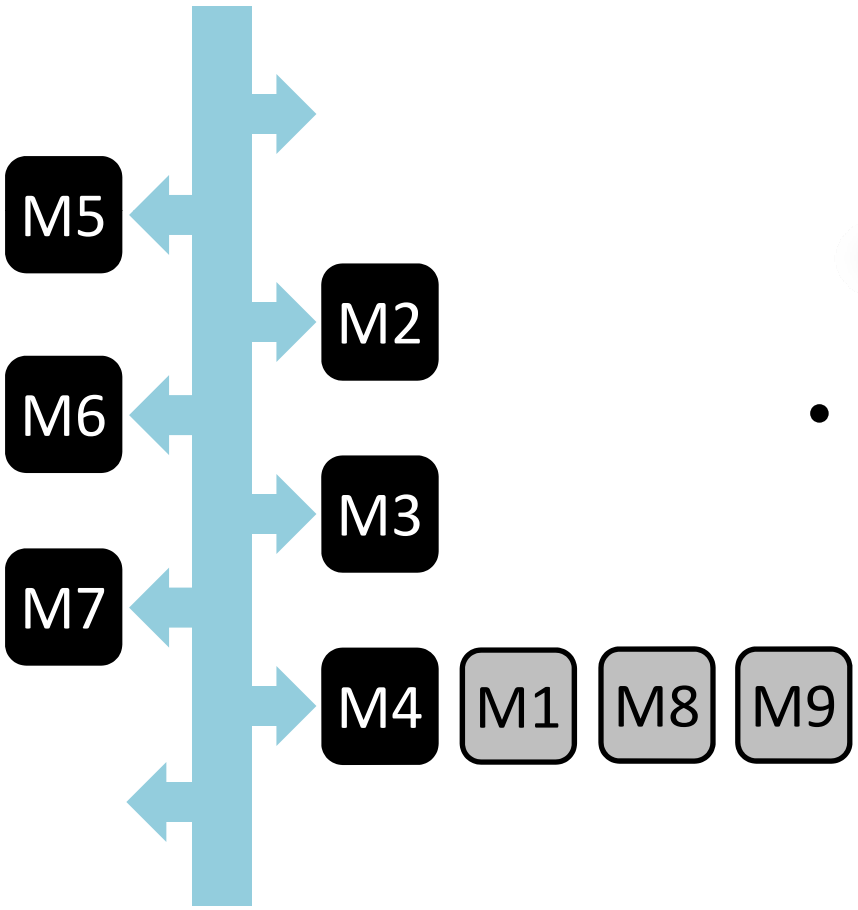

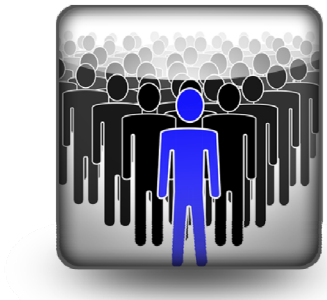

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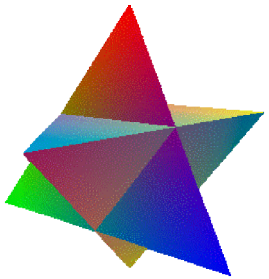

- **Theorem**. Expected max load = $n/d \times H_d$.

awake machines

Harmonic numbers

Other solutions

- Sleep proxy idea: Christensen & Gulledge ’98
- Recently:

System	Technique
Somniloquy, NSDI ’09	augmented NICs
LiteGreen, ATC ’10 Jettison, EuroSys ’12	VM migration
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Barriers to deployment

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GreenUp

- Completely decentralized, software-only sleep proxy
- Useful distributed systems techniques
- High availability at low cost, even as machines sleep!

http://research.microsoft.com/en-us/projects/greenup/