Understanding and Evaluating Kubernetes

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Agenda

- Overview of project
- Kubernetes background and overview
- Experiments
- Summary and Conclusion

1.

Overview of Project

- Goals
- Our approach
- Observations

Goals

- Kubernetes
  - Platform to manage containers in a cluster
- Understand its core functionality
  - Mechanisms and policies
- Major questions
  - Scheduling policy
  - Admission control
  - Autoscaling policy
  - Effect of failures

Our Approach

- Monitor state changes
  - Force system into initial state
  - Introduce stimuli
  - Observe the change towards the final state

- Requirements
  - Small Kubernetes cluster with resource monitoring
  - Simple workloads to drive the changes

Observations

- Kubernetes tries to be simple and minimal
- Scheduling and admission control
  - Based on resource requirements
  - Spreading across nodes
- Response to failures
  - Timeout and restart
  - Can push to undesirable states
- Autoscaling as expected
  - Control loop with damping

2.

Kubernetes Background

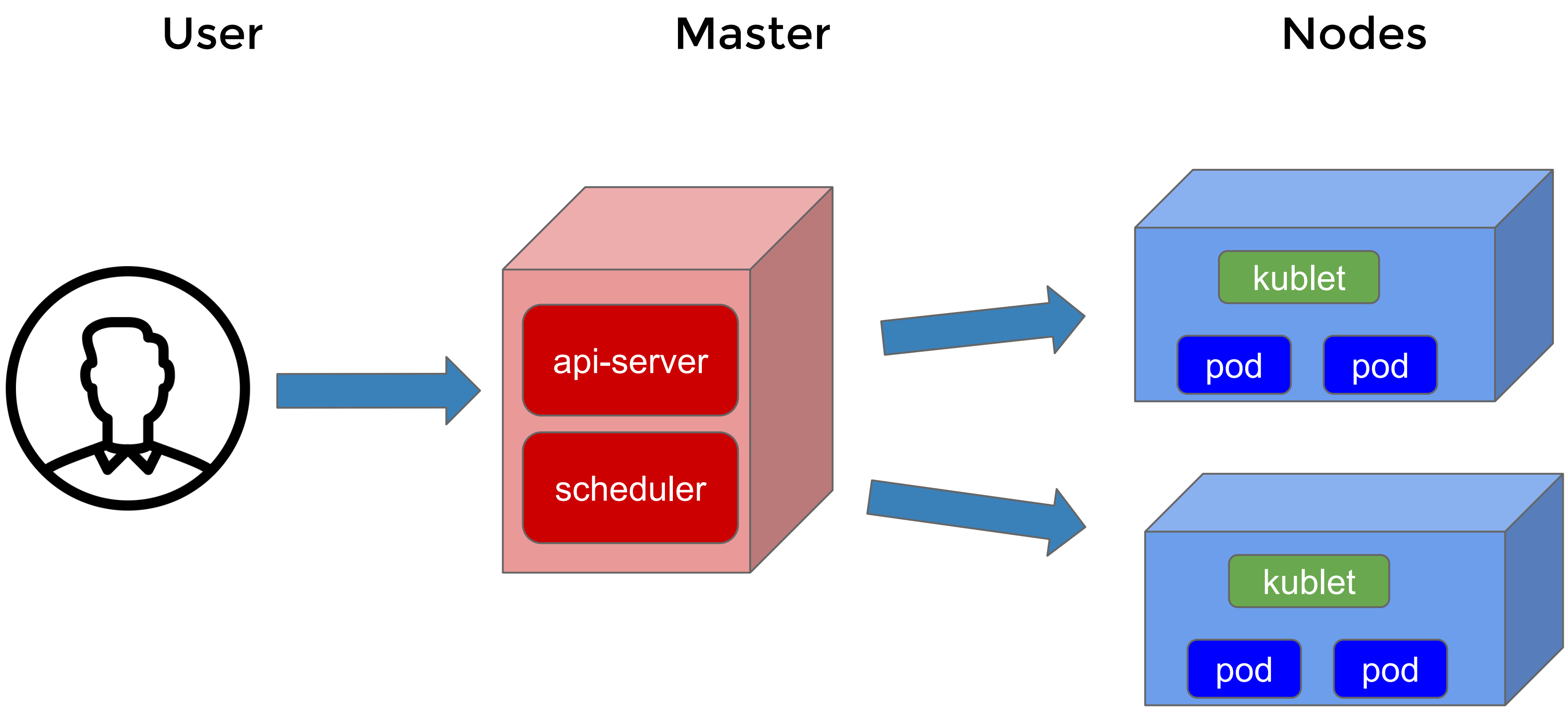
- Motivation
- Architecture
- Components

Need for Container Management

- Workloads have shifted from using VMs to containers
  - Better resource utilization
  - Faster deployment
  - Simplifies config and portability

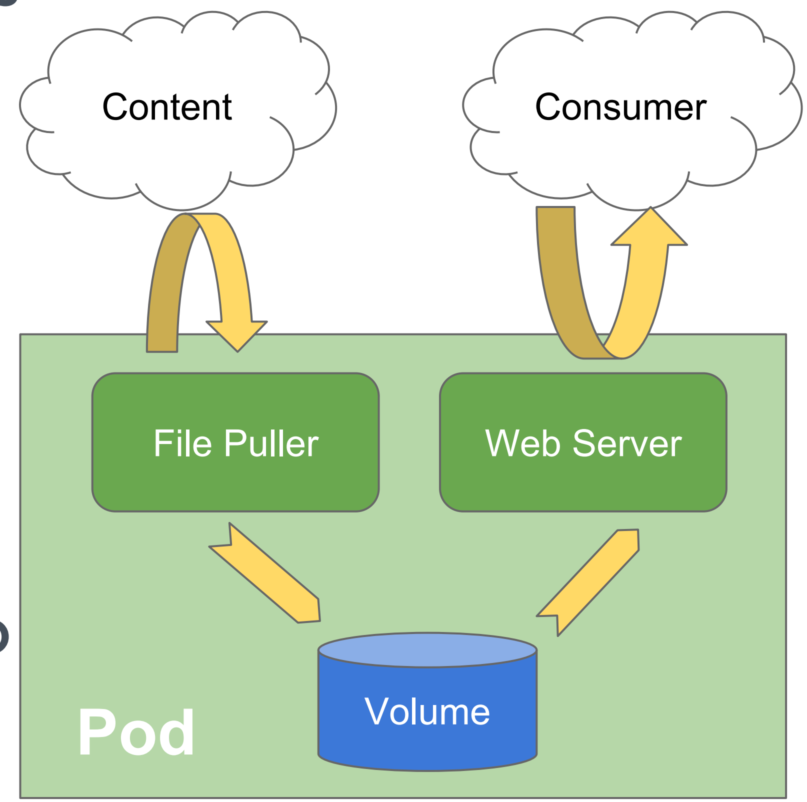
- More than just scheduling
  - Load balancing
  - Replication for services
  - Application health checking
  - Ease of use for
    - Scaling
    - Rolling updates

High Level Design



Pods

- Small group of containers
- Shared namespace
  - Share IP and localhost
  - Volume: shared directory
- Scheduling unit
- Resource quotas
  - Limit
  - Min request
- Once scheduled, pods do not move



General Concepts

- Replication Controller
  - Maintain count of pod replicas
- Service
  - A set of running pods accessible by virtual IP
- Network model
  - IP for every pod, service and node
  - Makes all to all communication easy

3.

Experimental Setup

Experimental Setup

- Google Compute Engine cluster
  - 1 master, 6 nodes
- Limited by free trial
  - Could not perform experiments on scalability

Google Compute Engine

Simplified Workloads

- Simple scripts running in containers
- Consume specified amount of CPU and Memory
- Set the request and usage

Yellow	Low request - Low usage
Green	Low request - High usage
Pink	High request - Low usage
Red	High request - High usage

5.

Experiments

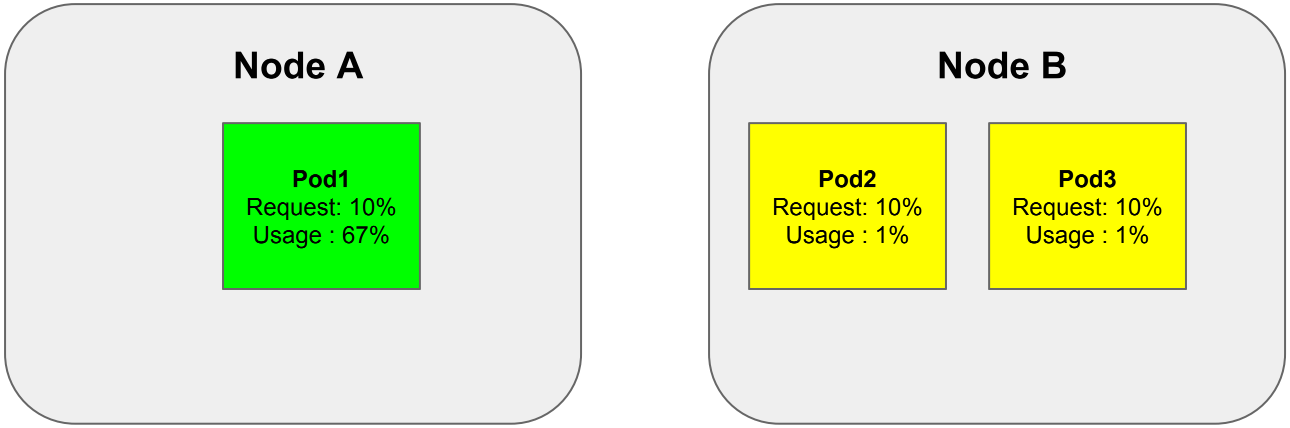
Scheduling Behavior

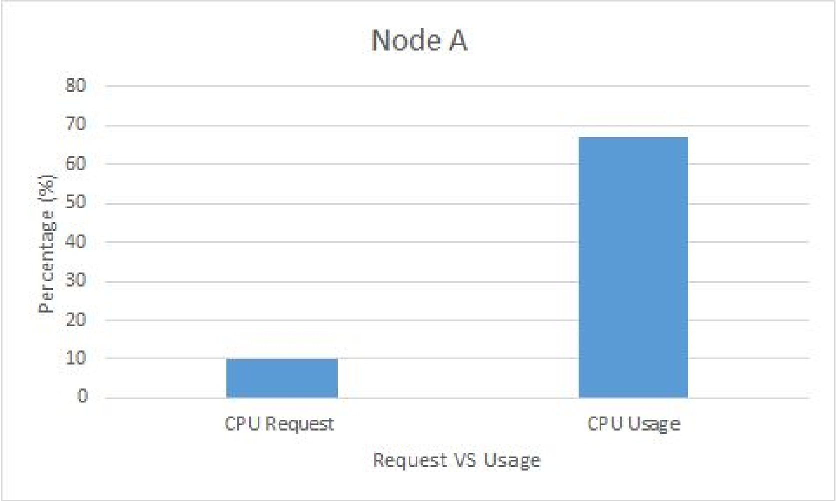
- Scheduling based on min-request or actual usage?

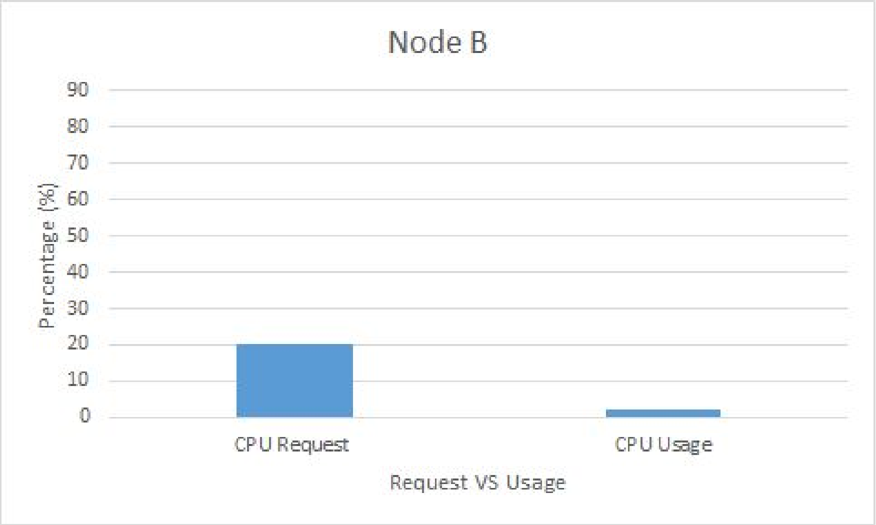
Scheduling based on min-request or actual usage?

- Initial experiments showed that scheduler tries to spread the load,
  - Based on actual usage or min request?
- Set up two nodes with no background containers
  - Node A has a high cpu usage but a low request
  - Node B has low cpu usage but higher request
- See where a new pod gets scheduled

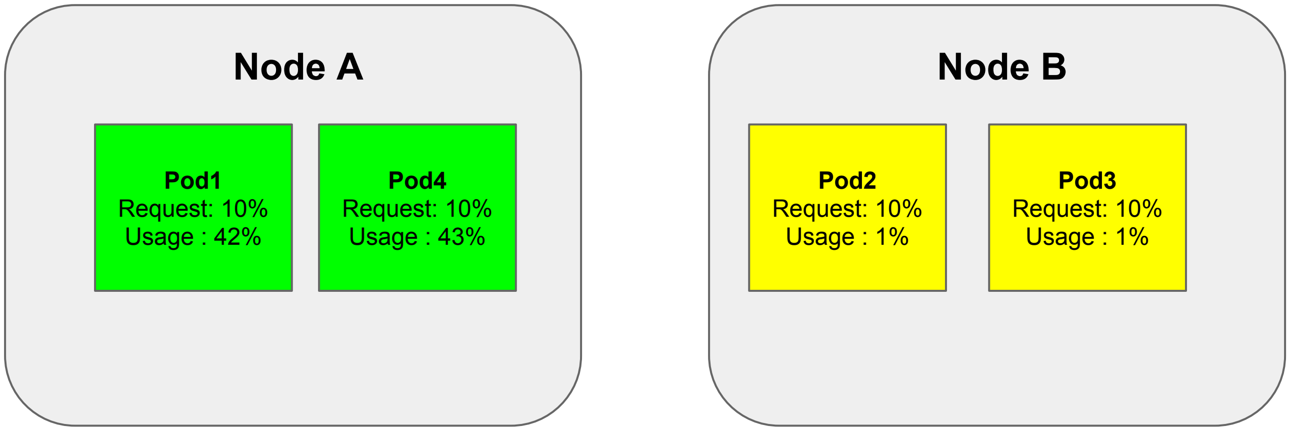
Scheduling based on Min-Request or Actual Usage CPU? - Before

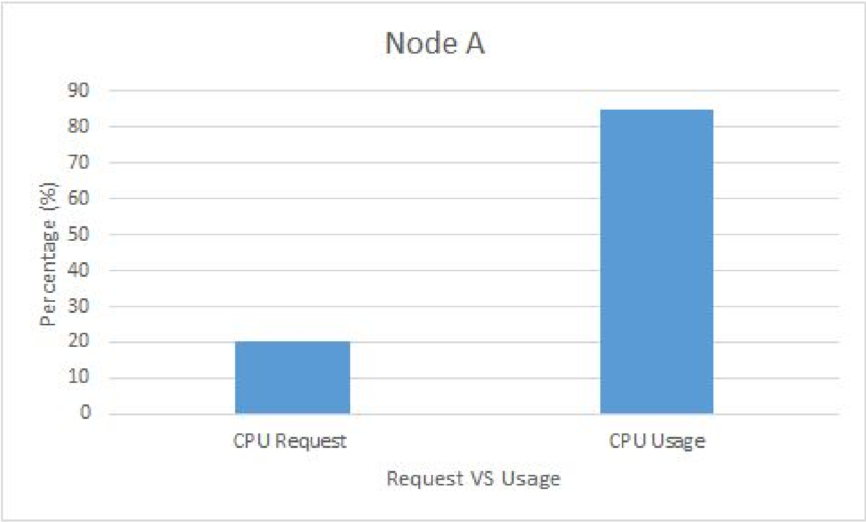


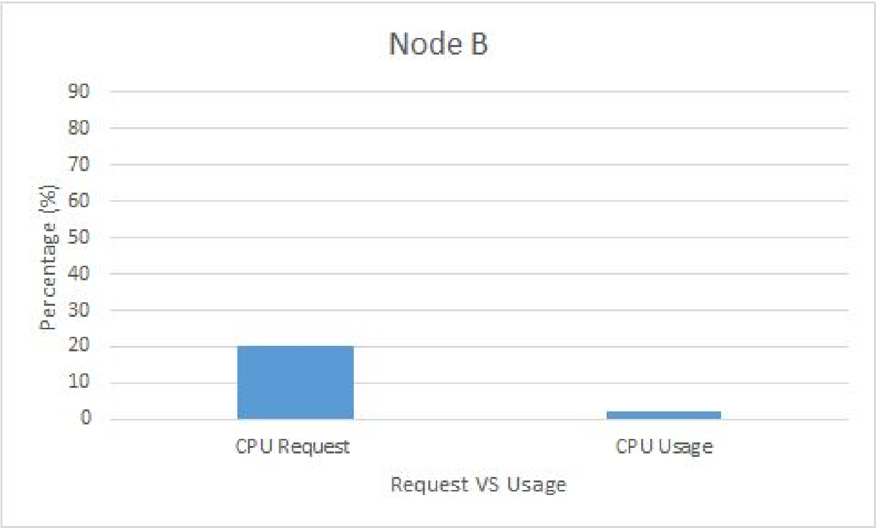




Scheduling based on Min-Request or Actual Usage CPU? - Before







Scheduling based on Min-Request or Actual Usage Memory?

- We saw the same results when running pods with changing memory usage and request

- Scheduling is based on min-request

5.

Experiments

Scheduling Behavior

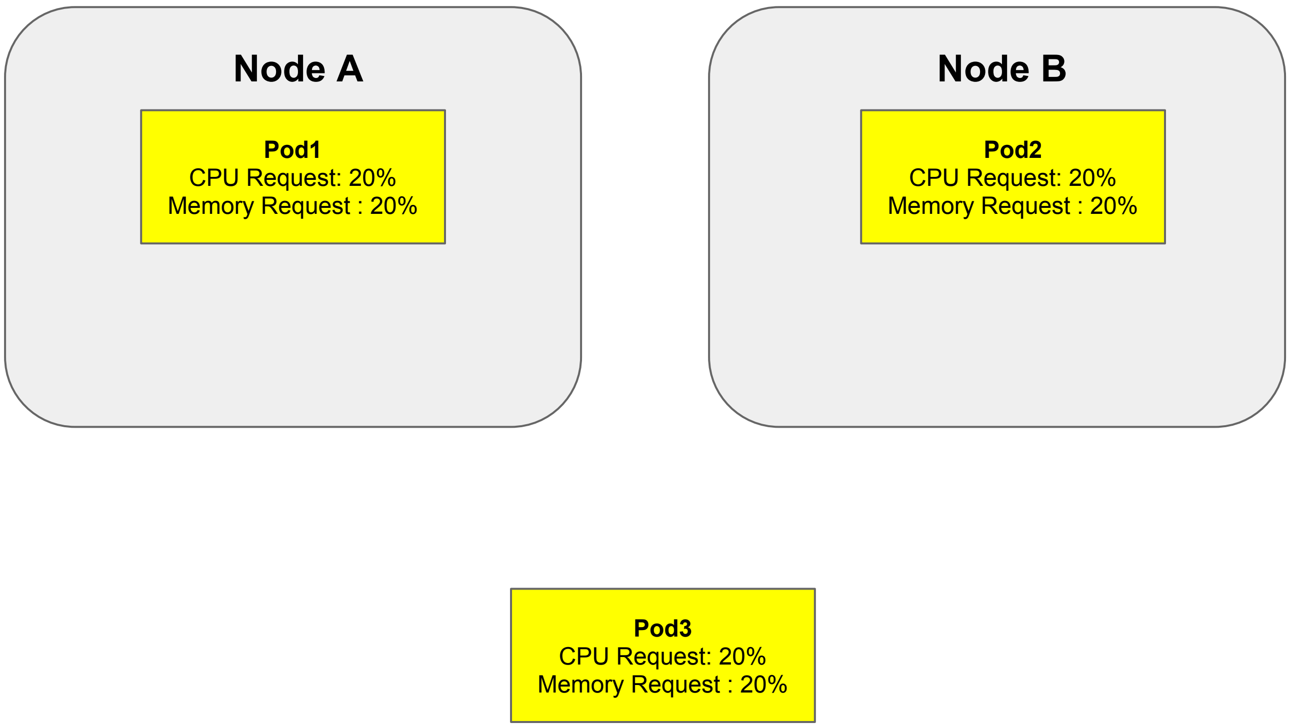
- Are Memory and CPU given equal weightage for making scheduling decisions?

Are Memory and CPU given Equal Weightage?

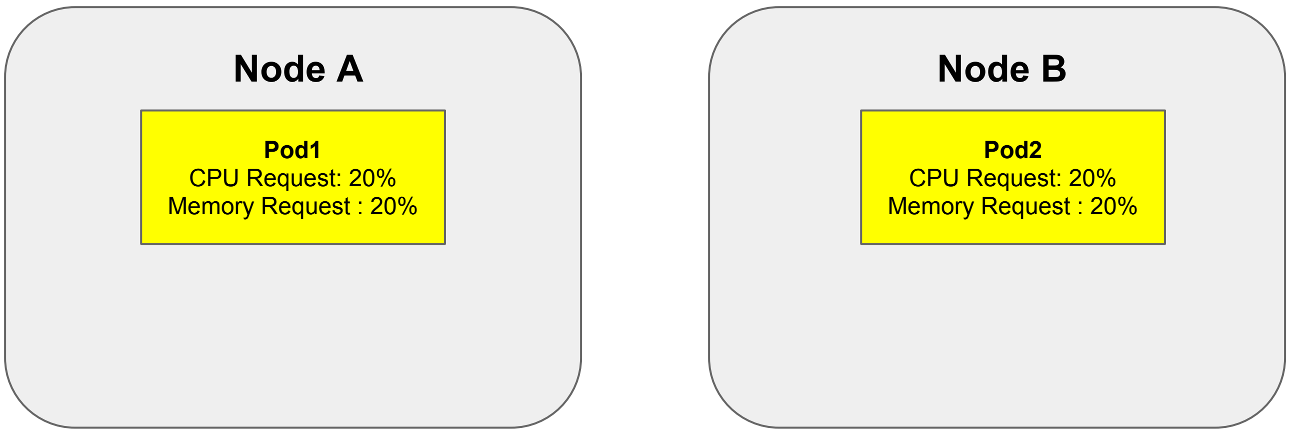
- First Experiment (15 trials):
  - Both nodes have 20% CPU request and 20% Memory request
  - Average request 20%

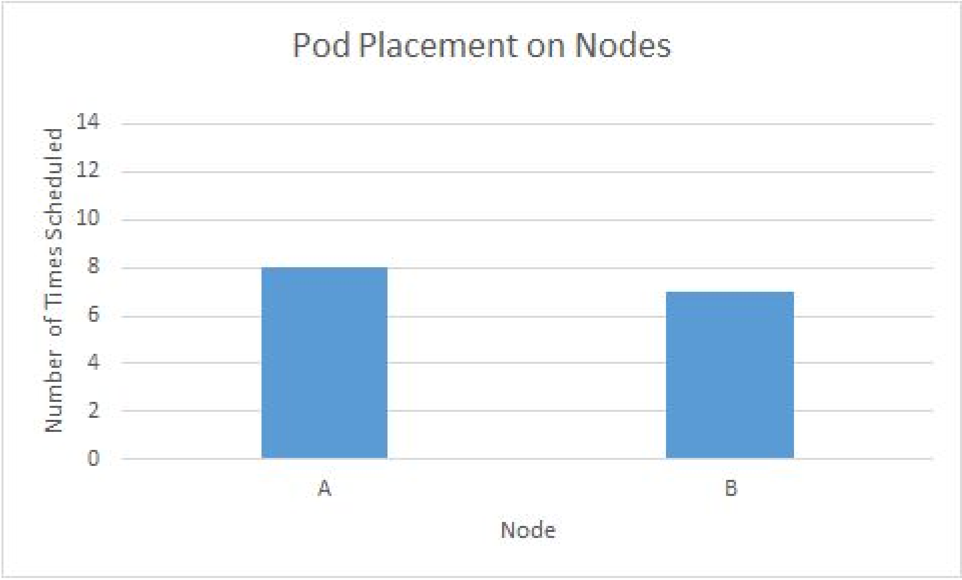
- New pod equally likely to get scheduled on both nodes.

New Pod with 20% CPU and 20% Memory Request



New Pod with 20% CPU and 20% Memory Request

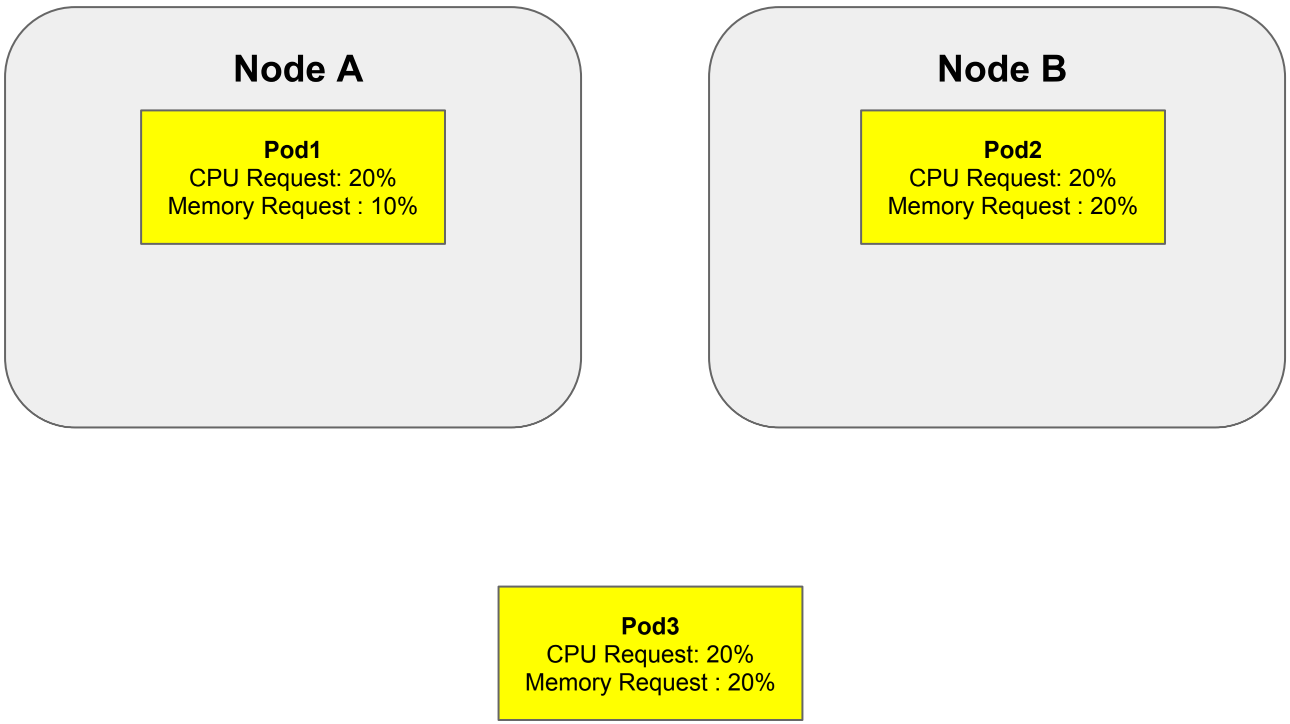




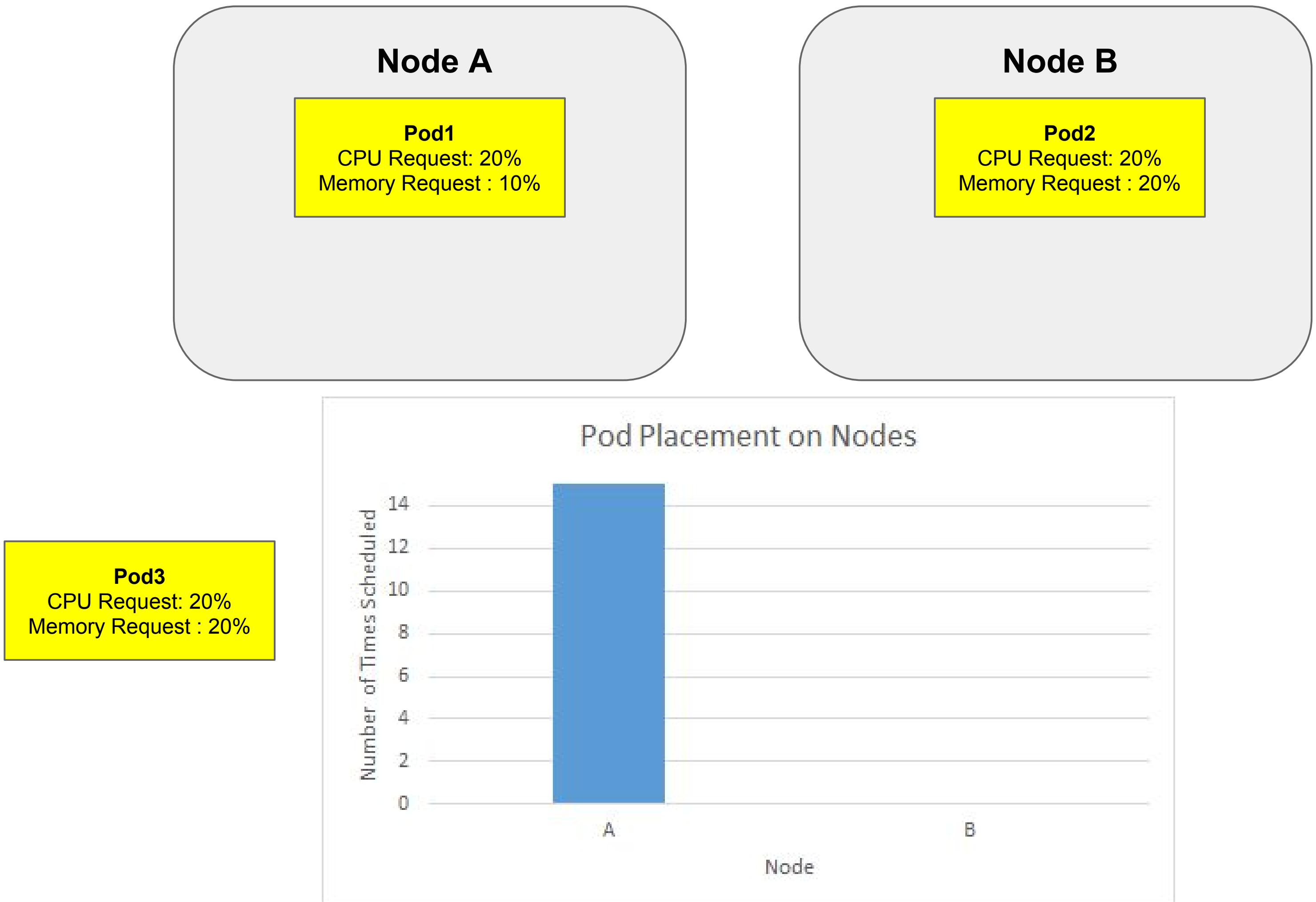
Are Memory and CPU given Equal Weightage?

- Second Experiment (15 trials):
  - Node A has 20% CPU request and **10% Memory** request
    - Average request 15%
  - Node B has 20% CPU request and 20% Memory request
    - Average request 20%
- New pod should always be scheduled on Node A

New Pod with 20% CPU and 20% Memory Request



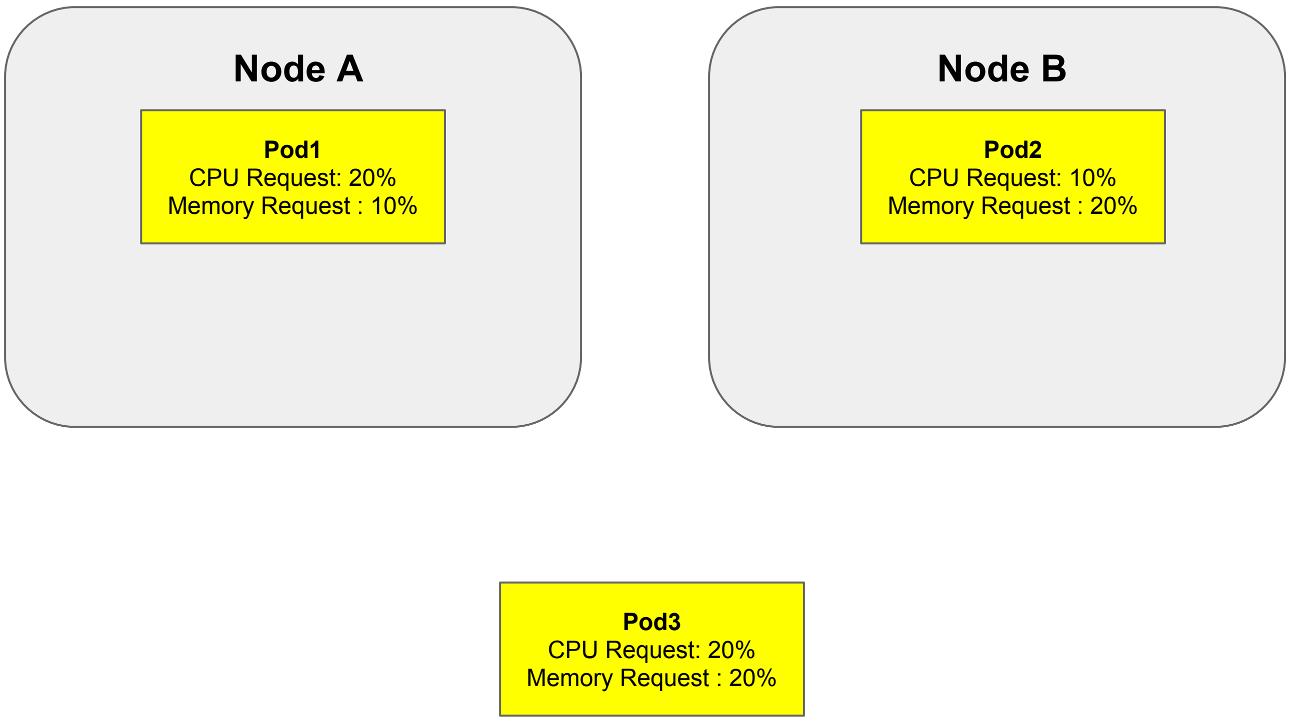
New Pod with 20% CPU and 20% Memory Request



Are Memory and CPU given Equal Weightage?

- Third Experiment (15 trials):
  - Node A has 20% CPU request and 10% Memory request.
    - Average 15%
  - Node B has 10% CPU request and 20% Memory request
    - Average 15%
- Equally likely to get scheduled on both again

New pod with 20% CPU and 20% Memory Request



New pod with 20% CPU and 20% Memory Request

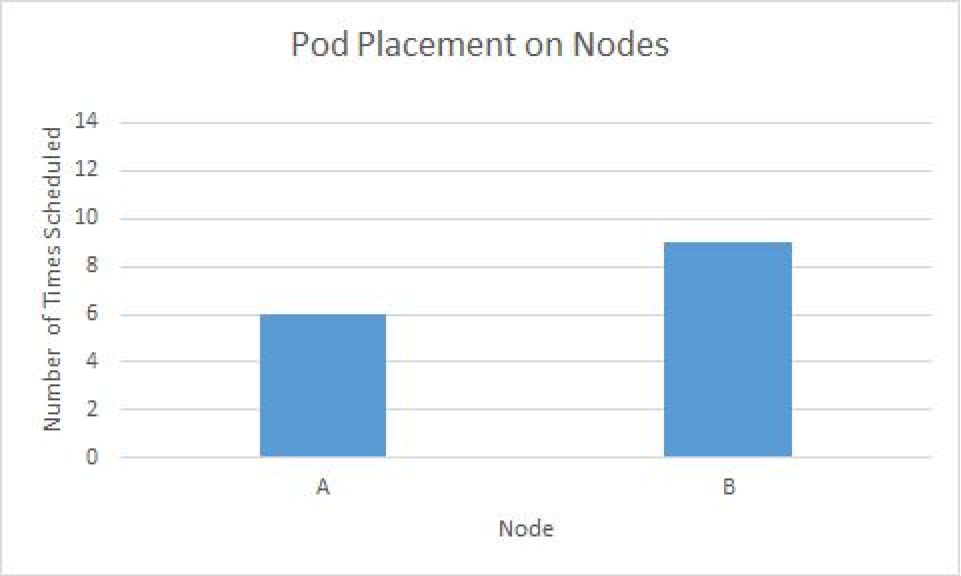
Node A

Pod1
CPU Request: 20%
Memory Request : 10%

Node B

Pod2
CPU Request: 10%
Memory Request : 20%

Pod3
CPU Request: 20%
Memory Request : 20%



Are Memory and CPU given Equal Weightage?

- From the experiments we can see that Memory and CPU requests are given equal weightage in scheduling decisions

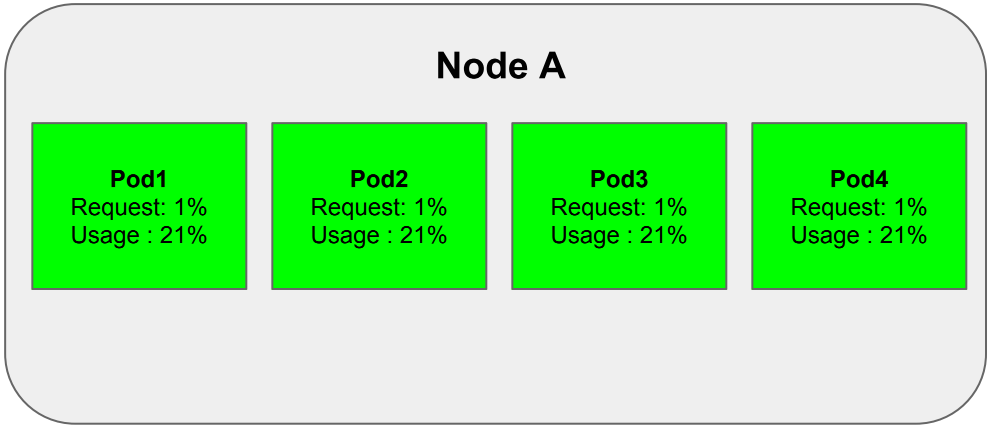
5.

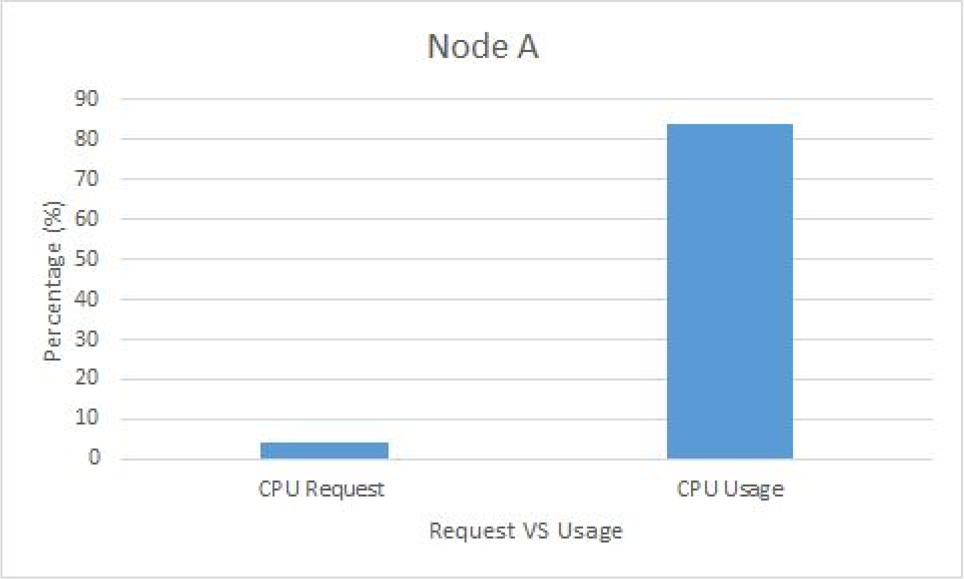
Experiments

Admission Control

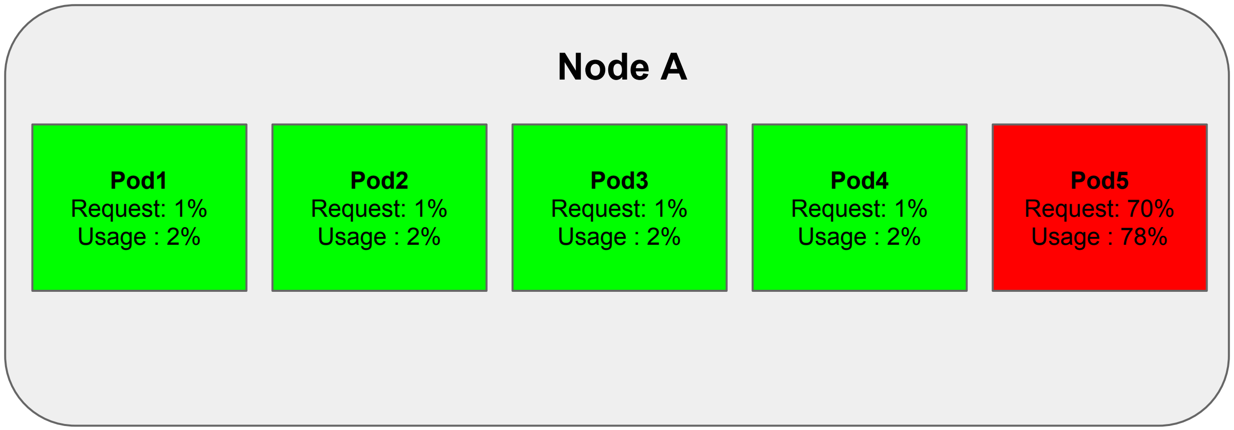
- Is Admission control based on resource usage or resource request?

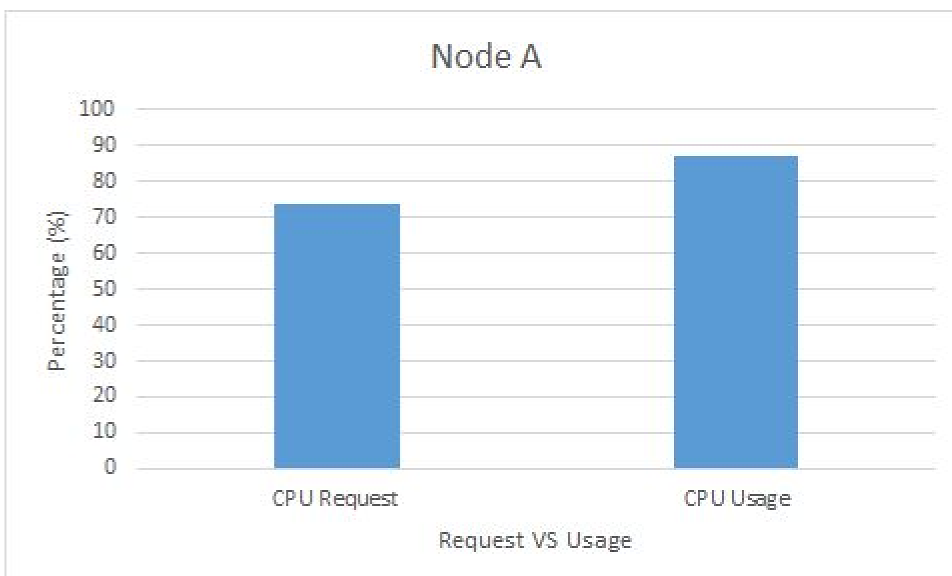
Is Admission Control based on Resource Usage or Request?



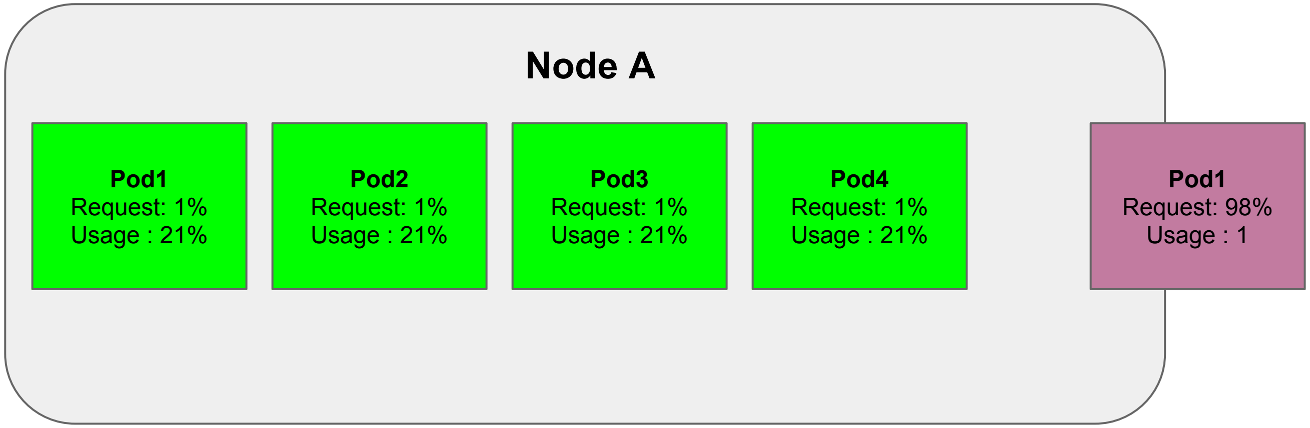


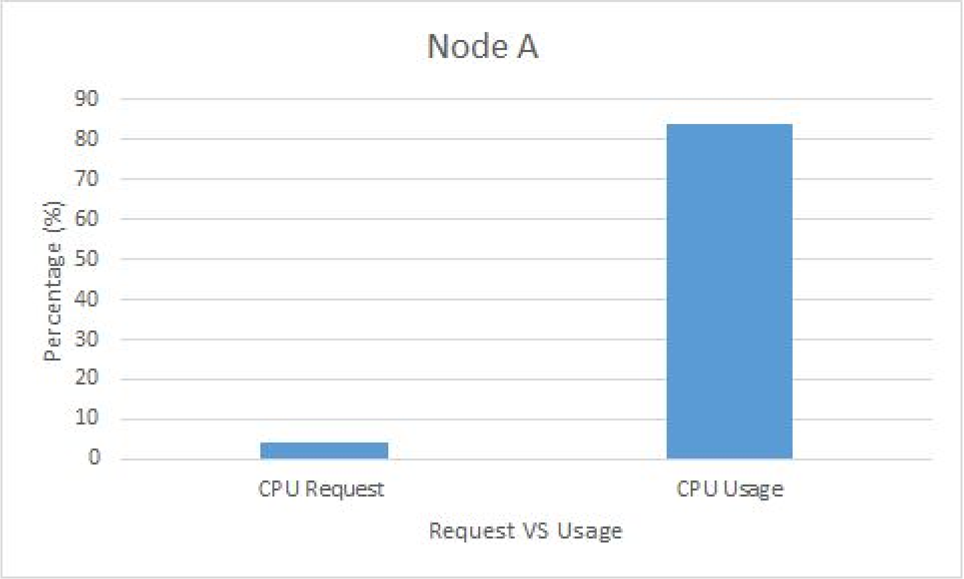
Is Admission Control based on Actual Usage? : 70% CPU request



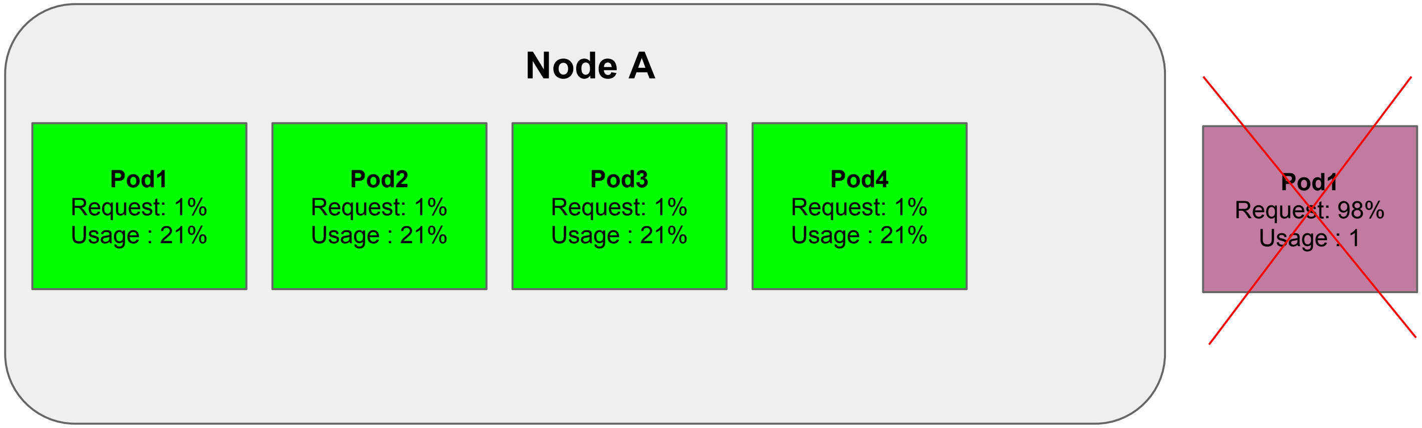


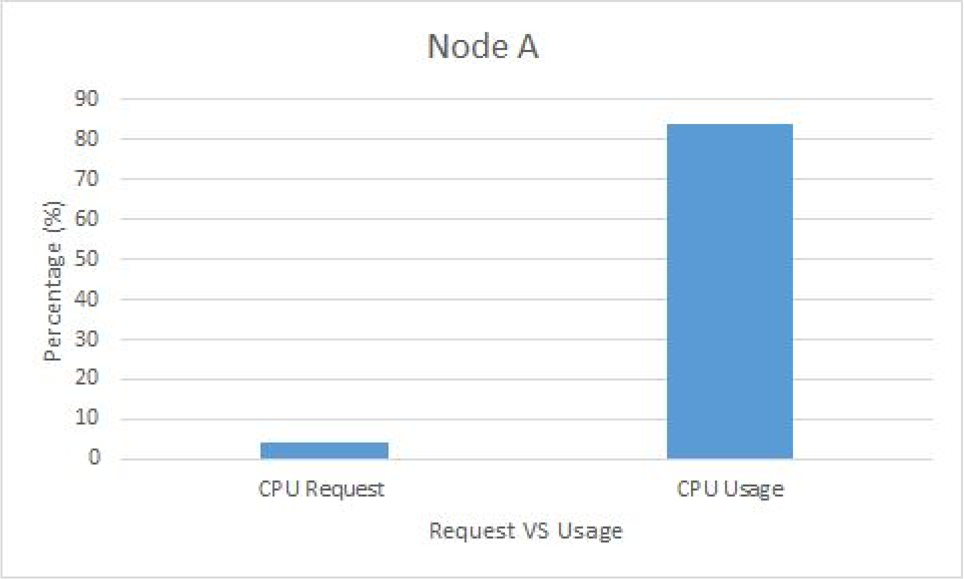
Is Admission Control based on Actual Usage?: 98% CPU request





Is Admission Control based on Actual Usage?: 98% CPU request





Is Admission Control based on Actual Usage?

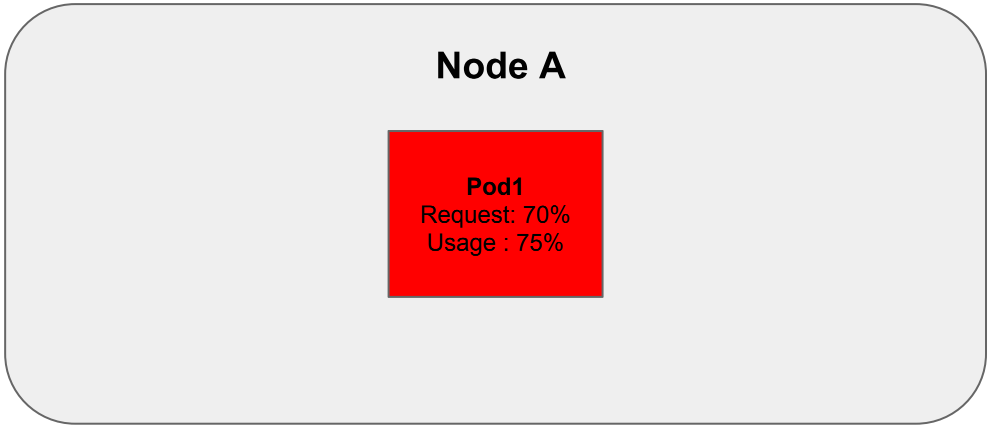
- From the previous 2 slides we can show that admission control is also based on min-request and not actual usage

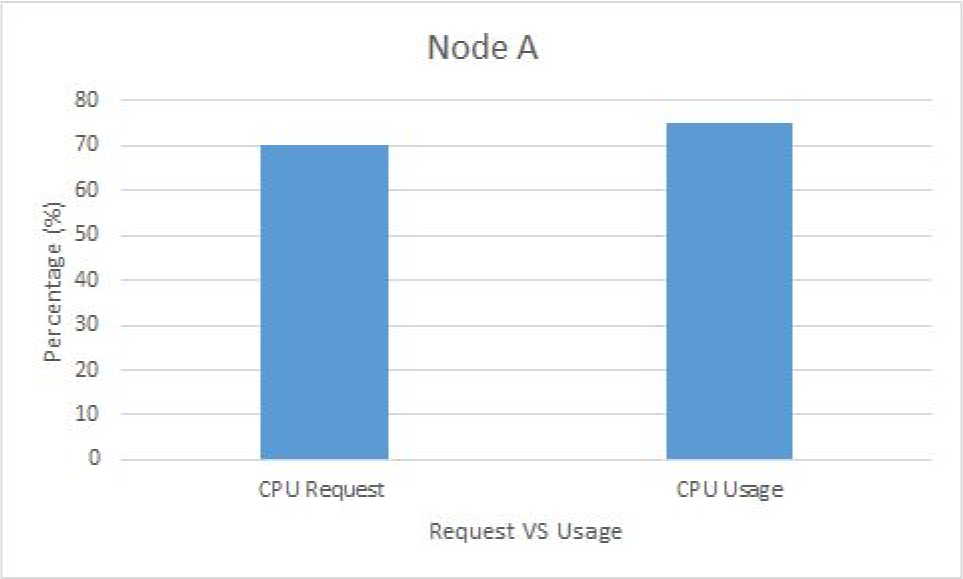
5.

Experiments

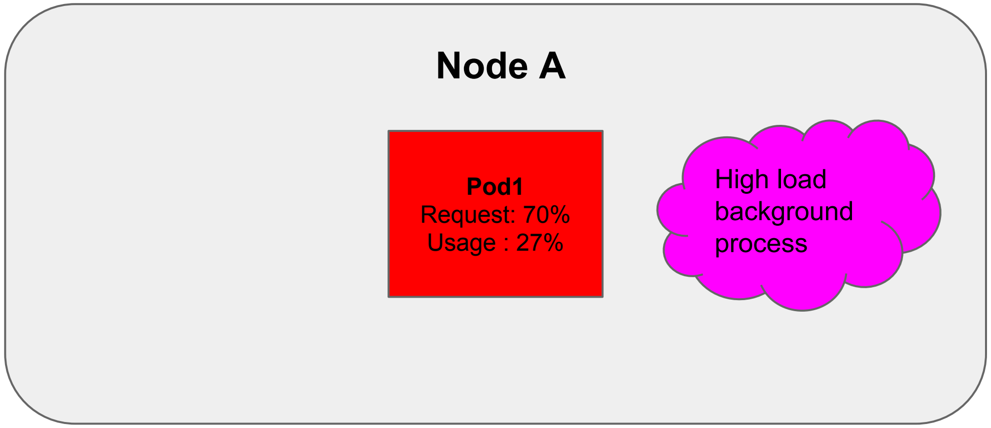
Does kubernetes always guarantee minimum request?

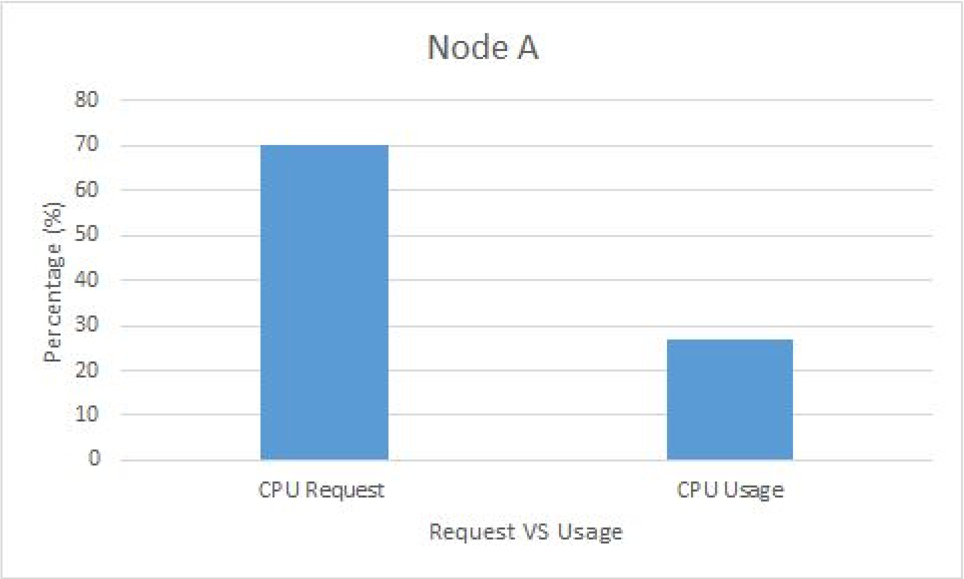
Before Background Load





After Background Load (100 Processes)





Does Kubernetes always guarantee Min Request?

- Background processes on the node are not part of any pods, so kubernetes has no control over them

- This can prevent pods from getting their min-request

5.

Experiments

Fault Tolerance and effect of failures

- Container and Node crash

Response to Failure

- Container crash
  - Detected via the docker daemon on the node
  - More sophisticated probes to detect slowdown deadlock
- Node crash
  - Detected via node controller, 40 second heartbeat
  - Pods of failed node, rescheduled after 5 min

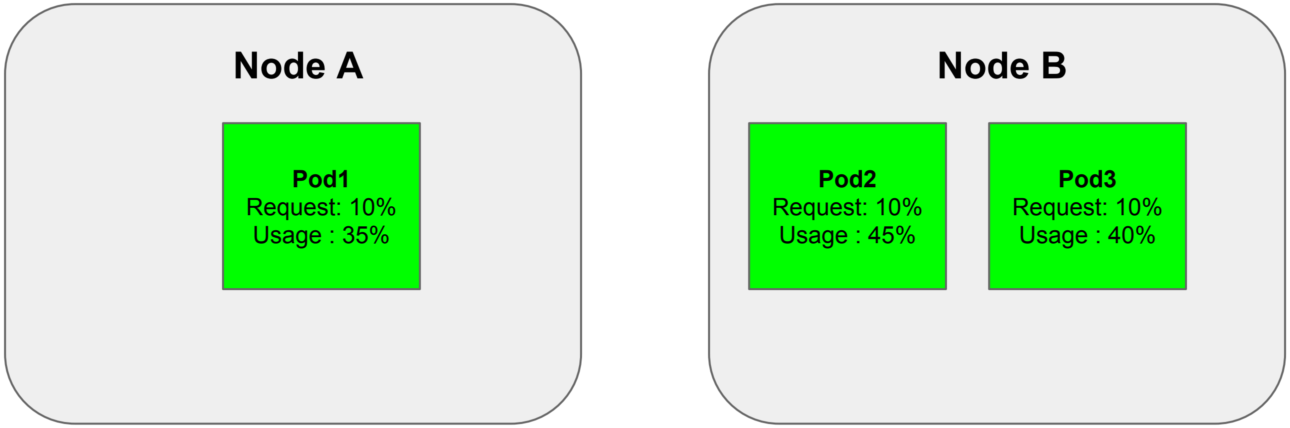
5.

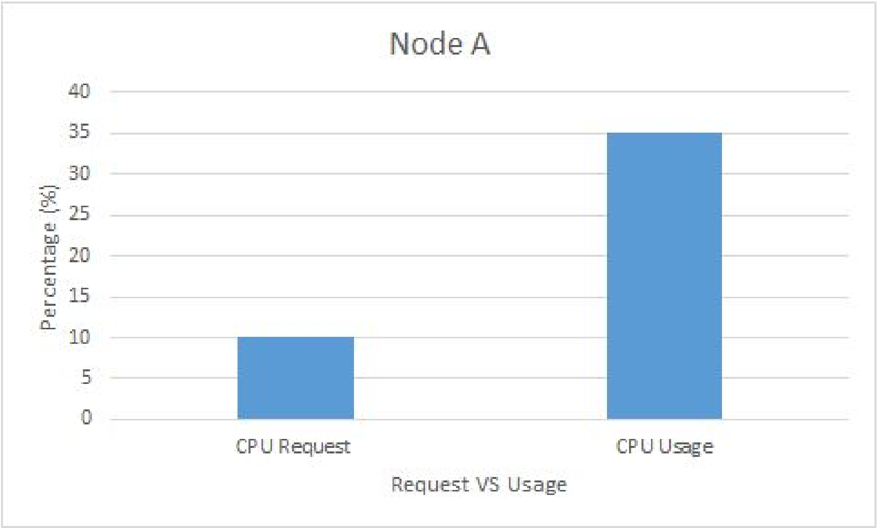
Experiments

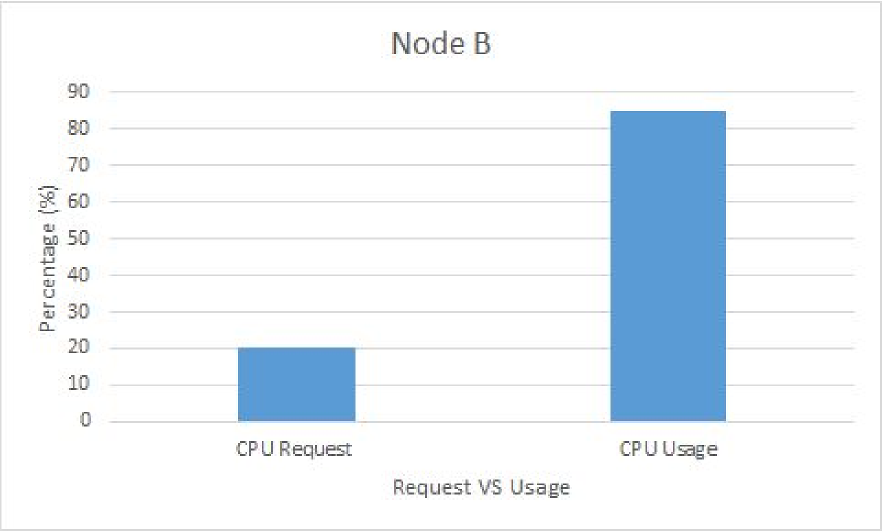
Fault Tolerance and effect of failures

- Interesting consequence of crash, reboot

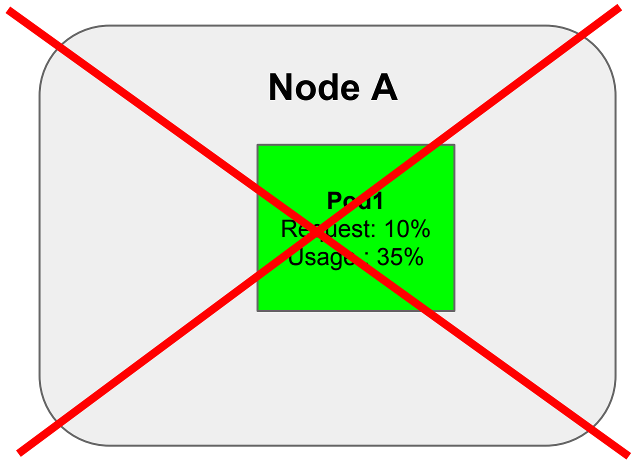
Pod Layout before Crash

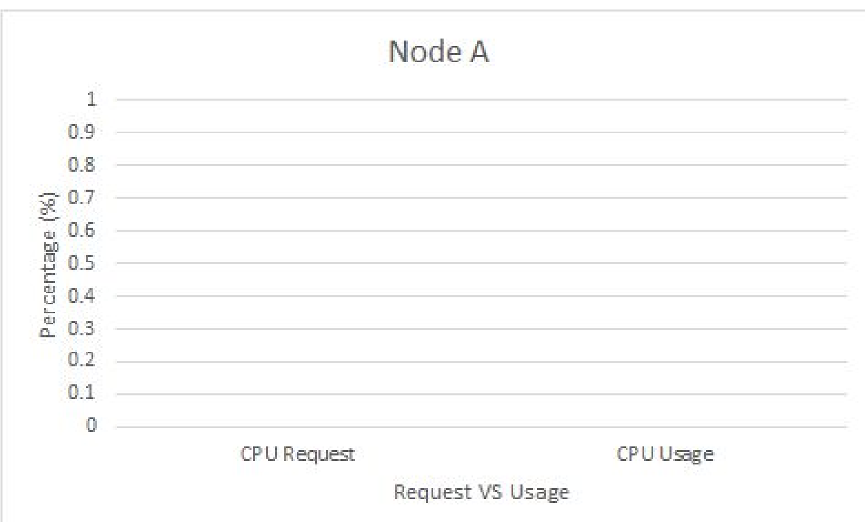


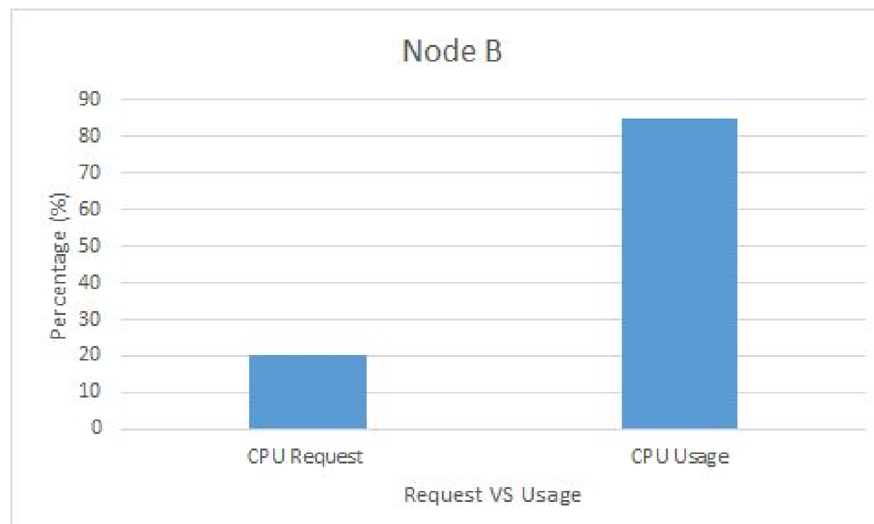




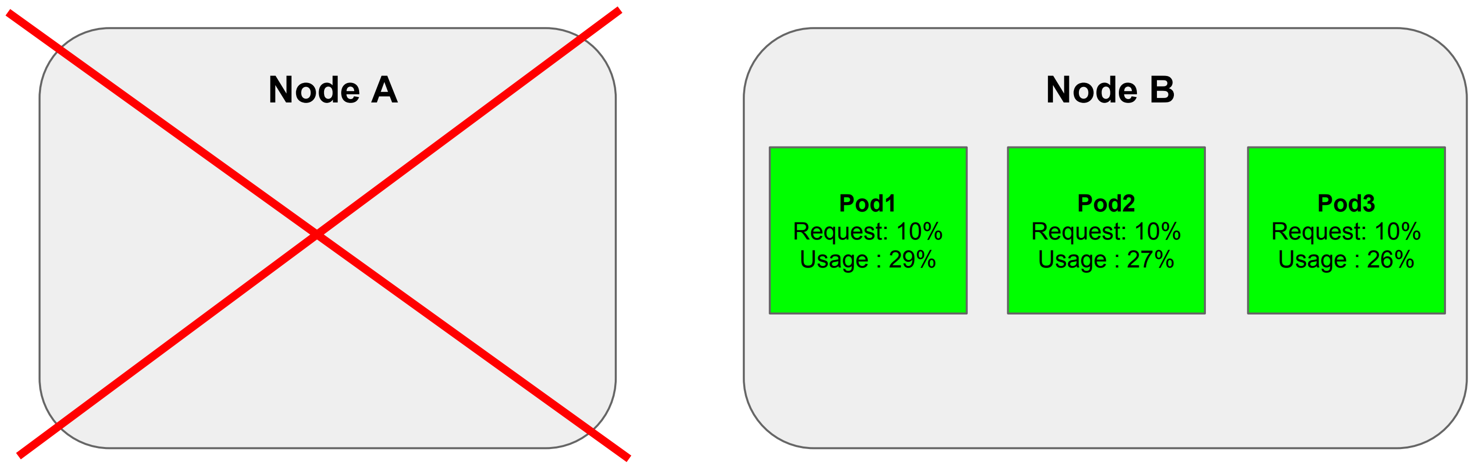
Pod Layout after Crash

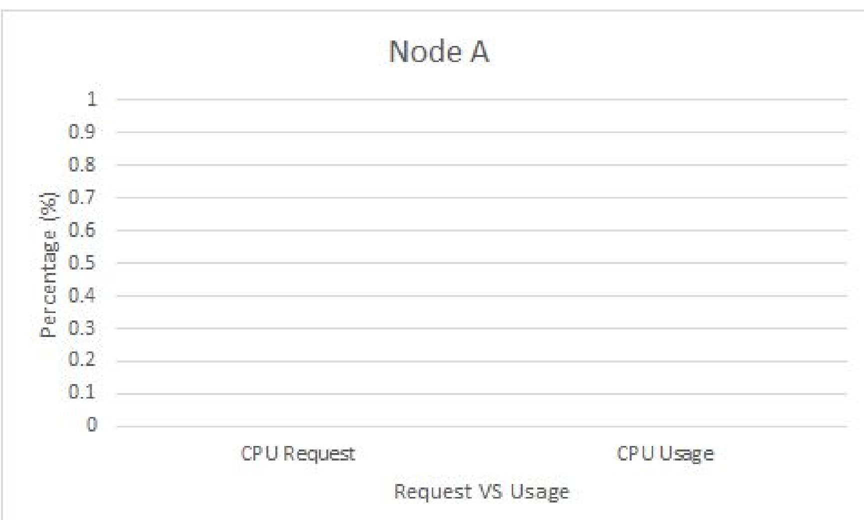


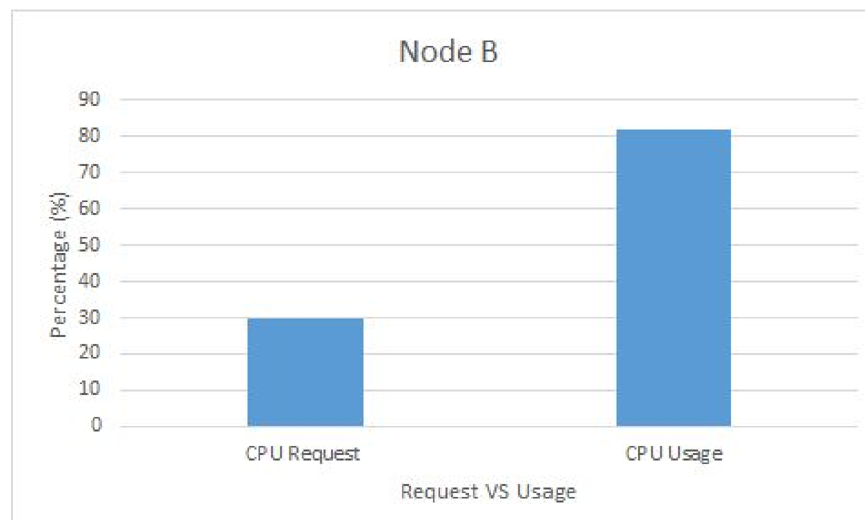




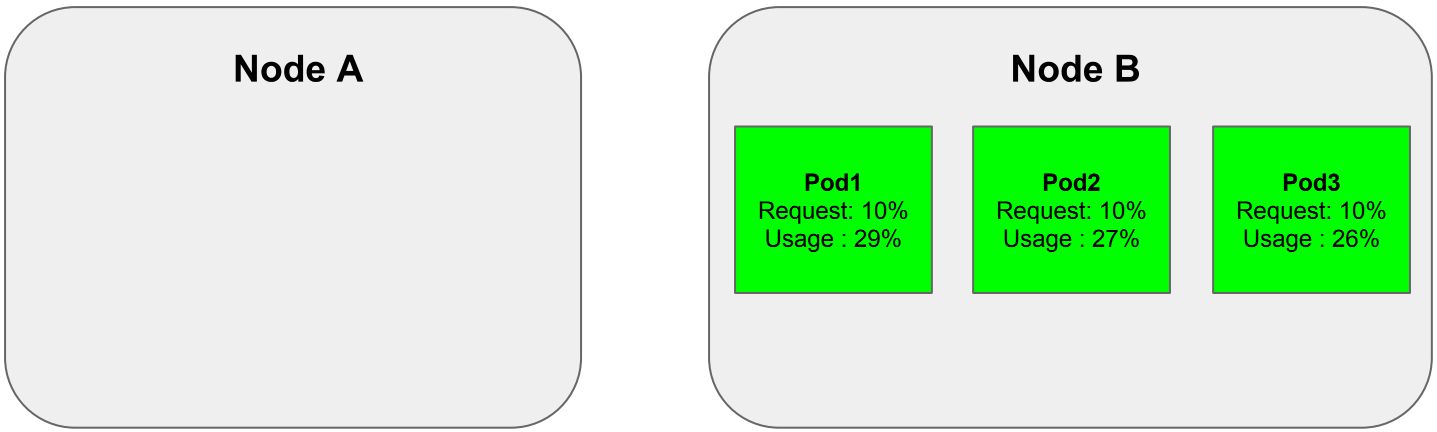
Pod Layout after Crash & before Recovery

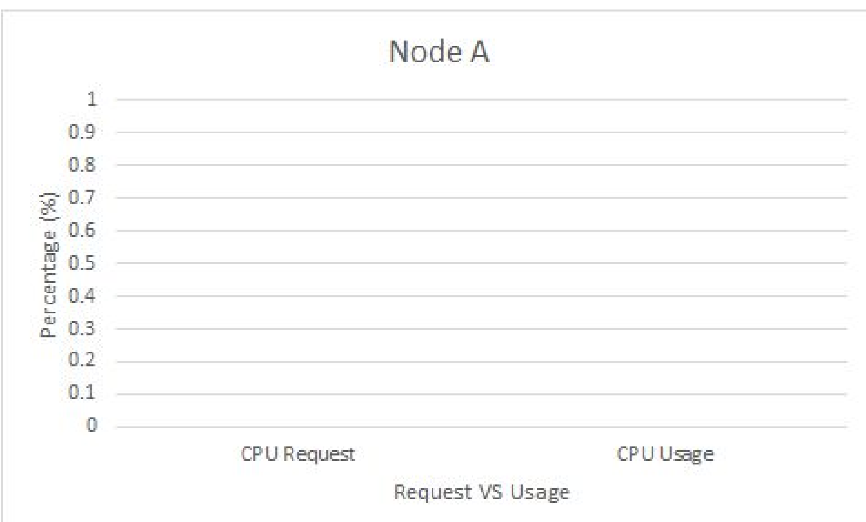


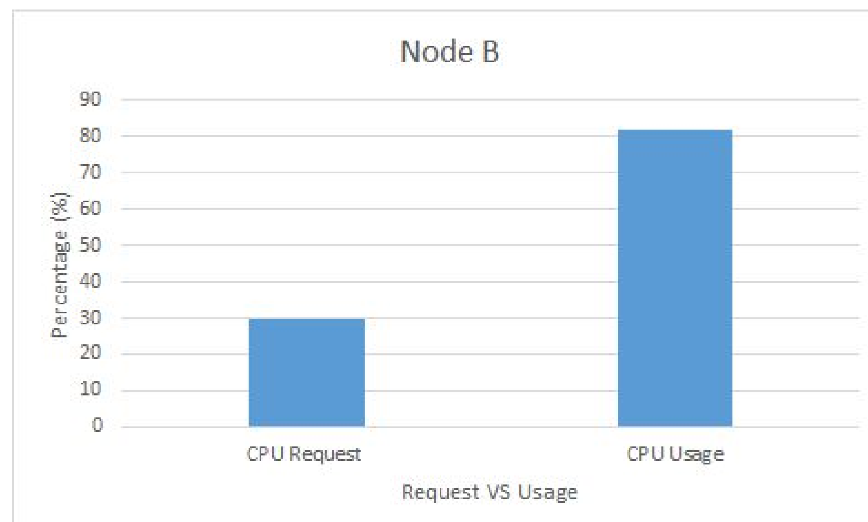




Pod Layout after Crash & after Recovery







Interesting Consequence of Crash, Reboot

- Can shift the container placement into an undesirable or less optimal state
- Multiple ways to mitigate this
  - Have kubernetes reschedule
    - Increases complexity
  - Users set their requirements carefully so as not to get in that situation
  - Reset the entire system to get back to the desired configuration

5.

Experiments

Autoscaling

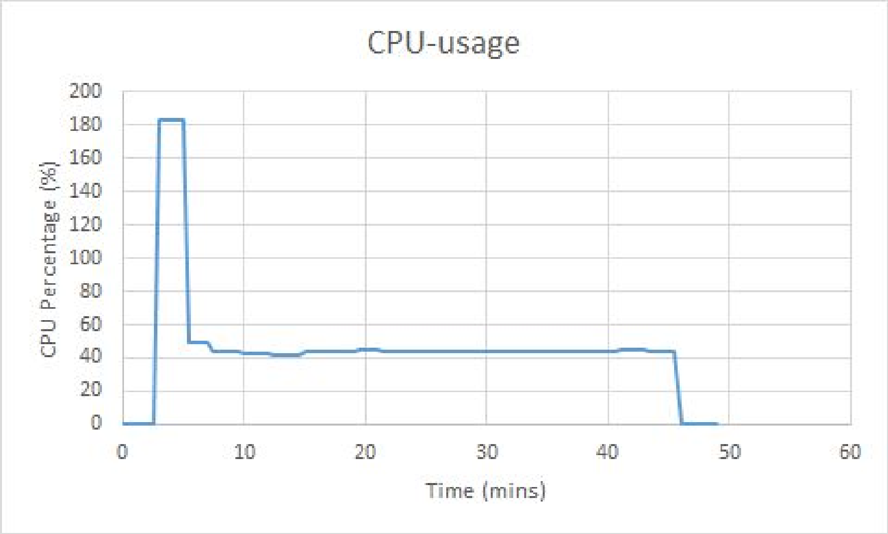
- How does kubernetes do autoscaling?

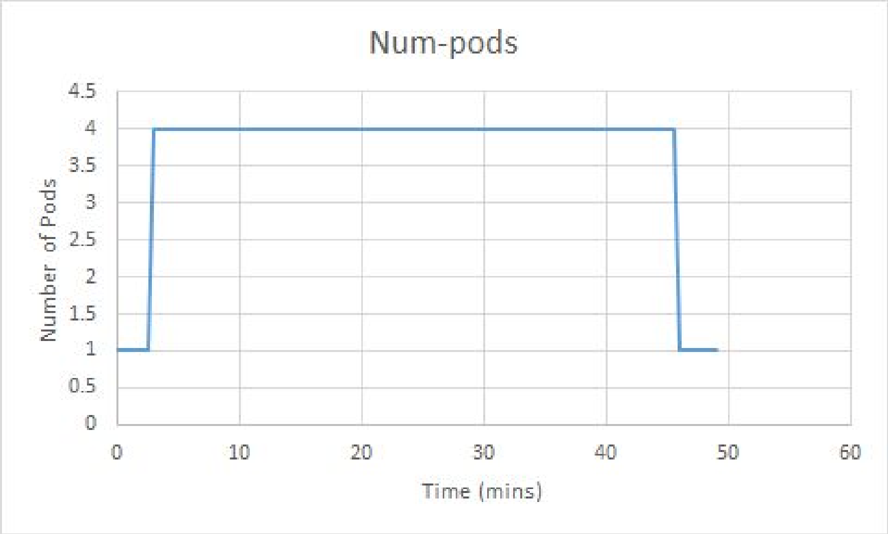
Autoscaling

- Control Loop
  - Set target CPU utilization for a pod
  - Check CPU utilization of all pods
  - Adjust number of replicas to meet target utilization
  - Here utilization is % of Pod request
- How does normal autoscaling behavior look like for a stable load?

Normal Behavior of Autoscaler

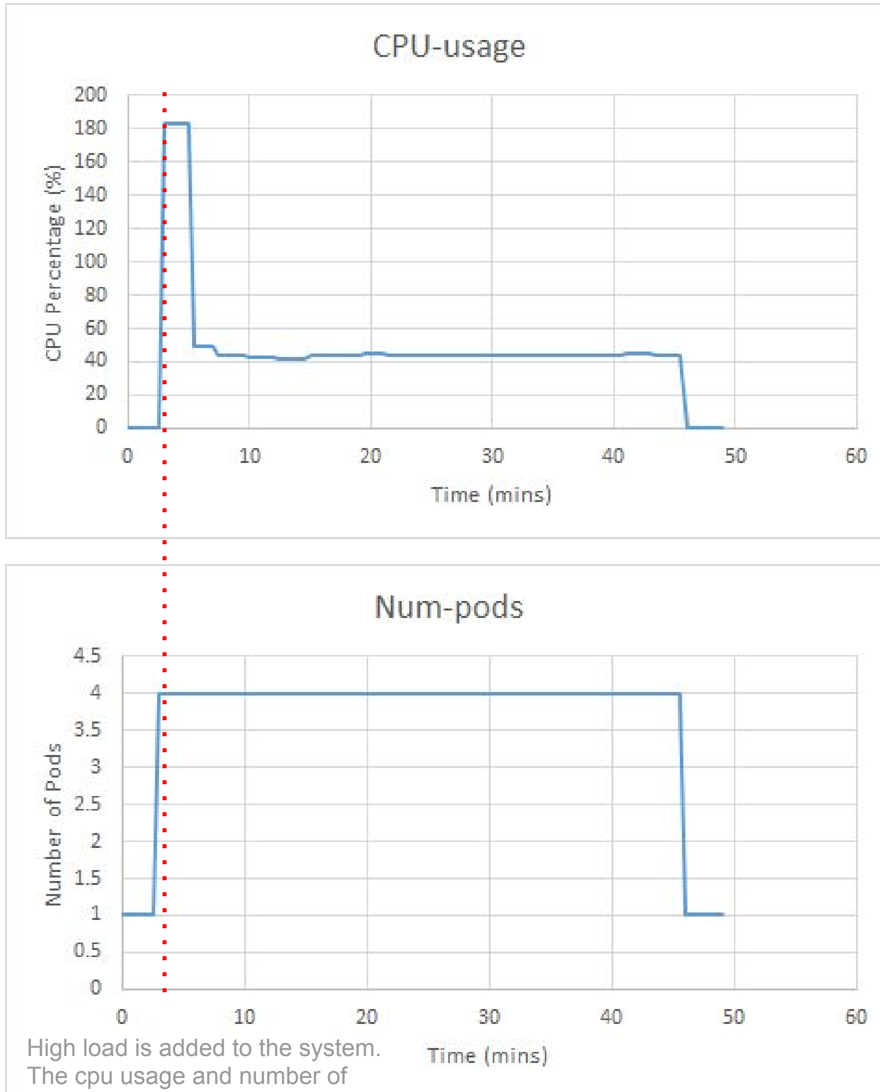
Target Utilization 50%





Normal Behavior of Autoscaler

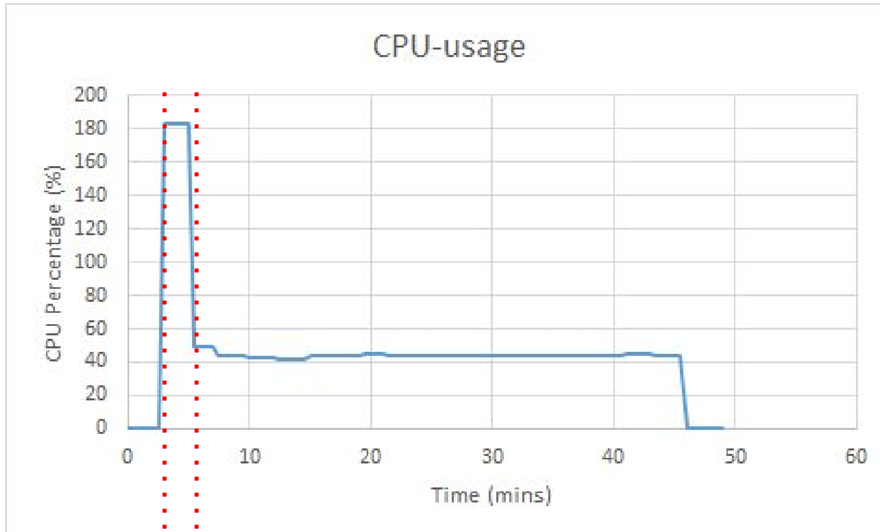
Target
Utilization
50%

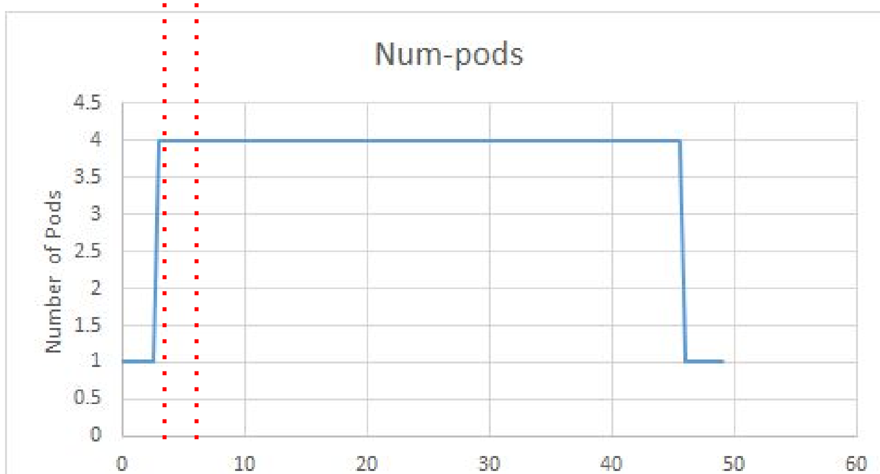


High load is added to the system. The cpu usage and number of pods increase

Normal Behavior of Autoscaler

Target
Utilization
50%

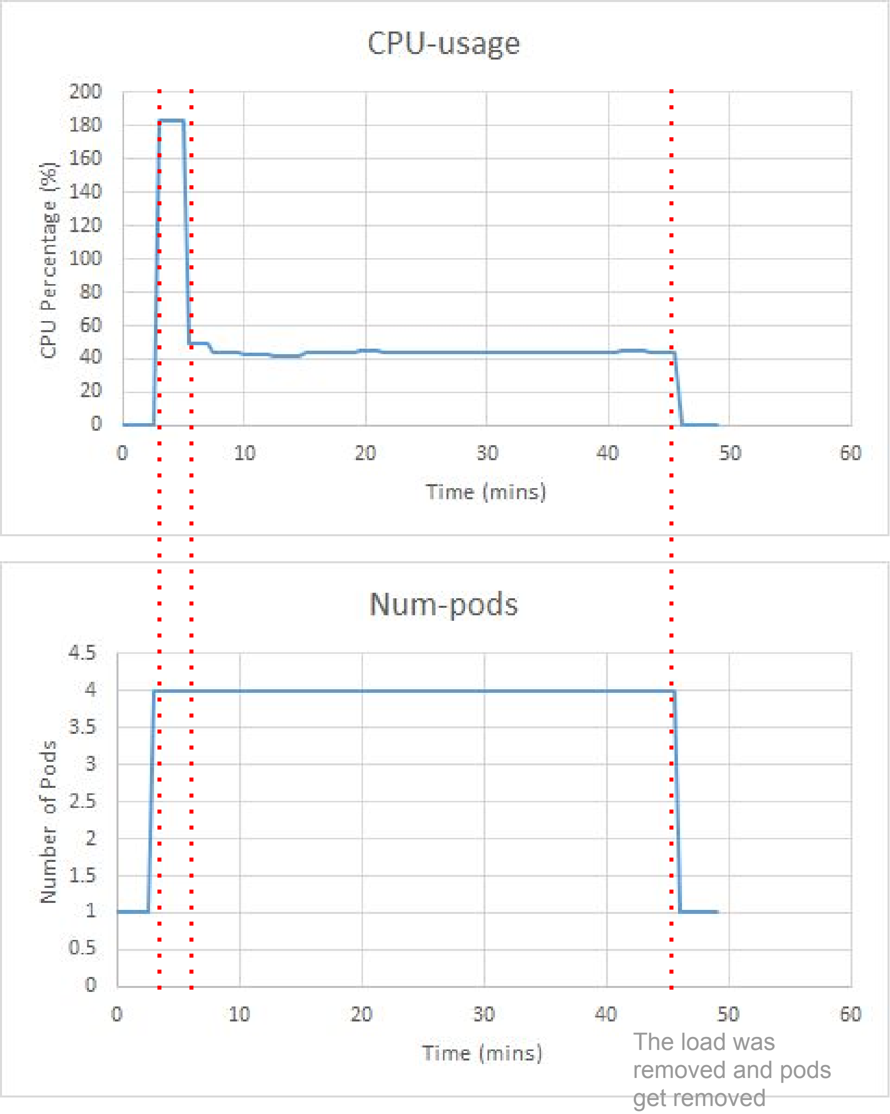




The load is now spread across nodes and the measured cpu usage is now the average cpu usage of 4 nodes

Normal Behavior of Autoscaler

Target Utilization 50%



The load was removed and pods get removed

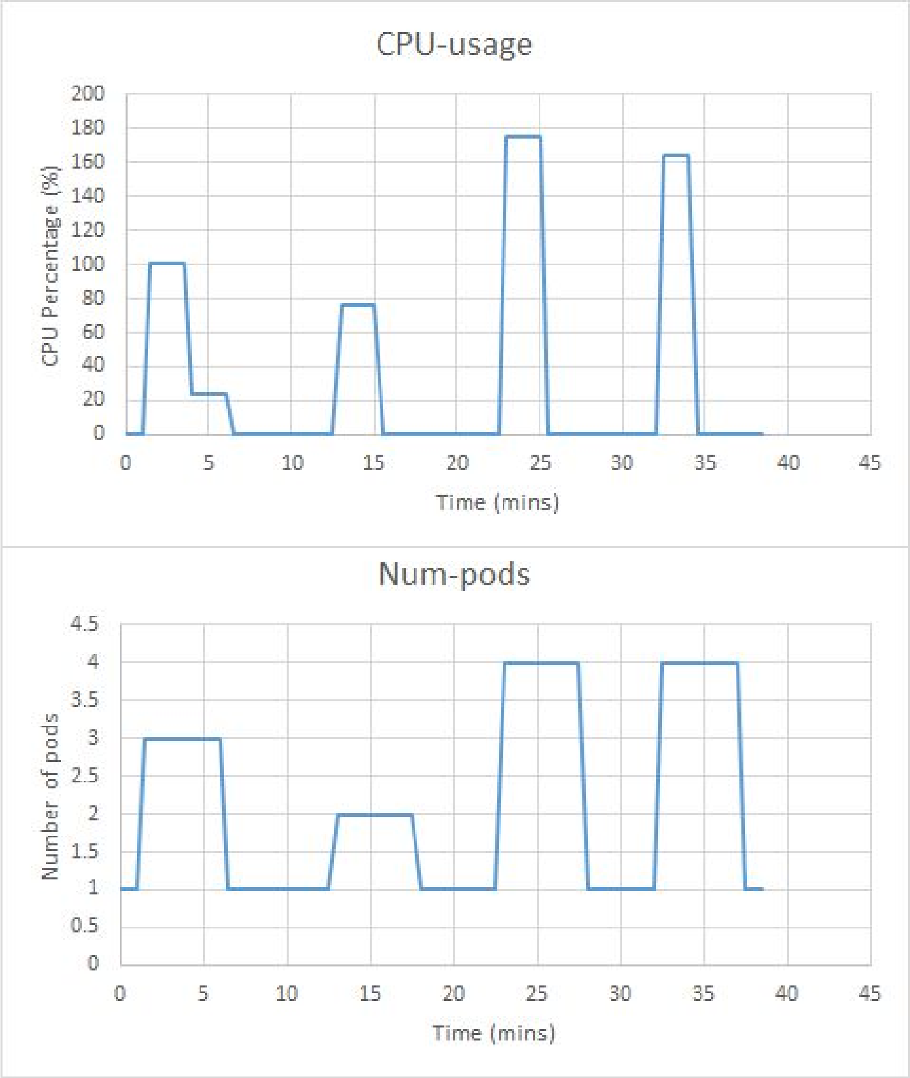
Autoscaling Parameters

- Auto scaler has two important parameters
- Scale up
  - Delay for 3 minutes before last scaling event
- Scale down
  - Delay for 5 minutes before last scaling event

- How does the auto scaler react to a more transient load?

Autoscaling Parameters

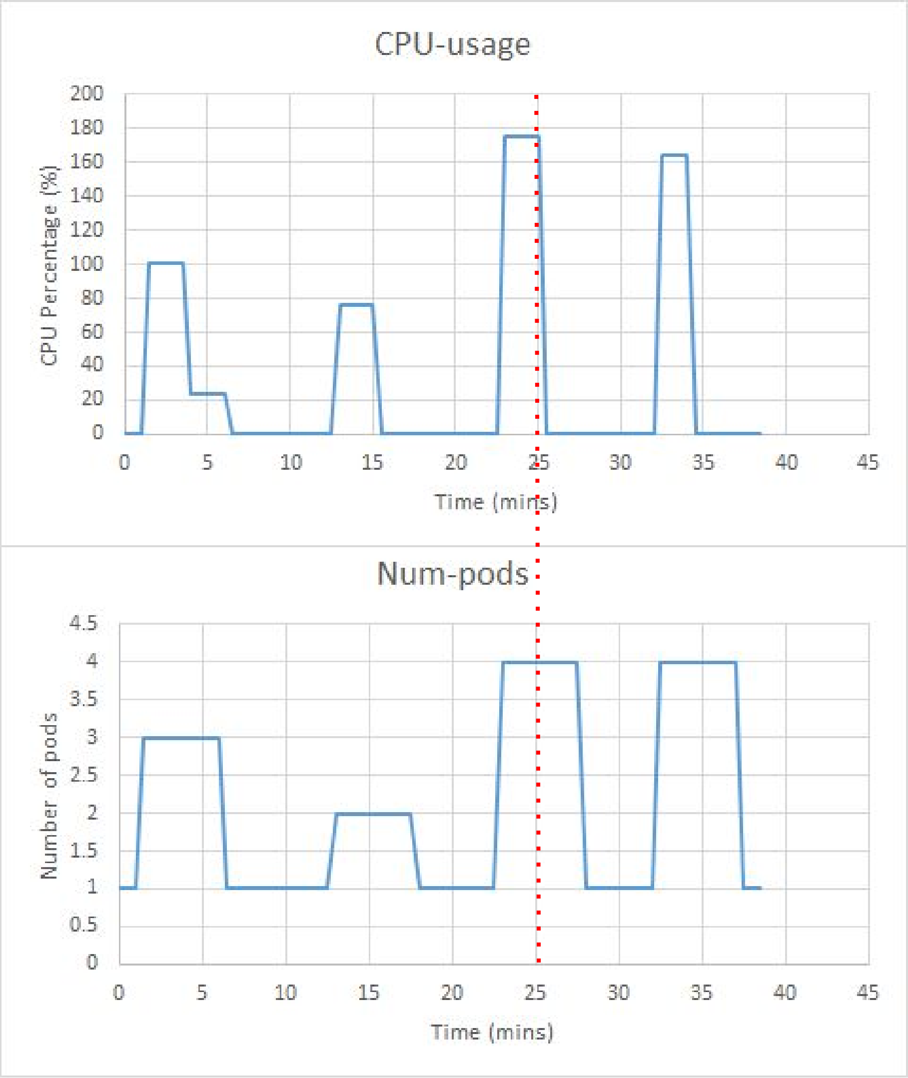
Target Utilization 50%



Autoscaling Parameters

Target Utilization 50%

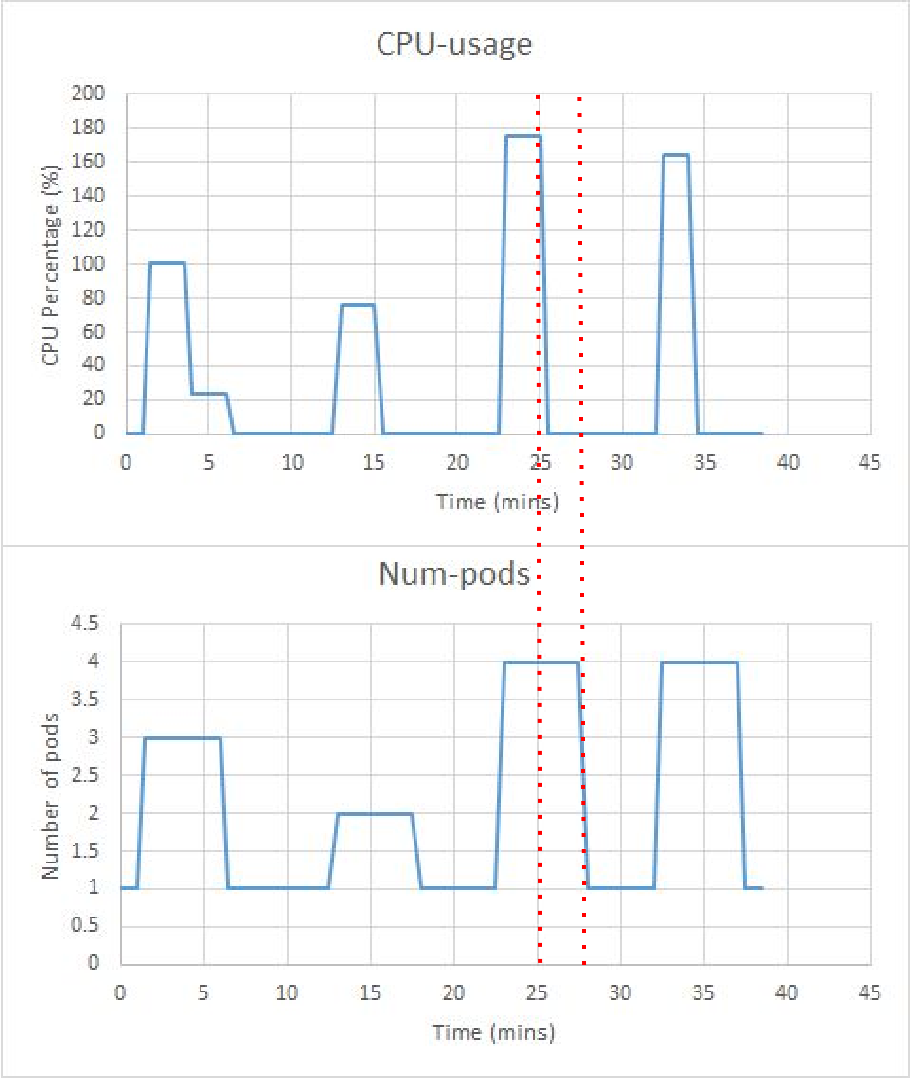
The load went down



Autoscaling Parameters

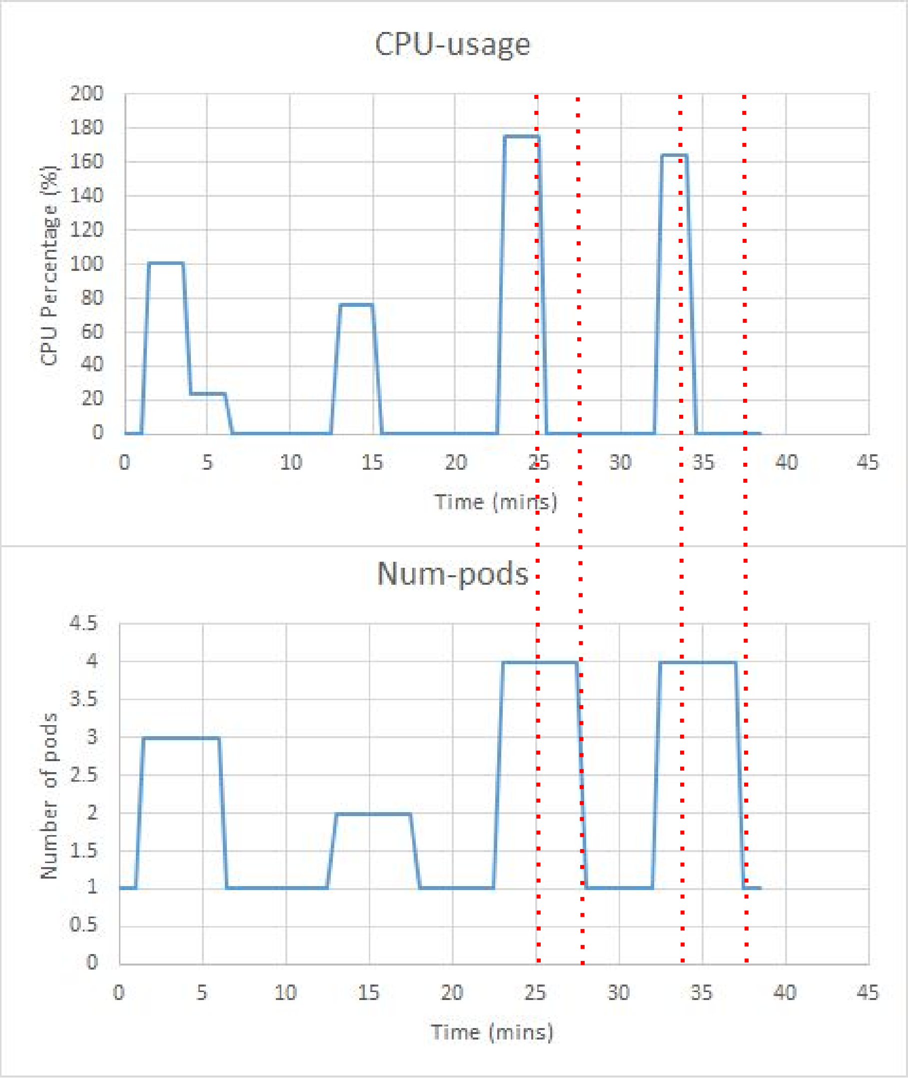
Target Utilization 50%

The number of pod don’t scale down as quick



Autoscaling Parameters

Target Utilization 50%



The number of pod don't scale down as quick

The is repeated in other runs too

Autoscaling Parameters

- Needs to be tuned for the nature of the workload
- Generally conservative
  - Scales up faster
  - Scales down slower
- Tries to avoid thrashing

5.

Summary

Summary

- Scheduling and Admission control policy is based on min-request of resource
  - CPU and Memory given equal weightage
- Crashes can drive system towards undesirable states
- Autoscaler works as expected
  - Has to be tuned for workload

6.

Conclusion

Conclusion

- Philosophy of control loops
  - Observe, rectify, repeat
  - Drive system towards desired state

- Kubernetes tries to do as little as possible
  - Not a lot of policies
  - Makes it easier to reason about
  - But can be too simplistic in some cases

Thanks!

Any questions?

References

- http://kubernetes.io/
- http://blog.kubernetes.io/
- Verma, Abhishek, et al. "Large-scale cluster management at Google with Borg." *Proceedings of the Tenth European Conference on Computer Systems*. ACM, 2015.

Backup slides

4.

Experiments

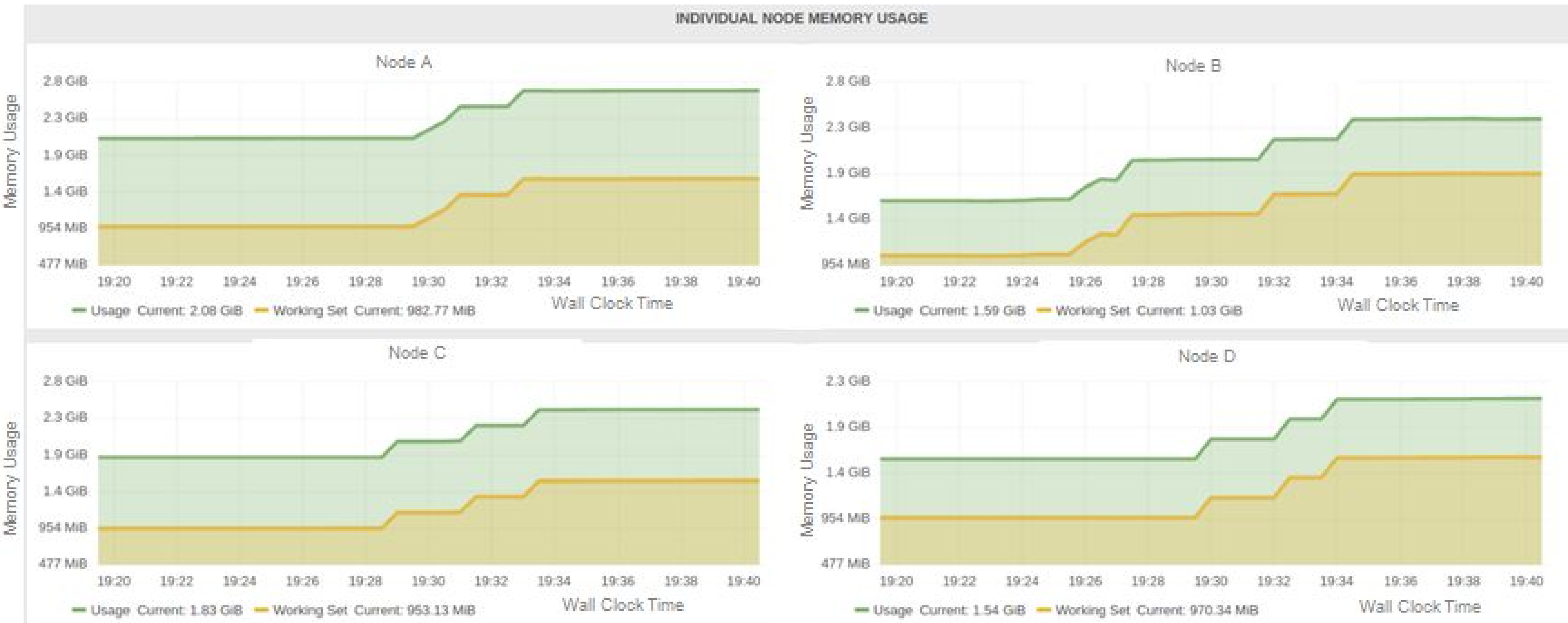
Scheduling Behavior

- Is the policy based on spreading load across resources?

Is the Policy based on Spreading Load across Resources?

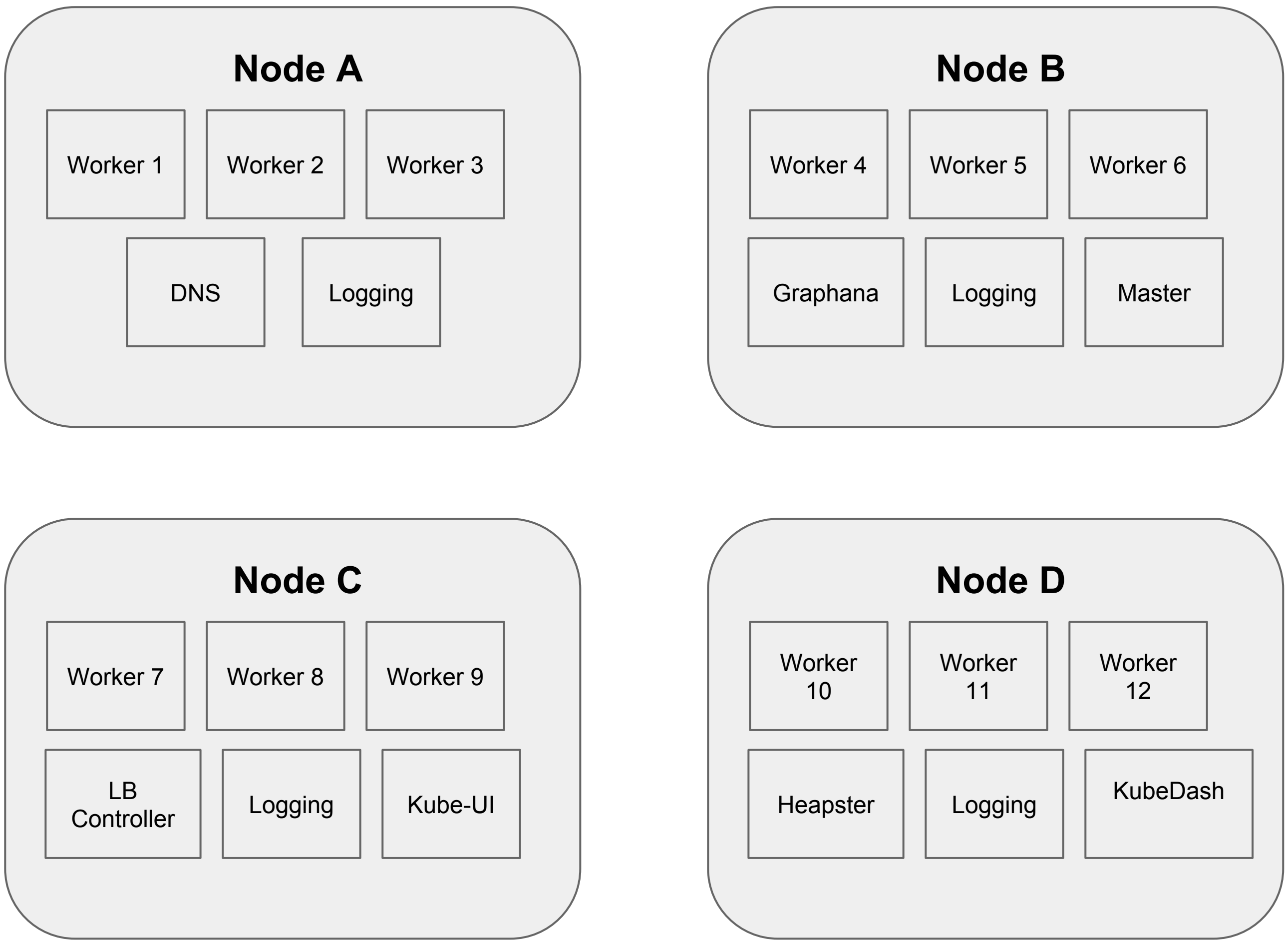
- Launch a Spark cluster on kubernetes
- Increase the number of workers one at a time
- Expect to see them scheduled across the nodes
- Shows the spreading policy of scheduler

Individual Node Memory Usage



Increase in Memory Usage across Nodes

Final Pod Layout after Scheduling



Is the Policy based on Spreading Load across Resources?

- Exhibits spreading behaviour
- Inconclusive
  - Based on resource usage or request?
  - Background pods add to noise
  - Spark workload hard to gauge

Autoscaling Algorithm

- CPU Utilization of pod
  - Actual usage / Amount requested

Target Num Pods = Ceil(Sum(All Pods Util) / Target Util)

Control Plane Components

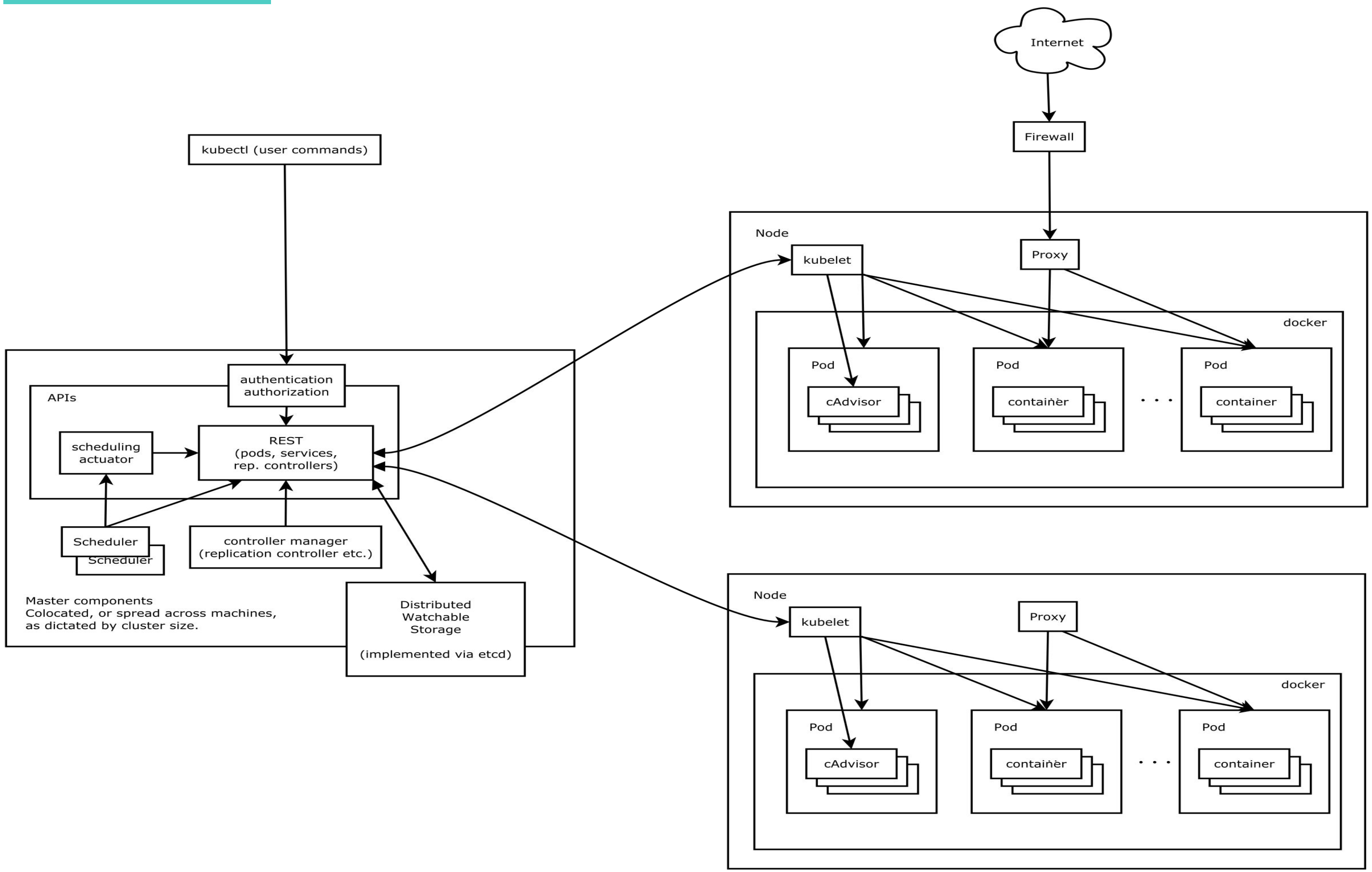
Master

- API Server
  - Client access to master
- etcd
  - Distributed consistent storage using raft
- Scheduler
- Controller
  - Replication

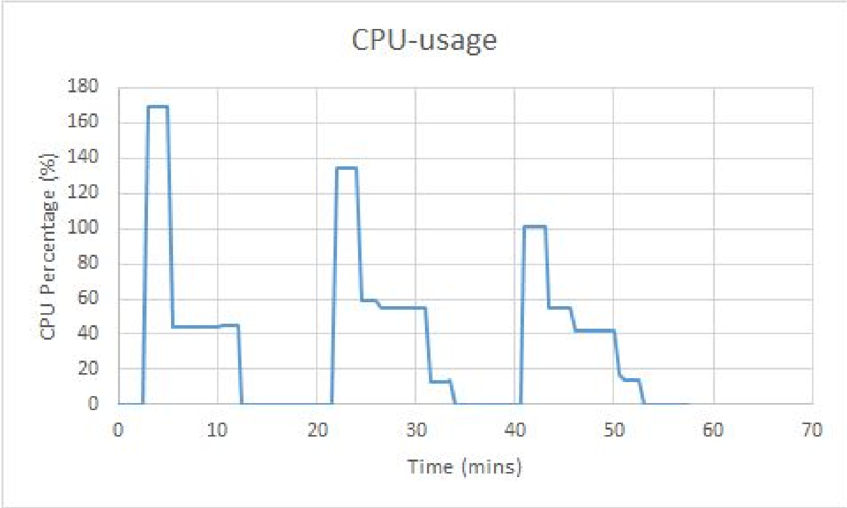
Node

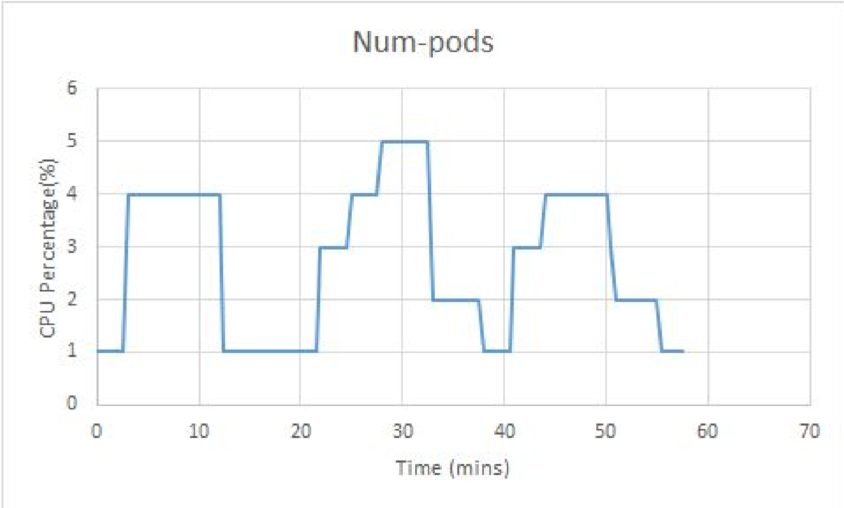
- Kubelet
  - Manage pods, containers
- Kube-proxy
  - Load balance among replicas of pod for a service

Detailed Architecture

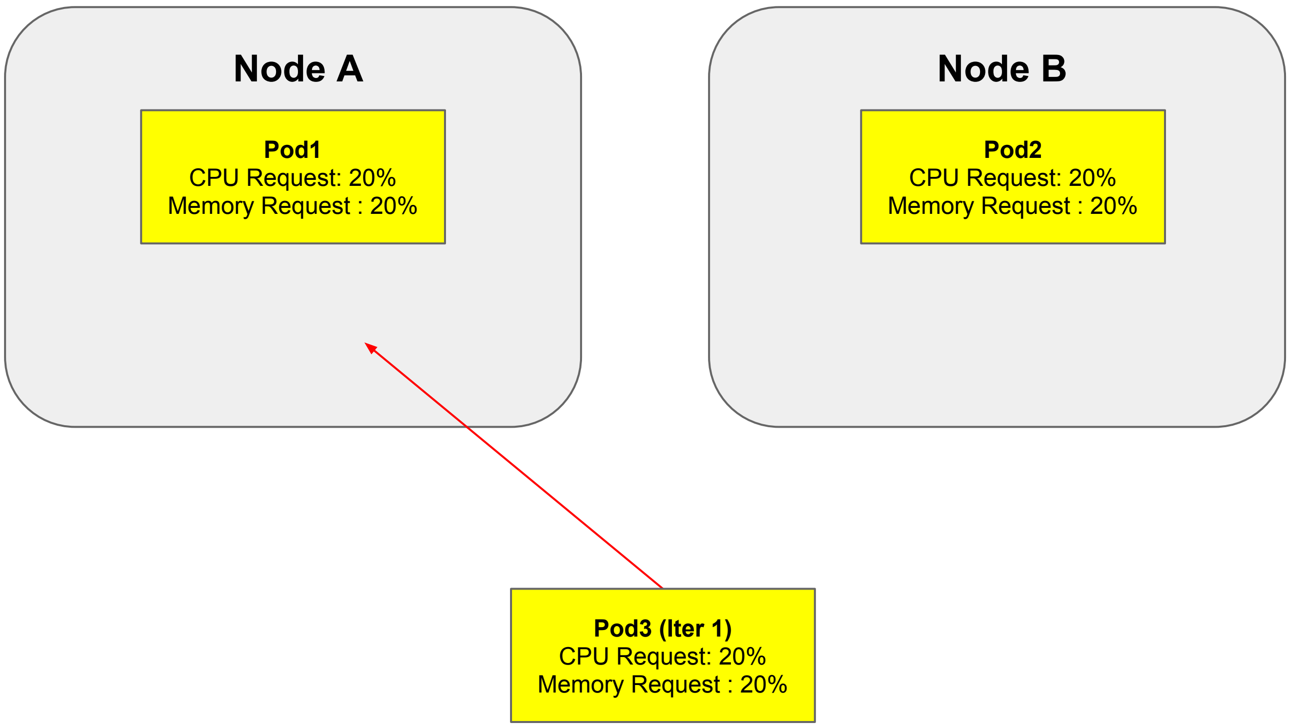


Autoscaling for Long Stable Loads (10 high, 10 low)





New Pod with 20% CPU and 20% Memory Request



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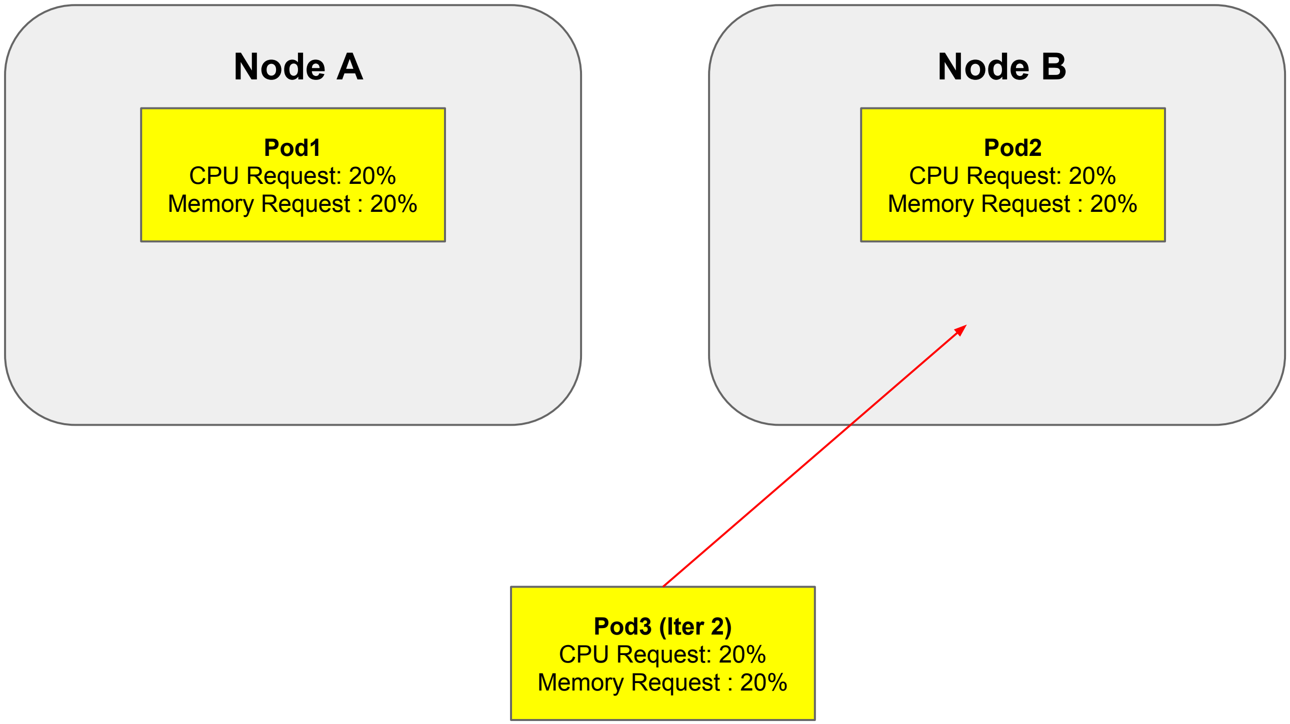

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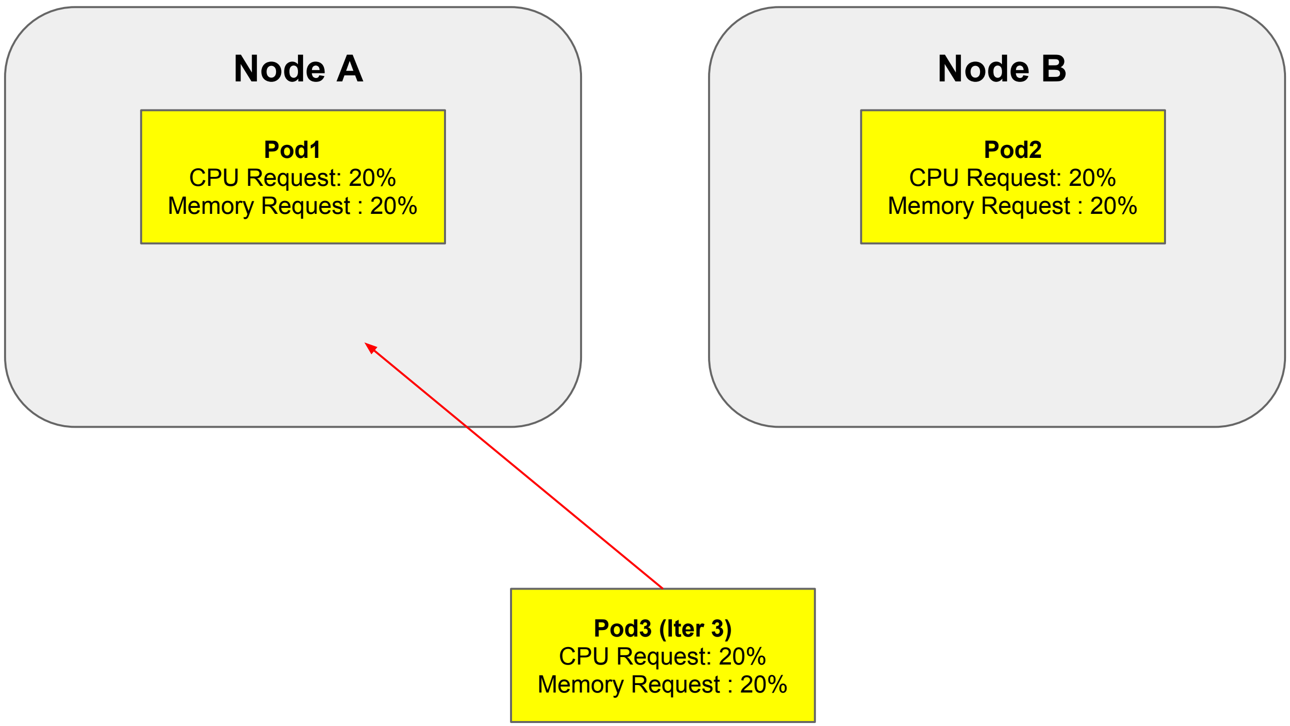
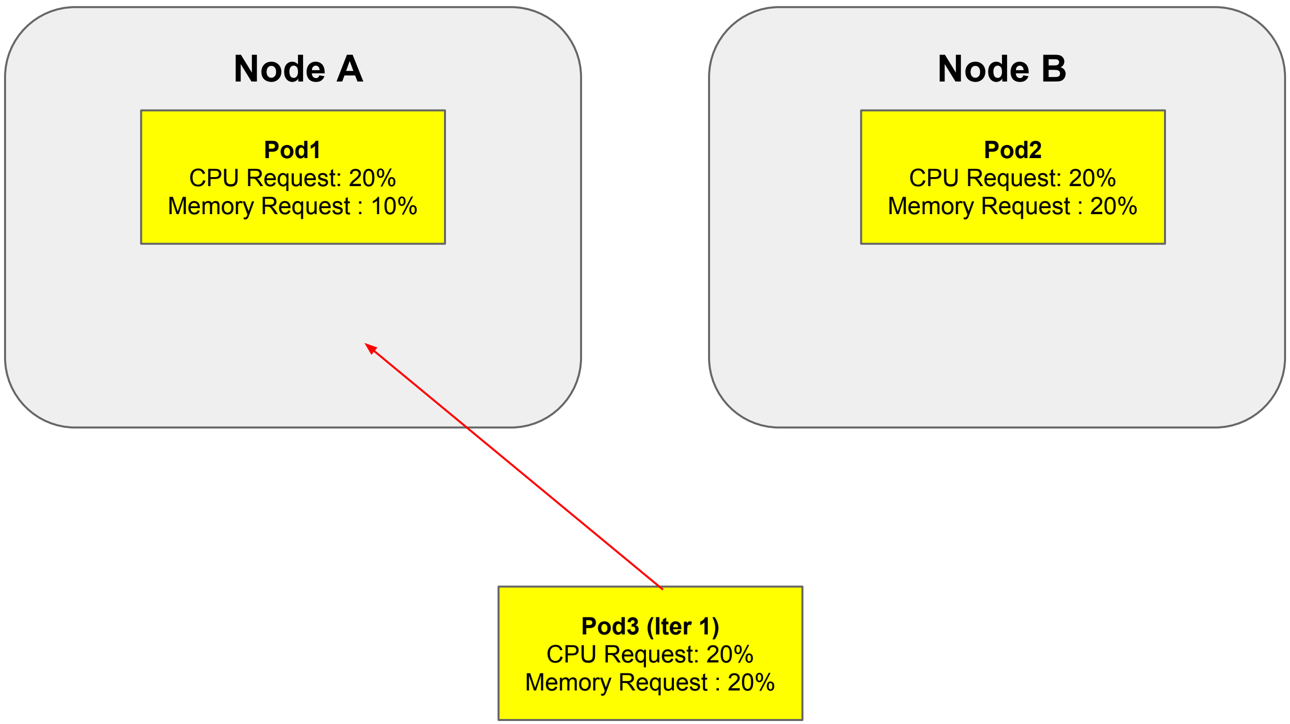
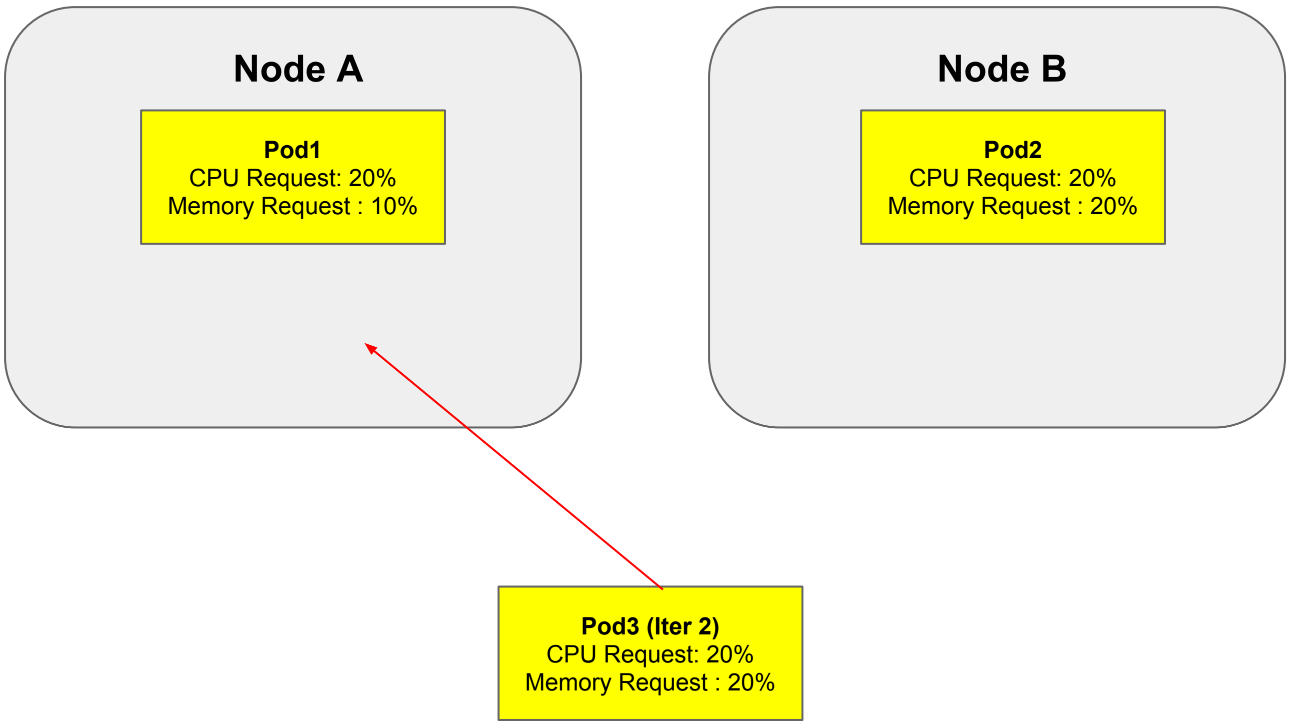


New Pod with 20% CPU and 20% Memory Request



New Pod with 20% CPU and 20% Memory Request



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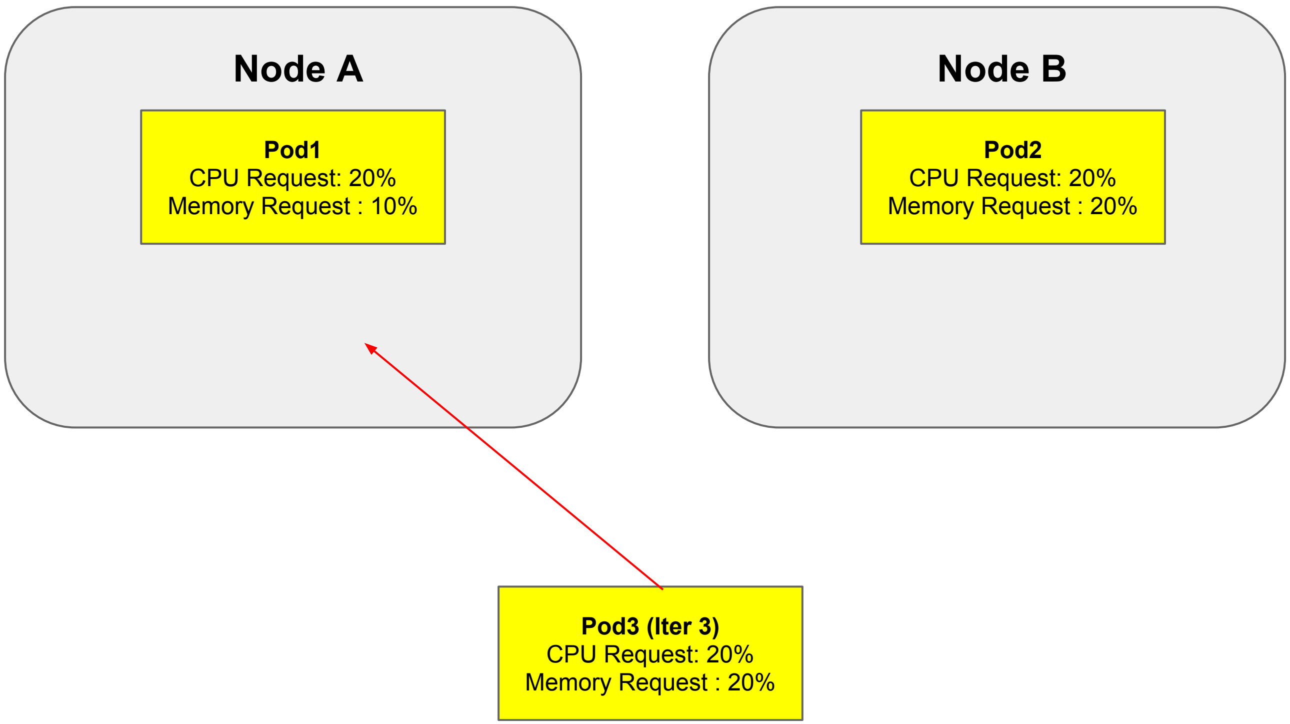
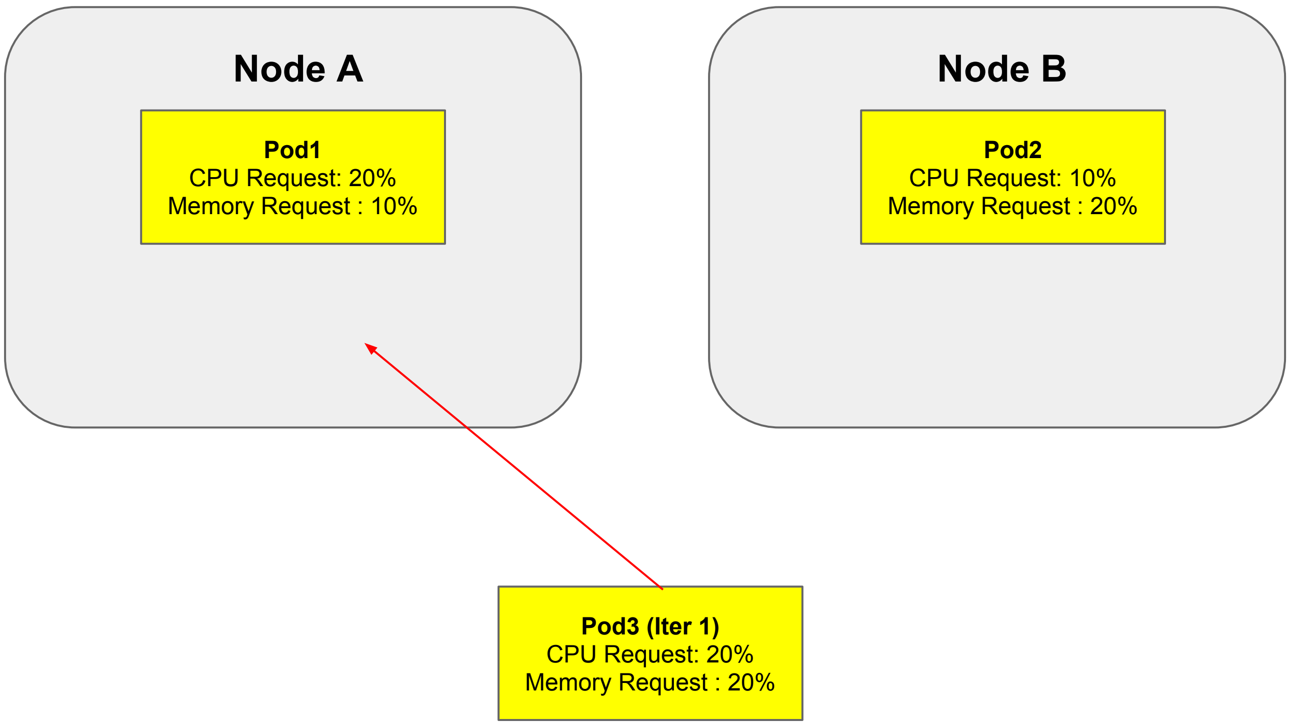
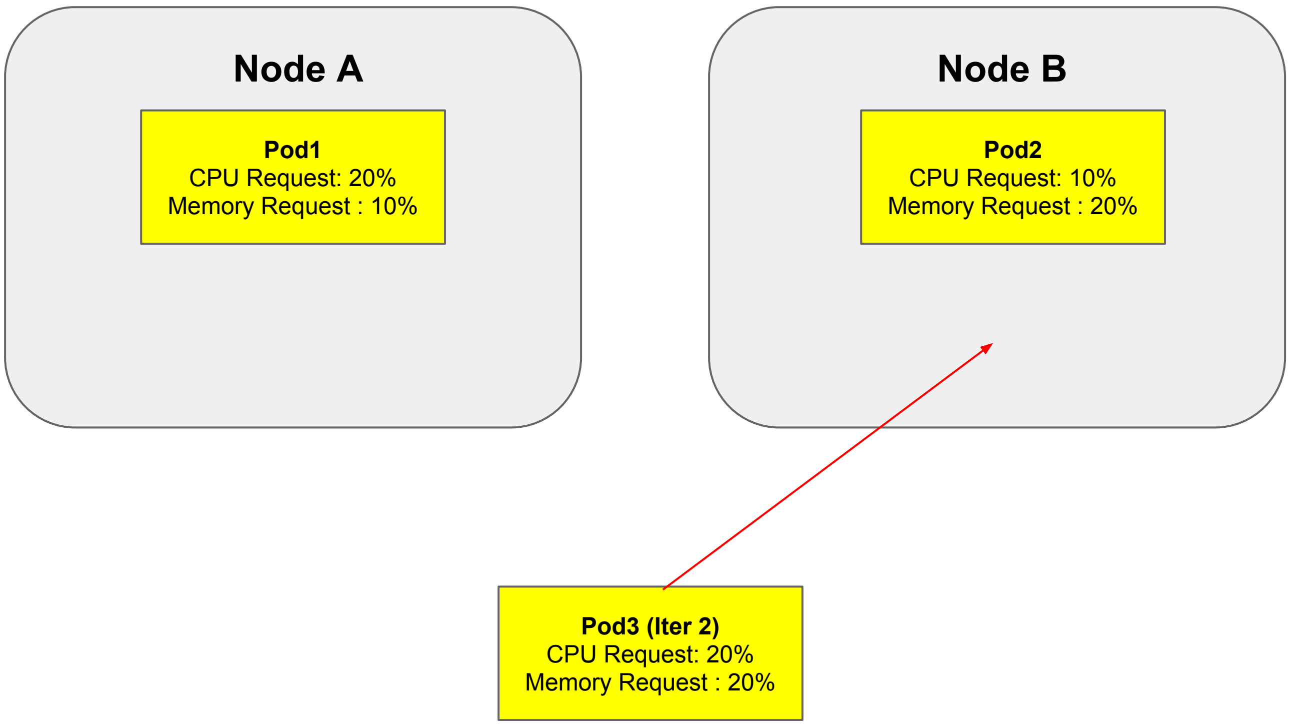


New pod with 20% CPU and 20% Memory Request



New pod with 20% CPU and 20% Memory Request



New pod with 20% CPU and 20% Memory Request