# Tetris: Predictive Pod Placement Strategy for Kubernetes

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Project Proposal

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# Agenda

- Problem Statement
- Idea
- Kubernetes Overview
- Related Work
- Prediction Strategies
- Experiment and Evaluations
- Project Roadmap

# Problem Statement

Kubernetes does not consider I/O utilization when provisioning pods. This could lead to performance degradation on an I/O bottleneck K8s Node. We propose to introduce a predictive pod placement strategy to avoid resource bottlenecks.

# Idea

- Manually categorizing pods by workload type.
  - CPU intensive
  - Memory intensive
  - IO intensive
- Policy based predictive modeling.
  - ARIMA, Gaussian - SVM
- Intelligent placement.
  - Choose a node for a pod

# Kubernetes (K8s)

- Automates container orchestration tasks
- Master-Slave Architecture
- Master
  - Scheduler
  - API Server
  - etcd
- Node
  - cAdvisor
  - Kubelet
  - Pods

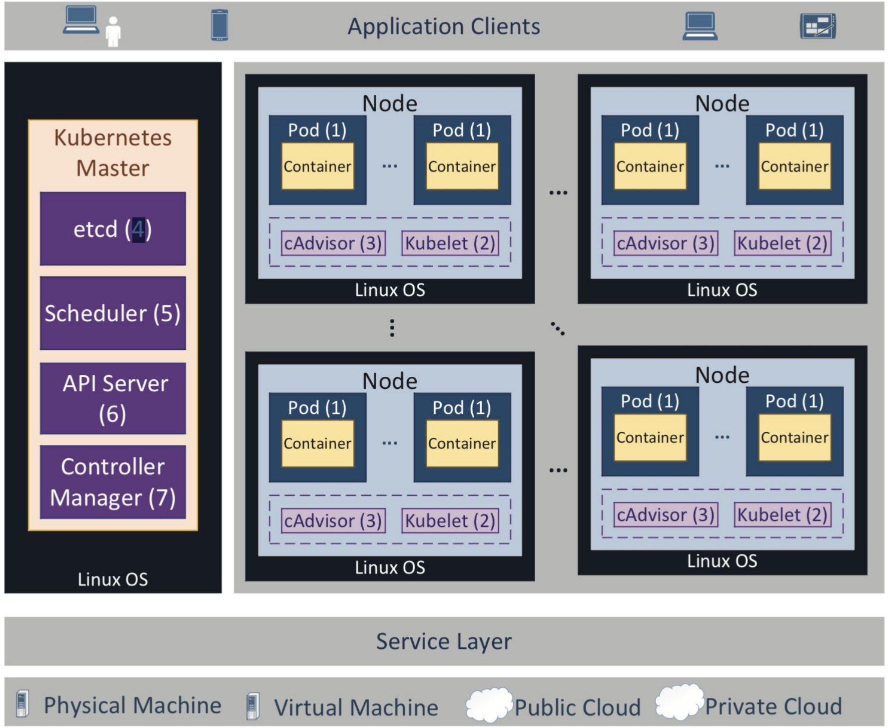



Figure from “A Kubernetes-Based Monitoring Platform for Dynamic Cloud Resource Provisioning” [3]

# Monitoring Frameworks

- Monitoring is hard - dynamic cluster
- cAdvisor: built-in monitoring solution
- K8s is now designed to behave as a platform
- Core-metrics-pipeline
  - Metrics-server: does not store historical metrics
- Monitoring-pipeline
  - custom-metrics-API
  - Full monitoring solution: Ex: Prometheus, Datadog

# IO-RE

- Load balance decisions
  1. $Load_{IO}$ at $node_i$ updated by $Task_j$
  2. $Threshold_{IO}$ calculated for $node_i$
  3. *If* $Load_{IO}$ > $Threshold_{IO}$ *Then* move $task_j$
  4. *If* Load I/O < $Threshold_{IO}$ $Task_j$ *Then* execute at $node_i$

$$load_{IO}(i) = \sum_{j \in N_i} page(i,j) + \sum_{j \in N_i} IO(j)$$

Equation 1

$$threshold_{IO}(i) = \frac{D_i}{\sum_{j=1}^{n} D_j} \times \sum_{j=1}^{n} load_{IO}(j)$$

Equation 2

Equations from “Dynamic load balancing for I/O-intensive tasks on heterogeneous clusters” [1]

# IOCM-RE

Algorithm: IO-CPU-Memory based load balancing (IOCM-RE):
/* Assume that a task j newly arrives at node i */
if $IO(j) + \sum_{j \in N_i} IO(k) > 0$ then
  The IO-RE policy is used to balance the system node; /* see Section 3.2 */
else  if $page(i,j) + \sum_{j \in N_i} page(i,k) > 0$ then /* see Section 3.1(2) */
    The memory-based policy is utilized for load balancing;
  else   /* see Section 3.1(1) */
    The CPU-based policy makes the load balancing decision;

**Fig. 1.** Pseudocode of the IO-CPU-Memory based load balancing

Pseudocode  from "Dynamic load balancing for I/O-intensive tasks on heterogeneous clusters" [1]

# PAC

- PAC: Pattern driven Application Consolidation [2]
- Extract resource-usage patterns from VMs using FFT - *signatures*
- DTW (Dynamic Time warping) for signature matching.

- VM placement to provide global application consolidation and load-balancing

- Predicts future resource demands with 50-90% less error

# Why is workload prediction necessary?

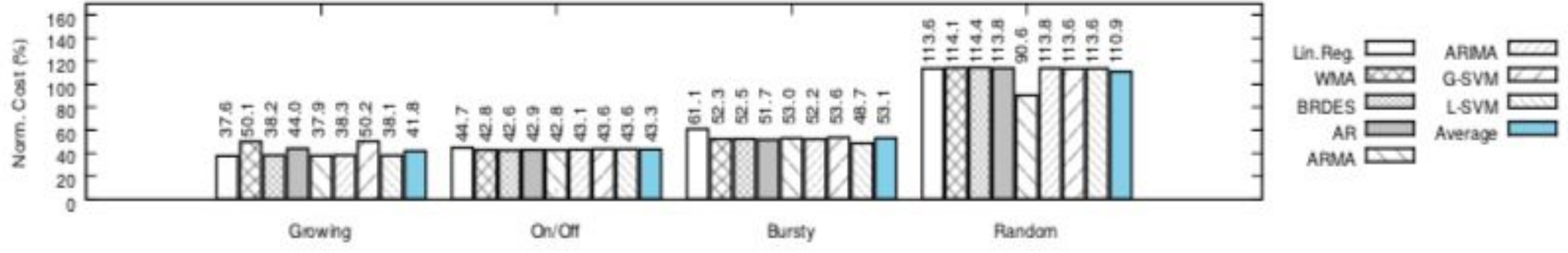
- Traditionally threshold based policies have been used.
- It's impossible to know the threshold in advance because workload patterns change over time.
- The threshold values are largely dependent on stability of a system.

# Predictive Approaches

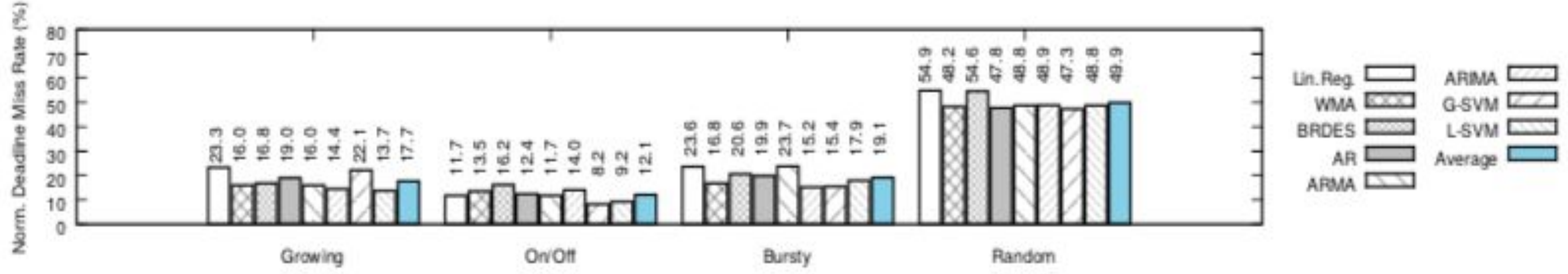
- Naive
  - Mean, KNN
- Regression
- Temporal
  - ARMA, ARIMA
- Non-temporal
  - SVM, decision trees
  - Least chosen for scaling

NO one predictive algorithm to rule them all!
(Image source: Wikipedia)

# Comparing Predictive Approaches



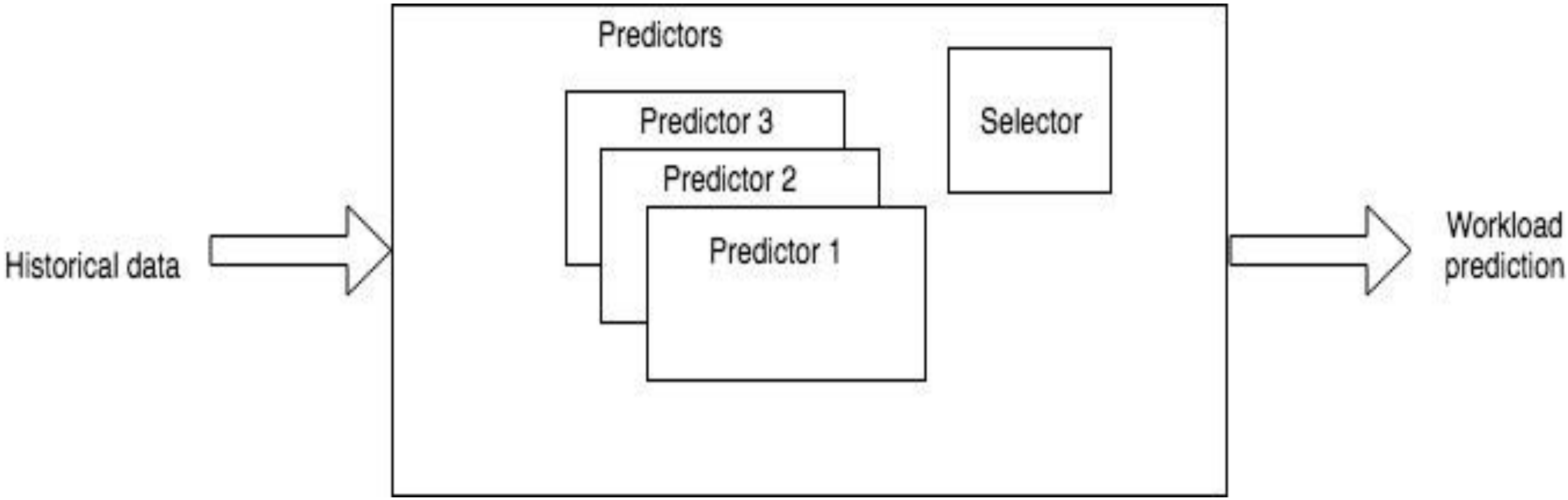

(a) Normalized Cost.




(b) Normalized Job Deadline Miss Rate.

Figure from “Empirical Evaluation of Workload Forecasting Techniques for Predictive Cloud Resource Scaling [4]

# Our Predictive Approach



# Experiment

- Provision Resources:
    - AWS EC2 (2 A1.xlarge)
    - VCL
- Deploy workload generator applications.
    - IOmeter
    - stress-ng
- Collect core system metrics to generate historic data.
- Train predictive algorithms to predict node workload.
- Analyze pod placement decisions.

# Evaluations

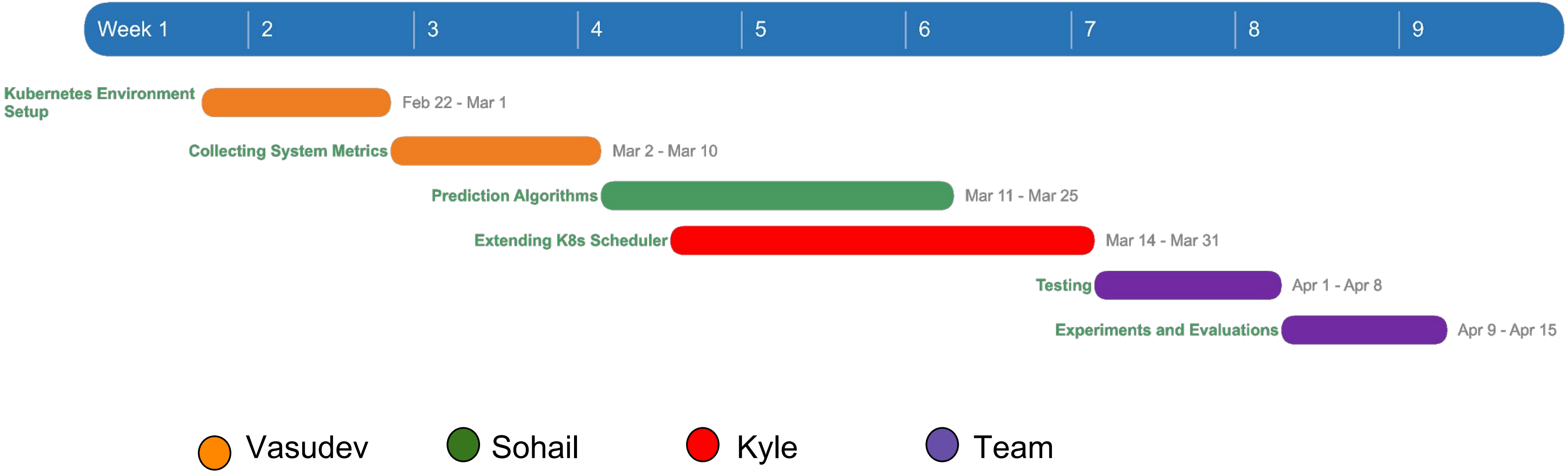
Native implementation

- No historical data involved for placement decisions
- May result in bad placement choices
- Not workload aware

Tetris

- Show improved resource utilization of entire cluster
- Placement decisions based on its workload

# Project Roadmap



# References

1. Xiao Qin, Hong Jiang, Yifeng Zhu, and David R Swanson. 2003. Dynamic load balancing for I/O-intensive tasks on heterogeneous clusters. In International Conference on High-Performance Computing Springer, 300–309.

2. Zhenhuan Gong and Xiaohui Gu. 2010. Pac: Pattern-driven application consolidation for efficient cloud computing. In18th IEEE/ACM International Symposium on Modelling, Analysis & Simulation of Computer and Telecommunication Systems(MASCOTS 2010). IEEE, 24–33

3. Chia-Chen Chang, Shun-Ren Yang, En-Hau Yeh, Phone Lin, and Jeu-Yih Jeng.2017. A Kubernetes-Based Monitoring Platform for Dynamic Cloud Resource Provisioning. In GLOBECOM 2017 - 2017 IEEE Global Communications Conference.IEEE, Singapore, 1–6

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# Questions?