



An Adaptive Technique to Model Virtual Machine Behavior for Scalable Cloud Monitoring

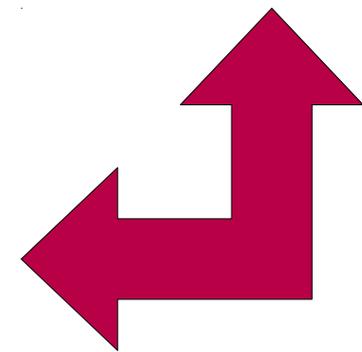
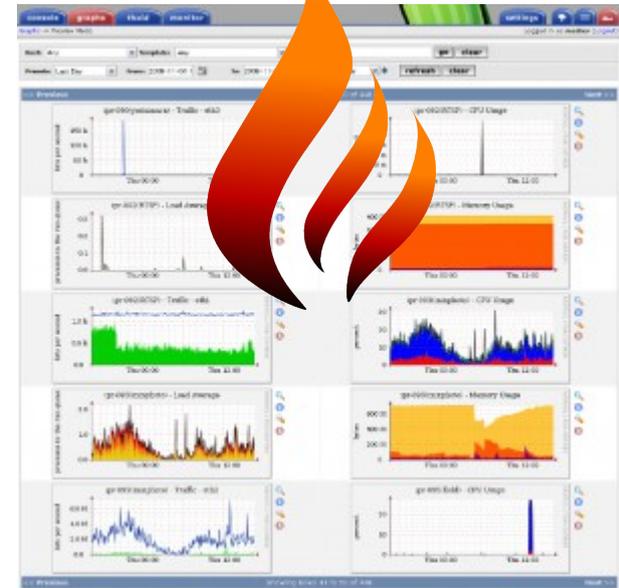
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Challenge: monitoring



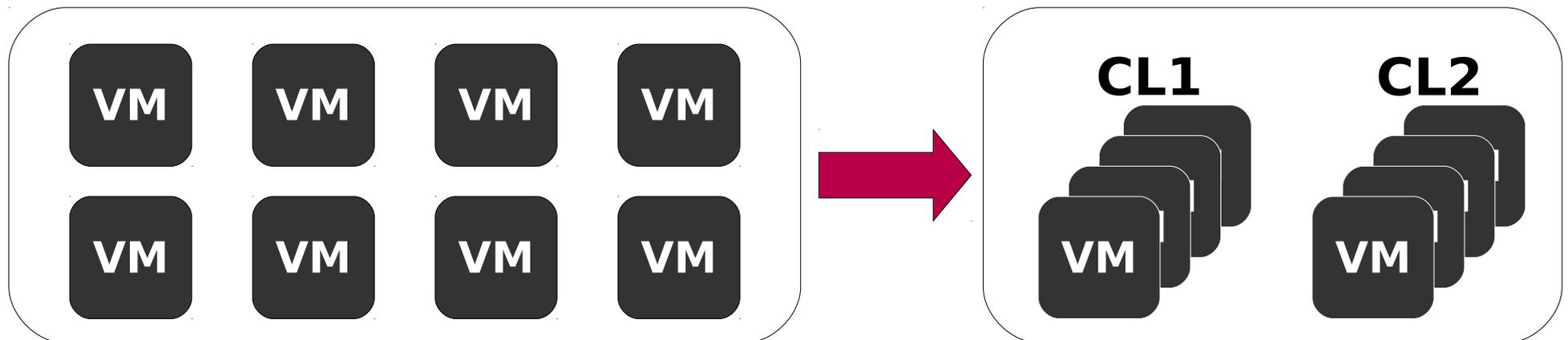
- **Large data centers ($> 10^5$ VMs)**
→ huge amount of data
- **Point of view: IaaS provider**
→ monitoring supporting infrastructure management
- **VM can be anything**
→ treat VM as black boxes
- → **Scalability issues** 



Challenge: monitoring



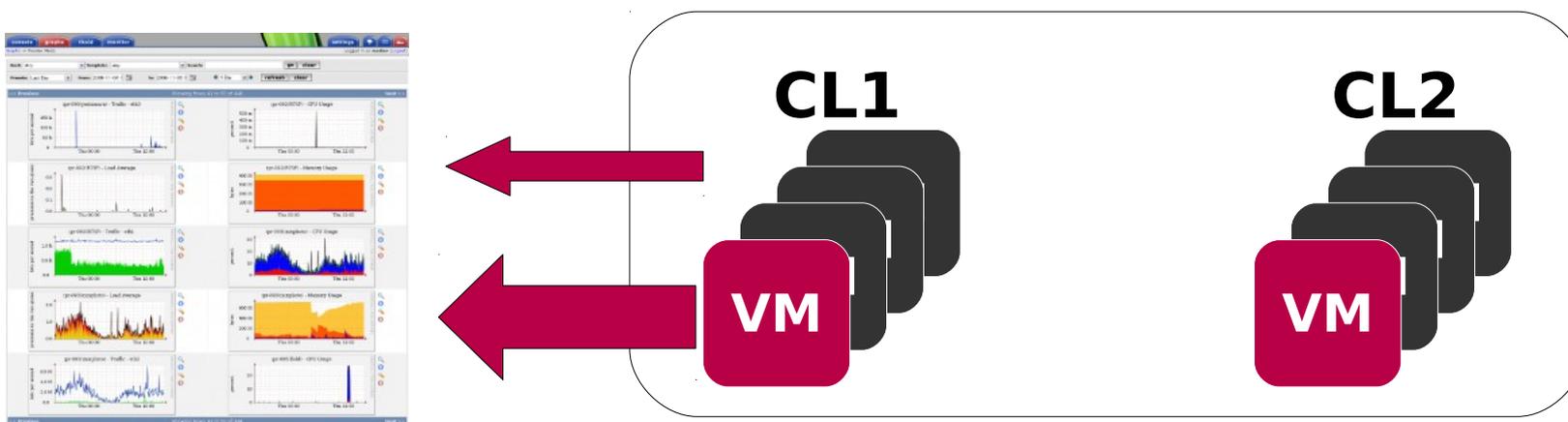
- **Current approach: reduce amount of data in a uniform way**
 - Reduce sampling frequency
 - Reduce number of metrics considered
- **→ Reduced monitoring effectiveness**
 - Less information available for management
- **Solution: Exploit VM similarity**



Improving monitoring scalability



- **Group similar VMs together**
- **Detailed monitoring of cluster representatives**
- **Reduced monitoring of other VMs**



- **→ Data collection reduced by one order of magnitude**

Challenge: fast identification

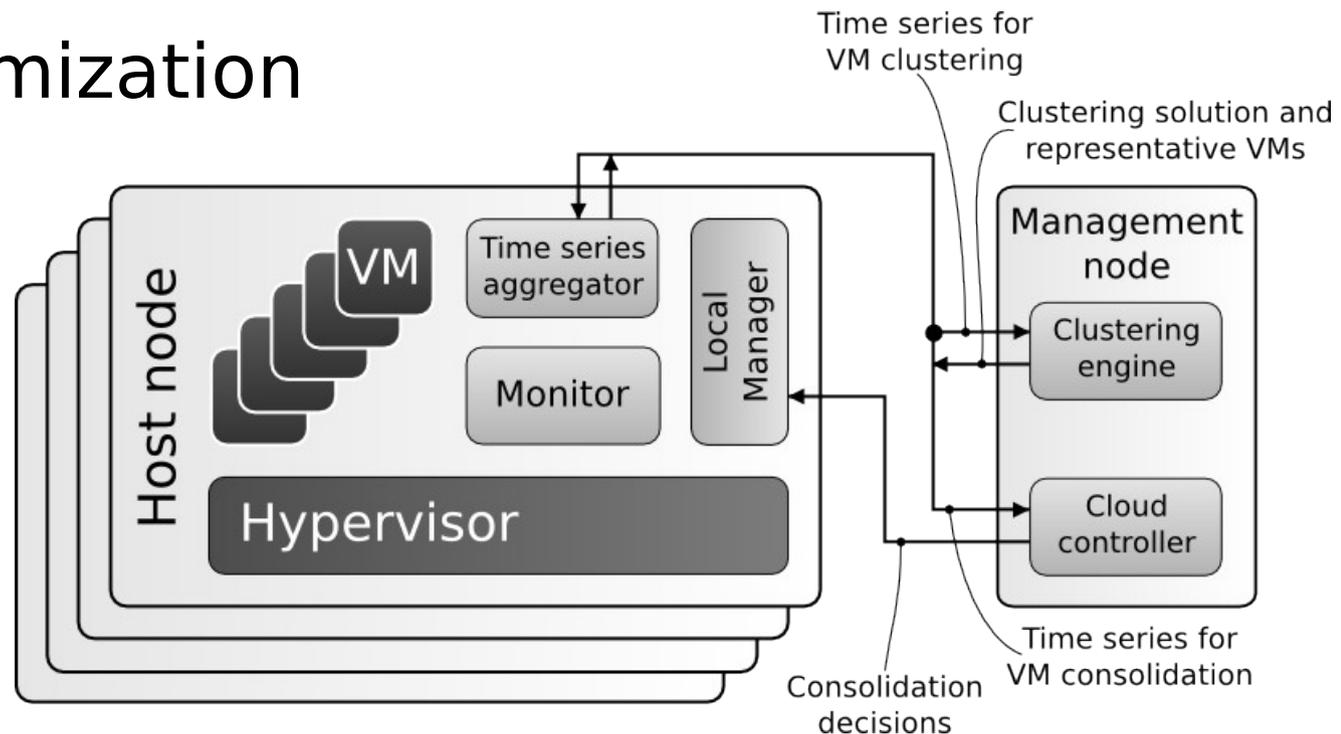


- **VM behavior model built starting with time series of resource usage on VMs**
- **Long time series to characterize VM behavior**
 - → Highly accurate clustering
- **Clustering accuracy decreased by shorter time series**
 - → problems coping with Cloud dynamic behavior
- **Need to combine fast and accurate identification of VM behavior**

Reference scenario



- **IaaS, medium-long term commitment**
 - Amazon Reserved instances, private cloud
- **Reactive VM relocation**
 - Local manager
- **Periodic global consolidation**
 - Global optimization



Our proposal: adaptive approach



- **Observation:**

- Some VMs are easily identified as belonging to a cluster even after short observation
- Other VMs require more detail to build a reliable behavior model

- **Proposal:**

- Cluster as fast as possible VMs clearly belonging to a cluster
- Postpone clustering of VMs when not sure

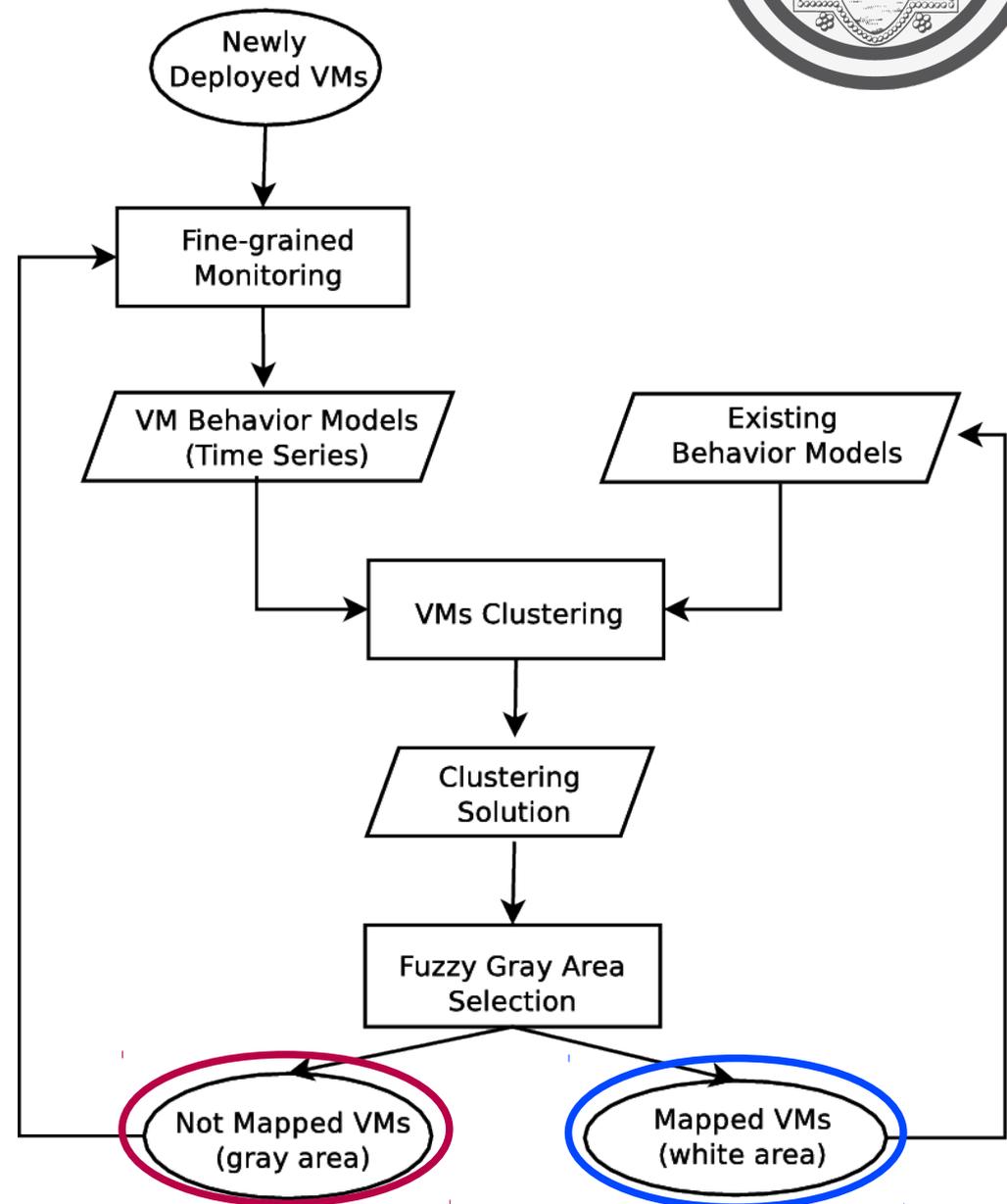
- **Adoption of fuzzy logic perspective**

- Introduce degree of belonging of VM to clusters to rate reliability of clustering result
- **Gray area** of uncertain clustering

Adaptive algorithm



- **Adaptive identification of time series length**
- **When clustering is not ambiguous (white area)**
 - VM behavior model is OK
 - No update required
- **When clustering is ambiguous (gray area)**
 - Need to improve VM behavior model
 - Further observation required



Definition of Gray Area



- **Feature space: k-dimensional space**

- Each VM described by a feature vector (point in feature space)
- Each cluster has a centroid described as a point in the feature space

- **For each VM n:**

- Vector of distances from the cluster centroids

$$D_n = \{d_1^n, d_2^n, \dots, d_C^n\}$$

- **Definition of gray area**

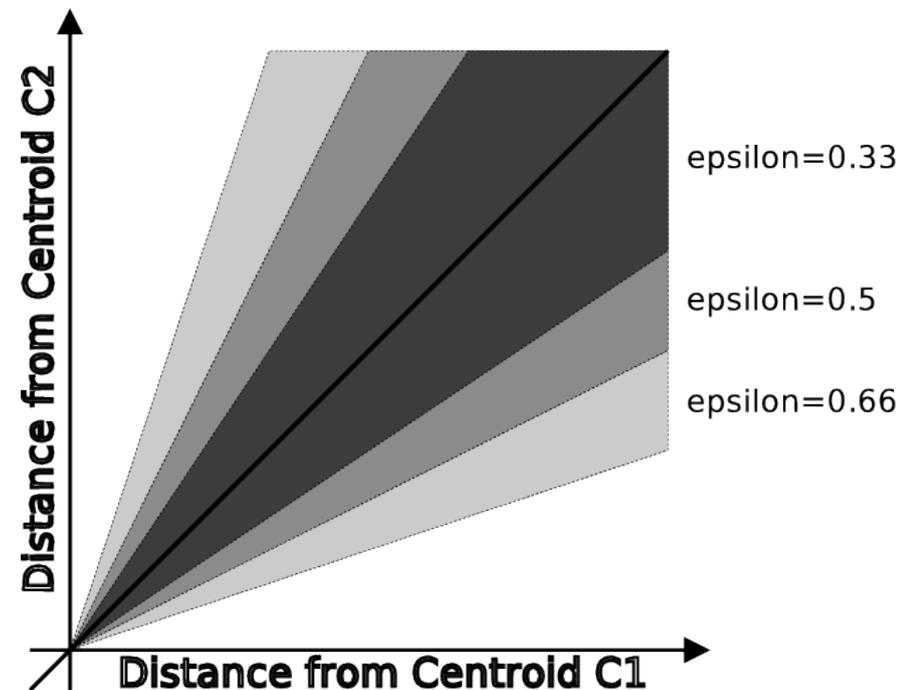
- A VM is in gray area *iif* exists a couple of

clusters i, j such that $1 - \varepsilon < \frac{d_i^n}{d_j^n} < \frac{1}{1 - \varepsilon}, 0 < \varepsilon < 1$

Definition of Gray Area



- **Higher epsilon → wider gray area**
- **Problem: definition of right value of epsilon**
 - Open problem, still working on that...
 - Experimental results suggest $\epsilon=0.33$ as a rule of thumb





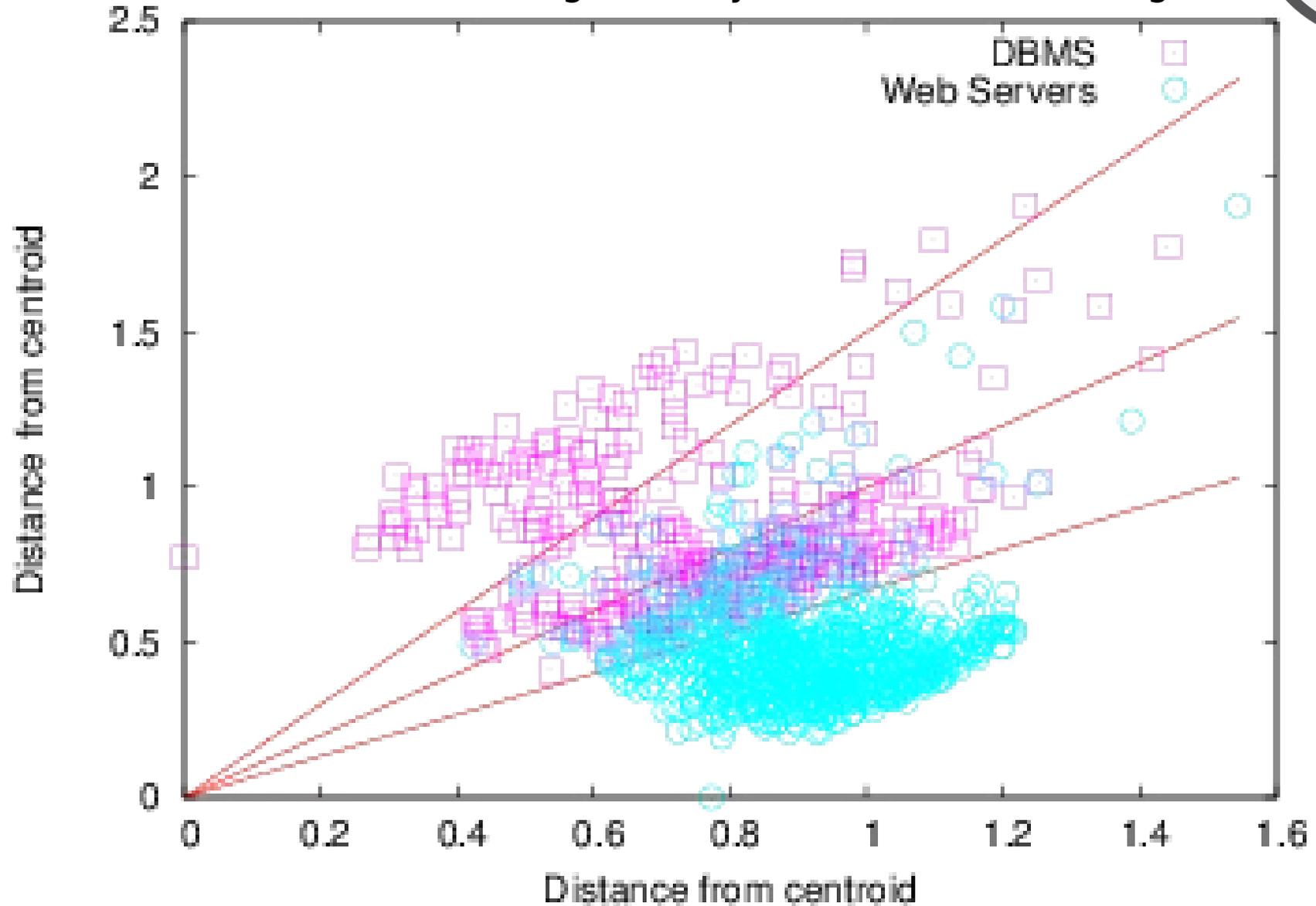
- **Datacenter supporting a e-health Web application**
 - Web server and DBMS
 - 110 VMs
 - 11 metrics for each VM,
 - Sampling frequency: 5 min
- **Goal: separate Web servers and DBMS**
 - Clustering accuracy
 - % of VM in gray area
- **2 VM behavior model approaches**
 - PCA-based
 - Bhattacharyya distance-based



Experimental results



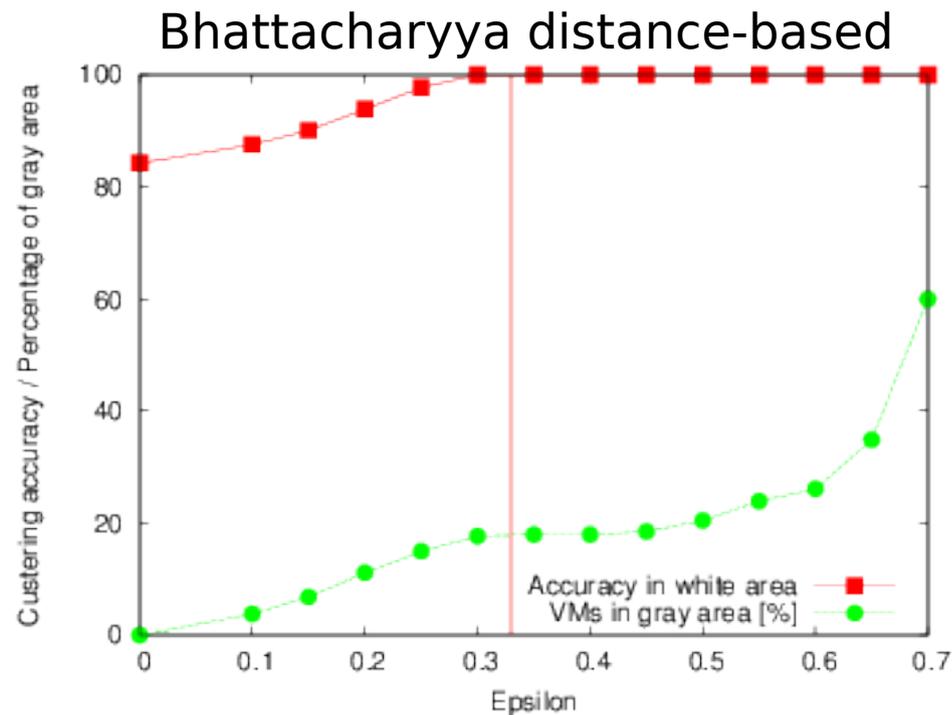
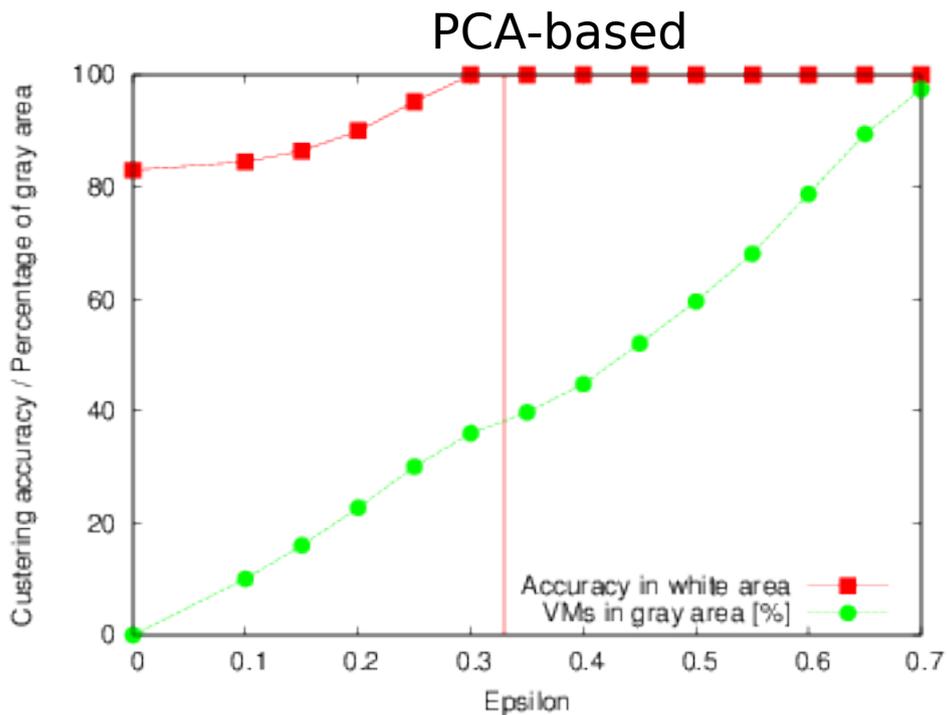
Time series length: 1 day, PCA-based clustering



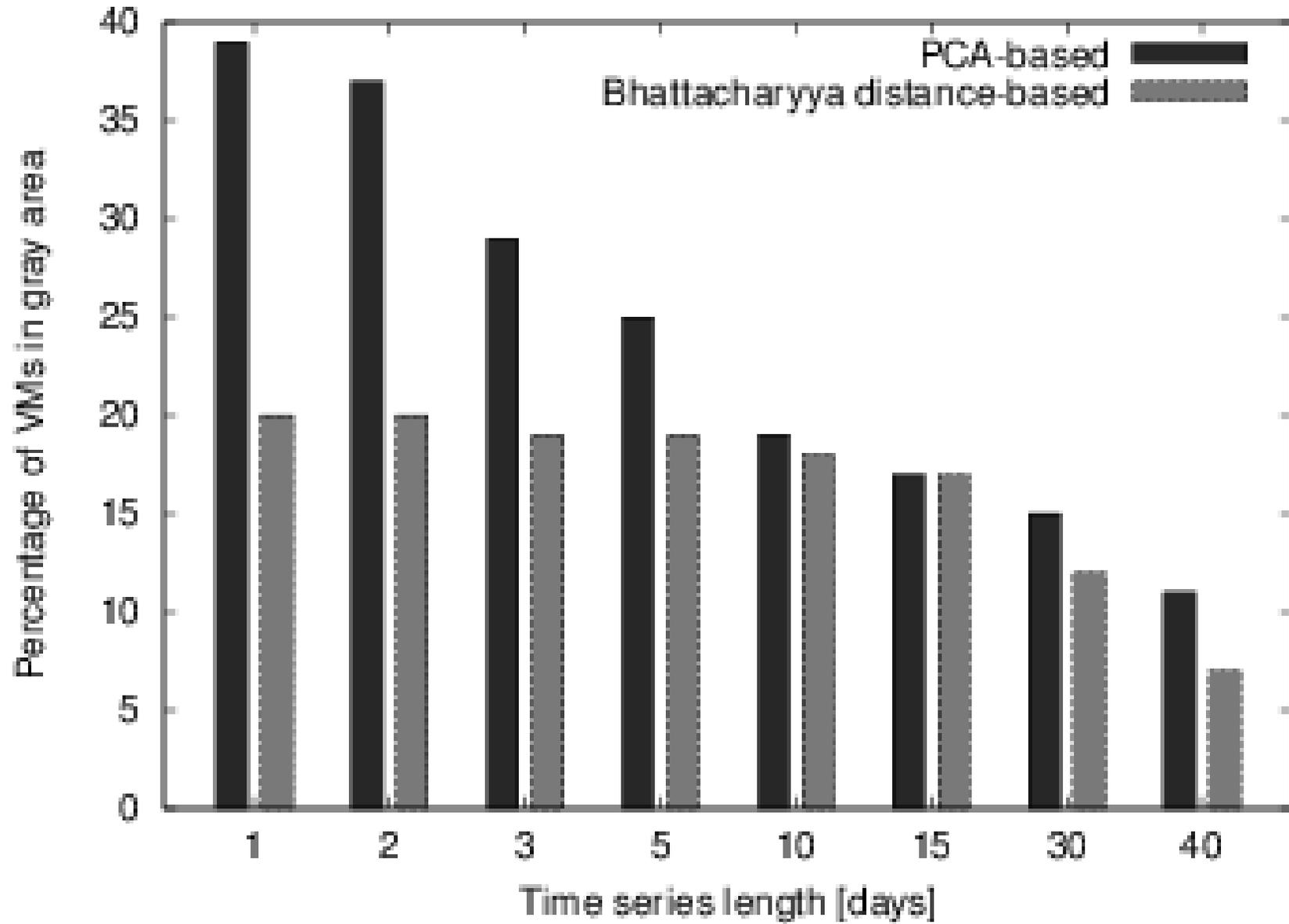
Experimental results



- **Validating the choice of epsilon**
 - For $\epsilon \geq 0.33$ the accuracy is 100% (absence of mis-classified VMs)
 - The size of the gray area depends on the clustering algorithms



Experimental results



Conclusion



- **Experimental results are encouraging**
 - Can achieve high clustering purity
 - Can provide accurate clustering even with very short time series
 - Works with different clustering algorithms
 - Adaptive approach to select the time series length
- **This is not a crystal ball**
 - But may be a useful tool to improve monitoring and management of cloud data centers



On-going works



- **Adaptive selection of the ϵ parameter**
- **Evaluation with time-series < 24 h**
- **Comparison with other fuzzy clustering algorithms**
- **Additional experiments with different workloads (*help appreciated*)**



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