DYNAMIC PLACEMENT OF VIRTUAL MACHINES FOR MANAGING SLA VIOLATIONS
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Why Are We here ?

- Minimize the number of working physical machines without violating the SLA agreement
  - SLA - Service Level Agreement
- Method: Dynamic management algorithm
  - Considering only CPU demand

Contribution

- Method for classification of workload signatures to identify those servers which benefit most from dynamic migration
- Adaptable forecasting technique suited for the classification
- Dynamic management algorithm, referred to as MFR

SLA agreement

- SLA as presented in the article:
  - SLA agreement insures some limit of resources
  - Maximum of p of the time SLA violation allowed
  - Payment for every SLA violation

Potential Impact

- Energy consumption and cost savings
  - Dynamically adjust number of active physical machines to demand
  - Reduce need for overflow capacity
- Reduce labor costs
  - Automatic SLA enforcement in a datacenter
  - Minimize frequency of resource distribution, automatic vs manual rebalancing of resources
- Decrease number of SLA violations
  - For the given number of physical resources workload reduced number of SLA violations (vs. static allocation)
  - Improved fairness of overloads, especially when combined with resource share management

Roadmap

- Static vs. Dynamic consolidation
- Provide intuition using one machine example
- Consider which workloads can achieve the most gain from dynamic management
- Describe the forecasting method
- Present the management algorithm
- Apply the algorithm and measure the benefits

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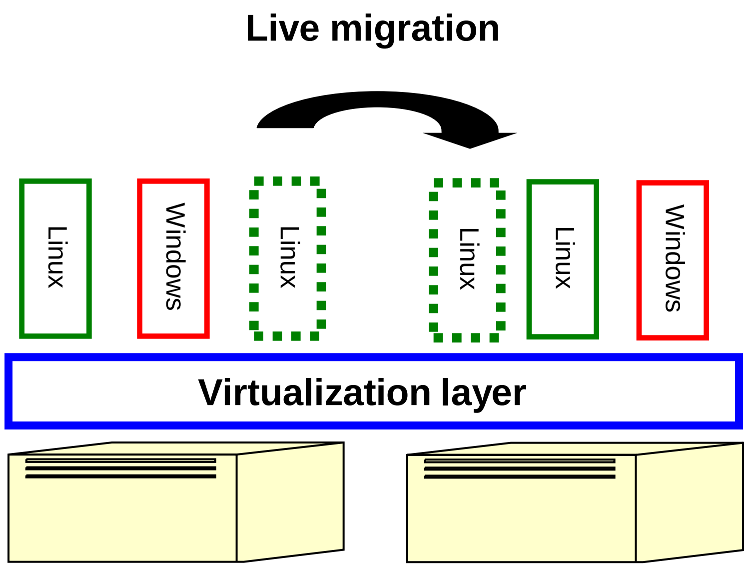
Workload Consolidation: Static and Dynamic

- Static consolidation using virtual machines
  - Determine the best placement of virtual machines on physical machines
  - Based on historical workload behavior e.g.'Phase' of workload important
  - Occasional manual rebalancing periods



- Dynamic resource reallocation
  - Virtual machine can be migrated between physical servers
    - Operation transparent to the user, e.g., TCP connections and other state maintained
    - Performance degradation during migration
  - Migration can be 'live' or via a shutdown/restart of the VM

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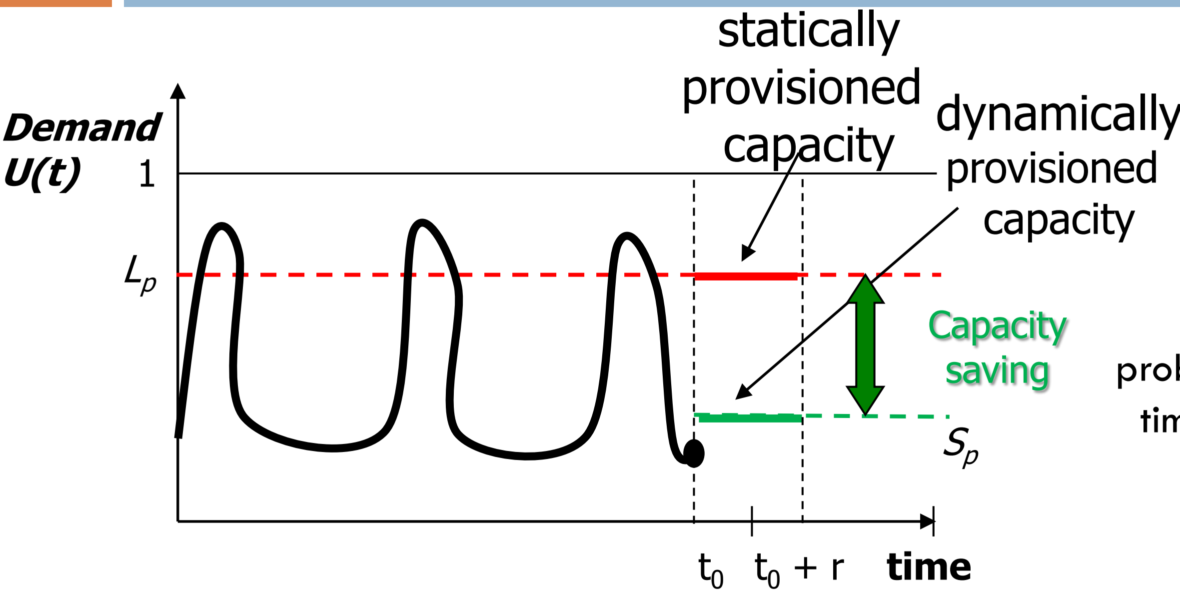
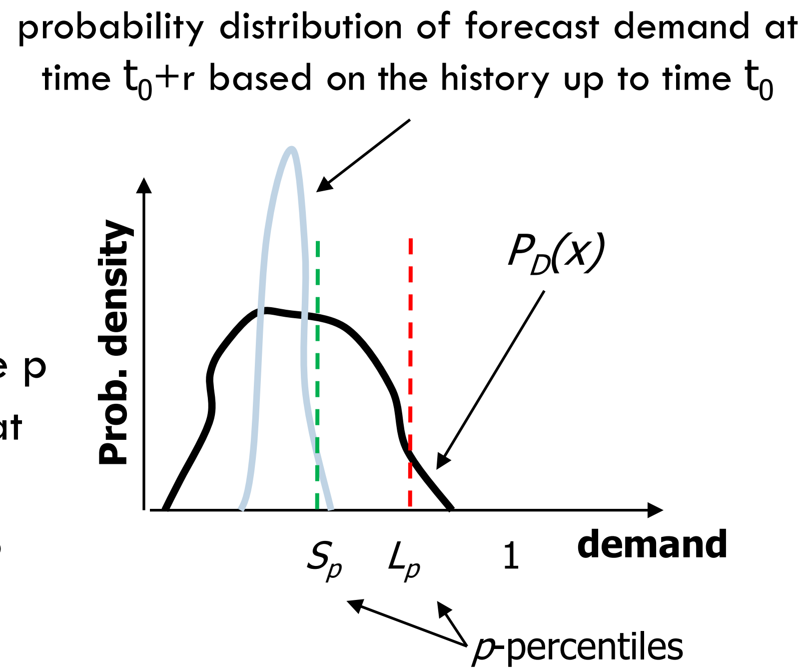
One Machine Example

- One PM
- One VM
- The PM is dynamically adjustable

One Machine Example





- Capacity savings dynamic vs static
  - Lp = static capacity required for overflow rate p
  - Sp = forecast capacity at t_0+r based on U(t) at overload rate p
  - Gain = average of (Lp – Sp), weighted by P_D

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Essential Properties For Dynamic Management

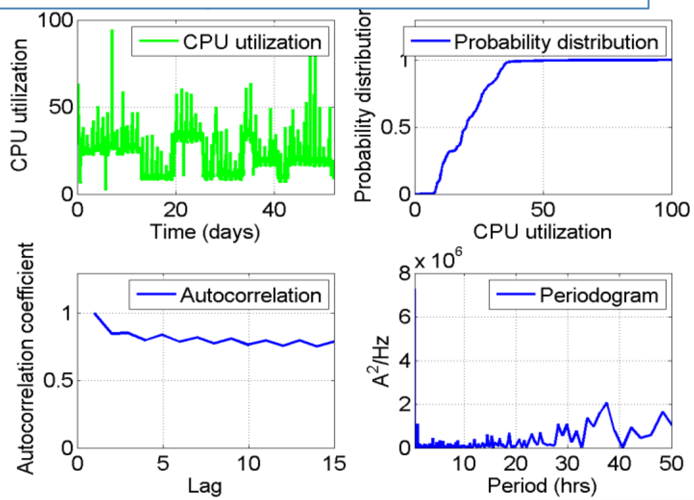
- Significant variability
- The timescale over which the resource demand varies must exceed the rebalancing interval
- The time series has to have significant periodic component or strong autocorrelation.

Cross-correlation : A measure of similarity of two waveforms

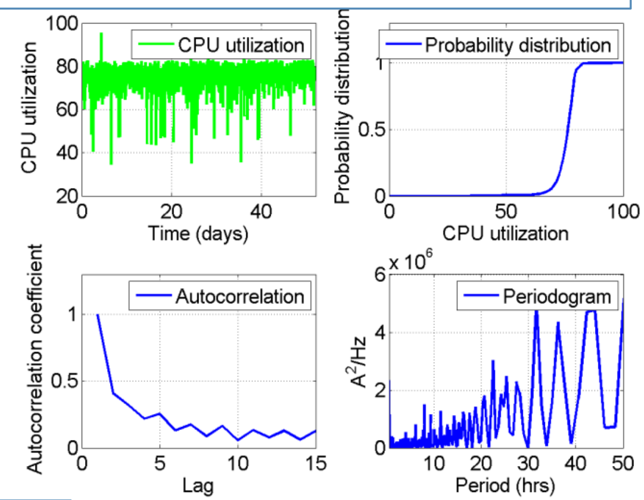
Autocorrelation : The cross-correlation of a signal with itself

Workload Types

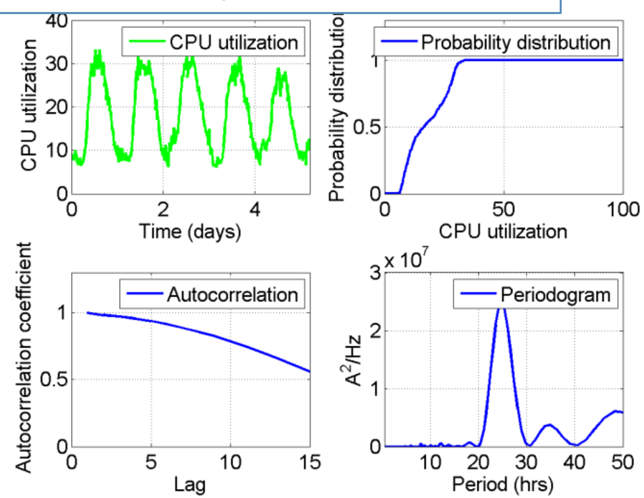
Variable, Autoregressive, no periodicity



Weak auto-regression, low variability



Variable, Autoregressive, 'seasonal'



Gain Calculation

Demand Expectancy

p-percentile of distribution of predictor error

$$E[G] \approx 1 - \frac{E[U] + E_p(\tau)}{L_p}$$

p-percentile of distribution

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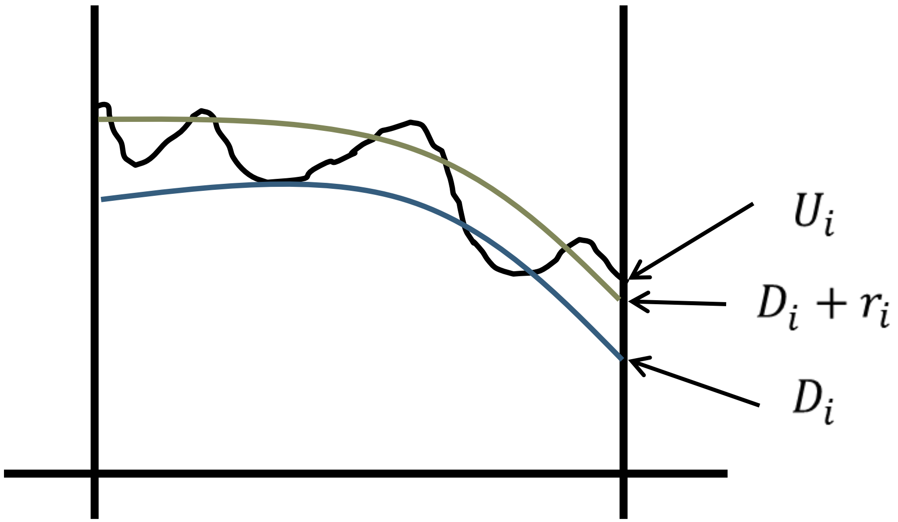
Demand Forecasting

- Demand forecast algorithm
  - Determine the periods in demand using ‘common sense’ aided by periodogram (e.g.time-of-day,day of week,…)
  - Decompose the process into deterministic periodic and residual components $D_i + r_i$
  - Estimate the deterministic part using averaging of multiple smoothed historical periods
  - Fit Auto Regressive Moving Average (ARMA) model to the residual process
  - Use the combined components for demand prediction



- $U_i = D_i + r_i$
- AR(2)
  - $r_i = \alpha_1 r_{i-1} + \alpha_2 r_{i-2} + \epsilon_i$

    ϵ_i – *error of interval i*

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Management Algorithm

- Goal: minimize the time-averaged number of active PMs hosting VMs, not breaking the SLA agreement
  - (The update intervals tested were larger than 15 min)
- Steps:
  - Collect resource data
  - Predict resource demand in the next interval
  - Compute a new mapping (using heuristic)
  - Migrate the machines

Algorithm Scheme

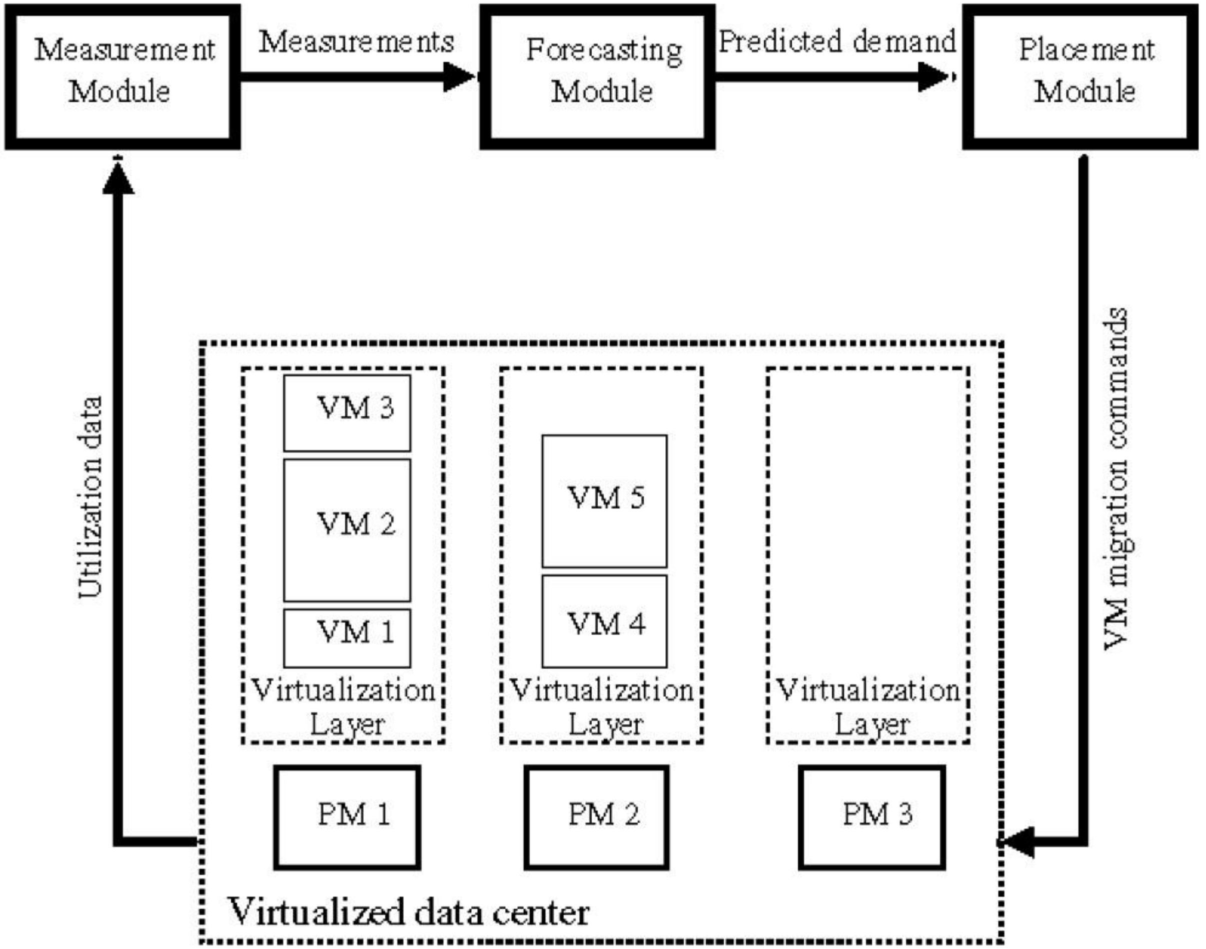
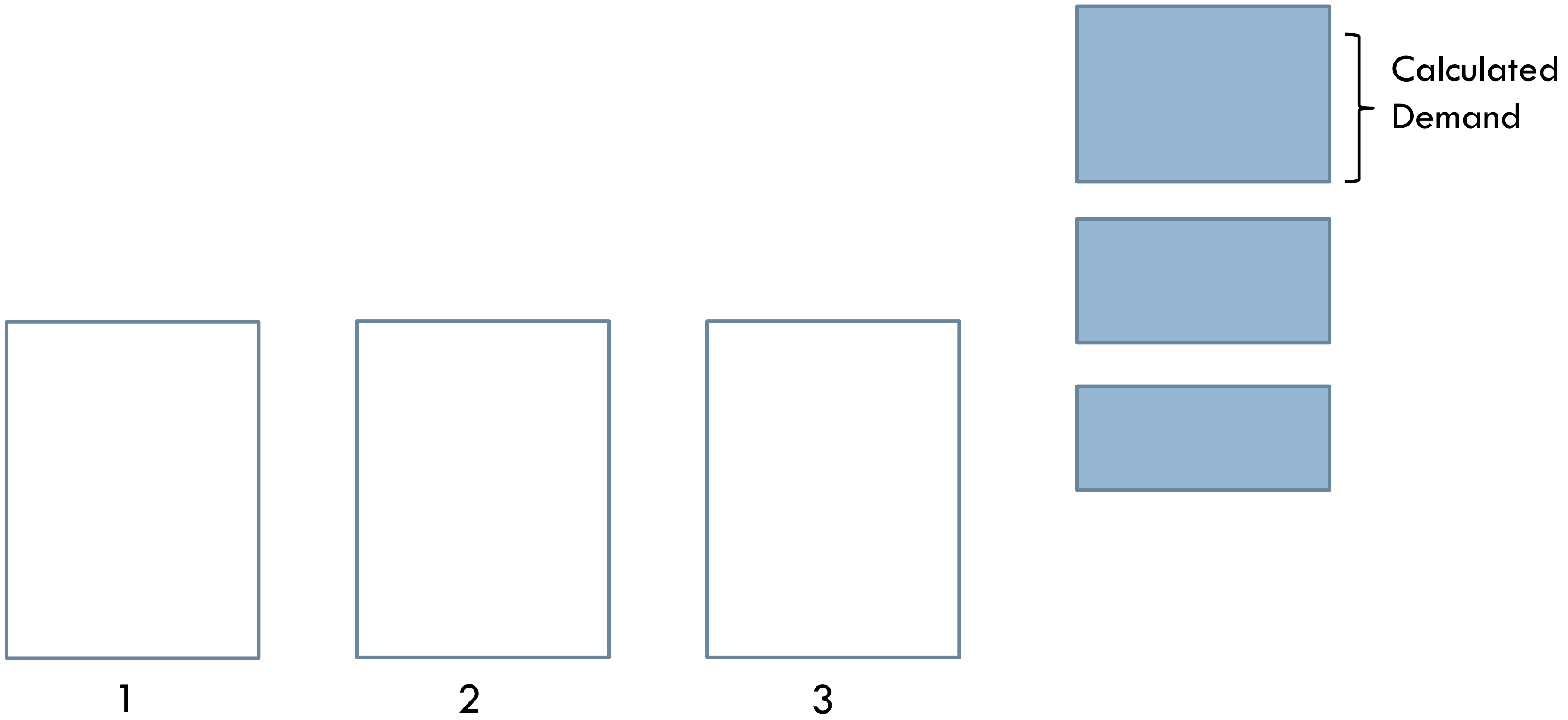


Fig. 5. The architecture of the management algorithm.

Mapping Heuristic

- First-fit bin packing heuristic
  - Used to minimizes the active PMs at each interval

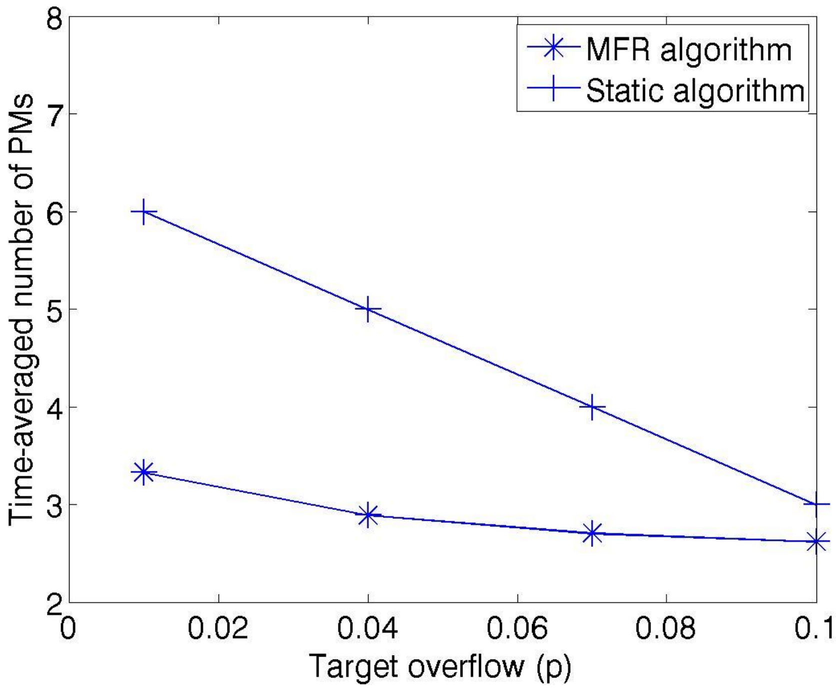


Dynamic Management Algorithm

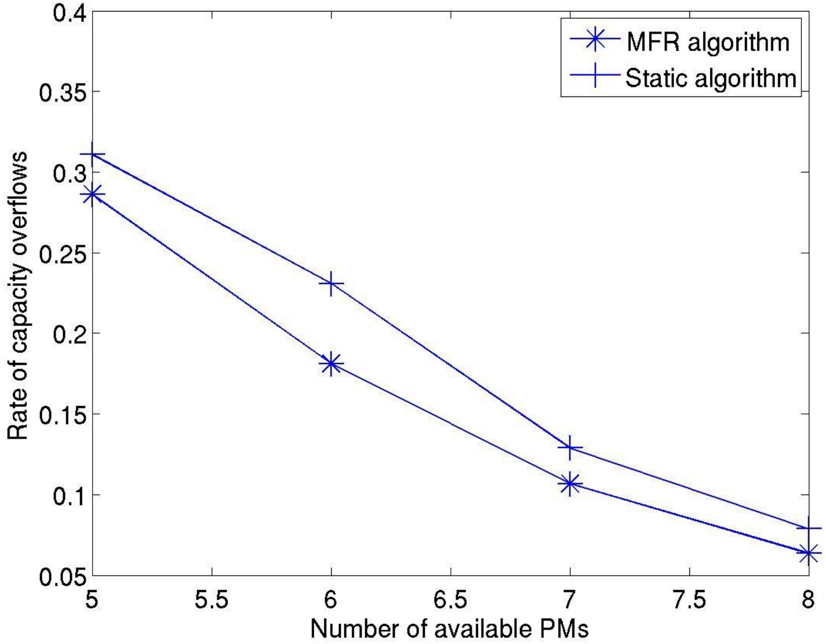
- Select virtual servers best suited for dynamic management
- Then Measure, Forecast, Remap (MFR)
- Remapping performed at regular intervals
  - Migration time provided by virtualization system
  - Degree of service disruption due to migrations
- At each prediction point remap the VMs to physical resources
- Remapping algorithm used in this work
  - Heuristic based, Designed to estimate 'best that can be done'
  - Alternatively, may want to optimize criteria such as fewest moves

Results

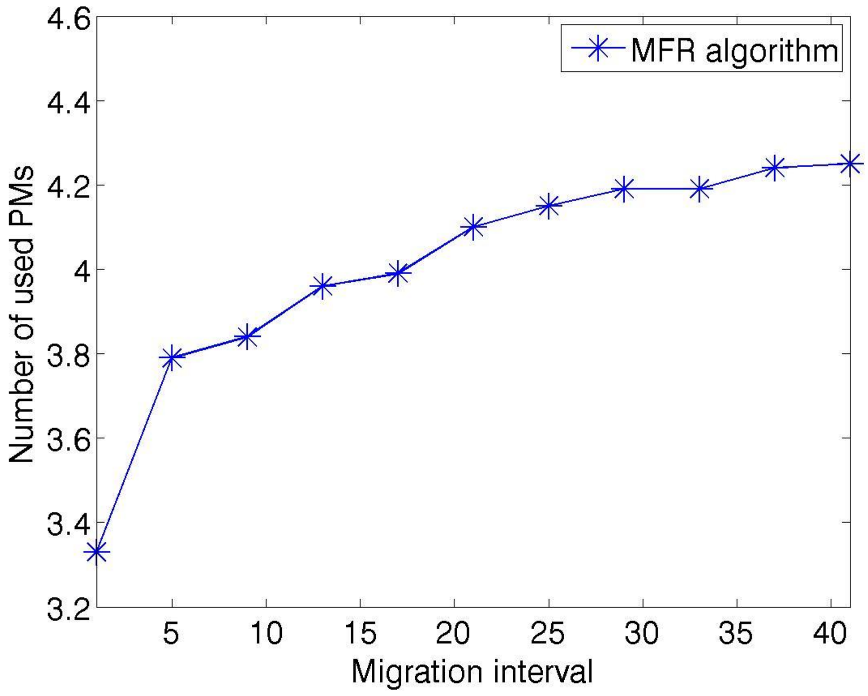
- Significantly reduce active physical resource at fixed overload rate



Results



Reduce overloads at fixed capacity



Forecast accuracy declines with horizon

Research Suggestions

- Dynamic management of datacenters
  - Develop methods for prioritizing migrations in each reallocation step
  - Test multi-resource versions of the algorithm
  - Derive formal relationships between migration interval, workload properties, and expected gain

Thank You!