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
Roadmap

- **Static vs. Dynamic consolidation**
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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
  - \( L_p \) = static capacity required for overflow rate \( p \)
  - \( S_p \) = forecast capacity at \( t_0 + r \) based on \( U(t) \) at overload rate \( p \)
  - Gain = average of \((L_p - S_p)\), weighted by \( P_D \)

\[
\text{Gain} = \frac{\text{average of } (L_p - S_p)}{\int_{-\infty}^{\infty} P_D(x) \, dx}
\]

**Demand:** \( U(t) \) vs Static vs Dynamic Capacity Provision

- Static capacity \( L_p \) for overflow rate \( p \)
- Dynamic capacity \( S_p \) forecast at \( t_0 + r \) based on history up to \( t_0 \)

\[
\text{Capacity saving} = \frac{\text{average of } (L_p - S_p)}{P_D(x)}
\]

\( \text{Demand} U(t) \)
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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

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

- Demand Expectancy
- \( p \)-percentile of distribution of predictor error
- \( p \)-percentile of distribution 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

\[ U_i = D_i + r_i \]

\[ r_i = \alpha_1 r_{i-1} + \alpha_2 r_{i-2} + \epsilon_i \]

$\epsilon_i$ - 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 minimize the active PMs at each interval

1. 2. 3.

Calculated Demand
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!