Optimizing Client-side Resource Utilization in Public Clouds

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Outline

• Motivation
• Solution
• Implementation
• Evaluation
• Conclusion
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Cloud Services
(Not a distraction anymore\(^1\))

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- 30% of total cloud revenue
- Annual revenues crossed $5 Billion

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Other Players:

Popularity

- ZERO up-front capital expenses
- On-demand hardware availability
- Flexible pricing options
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Elastic Cloud Compute
Popularity

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- On-demand hardware availability
- *Flexible pricing options*

"Amazon EC2 changes the economics of computing by allowing you to pay only for capacity that you actually use."

**Elastic** Cloud Compute
Limitations

• Allocate resources in fixed sized chunks (EC2 Instances)
  • 1 core, 1GB RAM -> 36 core, 244 GB RAM

• Accurately predict application requirements
  • Undersized VM - Performance degradation
  • Oversized VM - Extra costs

Multiple applications, multiple VMs, no peace
Challenges

• Application requirements vary widely
  • Black Friday for e-commerce websites

http://www.xad.com/media-mentions/mobile-activity-on-xmas-eve-24-pct-higher-than-black-friday/
Challenges

- Application requirements vary widely
  - Black Friday for e-commerce websites
  - Evenings and late nights for Netflix

Challenges

• Application requirements vary widely
  • Black Friday for e-commerce websites
  • Evenings and late nights for Netflix
  • Slashdot effect!

CMUSphinx Project
Challenges

- Humans are bad at estimating workload requirements\(^2\)
- Study of developers at Twitter submitting jobs to datacenter
  - 70% overestimated by 10x
  - 20% underestimated by 5x

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Resource as a Service\(^3\)

1. Fine grained cloud reservations
2. CPU (cycles), memory (pages), I/O (bandwidth), Time (seconds)

- Where does it stop?
- Reduces wasted costs, but difficult to reason about
- Hardware feasibility issues for service providers

Proposal

Take back control!
Tell me more!

Application Mobility + Real-time Management
Application Mobility

• On-demand application migration across machines

• Conventional issues -
  • Application state stored in kernel (file descriptors, sockets)
  • Residual dependencies left on source machine
  • Execution Continuity

We need
- Process Isolation (even from kernel)
- Minimal state in kernel
Now where did I see that before?

Image Source - Wikipedia
Where do I find one of these?

Old idea, but making a comeback in Cloud OS

• Drawbridge from Microsoft Research
• MirageOS from University of Cambridge

Both (claim to) support application-migration!
Real-time Management

• Monitor application requirements in real-time

• Use application migration to organize processes on VMs
Real-time Management

• Monitor application requirements in real-time
  • Relatively easy
  • Working set sizes, idle cycles

• Use application migration to organize processes on VMs
  • Complex
  • Varying configurations and prices of VMs
  • Identifying processes to migrate
  • Downtime / Budgets!
Policies

Steps
• Determine migration events
• Identify process(es) for migration
• Choose target from existing VMs, if possible
• Figure out instance types for creating new VMs
Policies

Metrics (in order of priority)
• Maximize VM utilization
• Satisfy performance guarantees
• Minimize costs

User-Defined Parameters
• Upper limit on cost
• Max downtime per process
Policies

- **Single Application per VM**
  - Easy to reason about
  - Use naive best fit model to find target VMs

- **Multiple Applications per VM**
  - Highly complex optimization problem (NP-Hard)
  - Use Heuristics!
  - Use best fit and explore nearby options to find target VMs
Software Architecture

- Migrator
- Observer
- Utilization Tracking
- VM A
- VM B
- VM C
Software Architecture

Utilization Updates

ACK / Control

Migration Packets

Observer

Observer

Observer

VM A

VM B

VM C

Utilization Tracking
Software Architecture

Observer -> Utilization Updates -> Migrator

Observer -> Migration Packets -> Observer

Observer -> Migration Packets -> Observer

Observer -> Utilization Tracking

VM A

VM B

VM C

Create/Remove VMs

System Admin Console

ACK / Control

Utilization Updates

Utilization Updates

Utilization Tracking

Deleted VM
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Proof of Concept Model

• Linux Containers (lxc)
  • Emulate isolated processes on Drawbridge/MirageOS

• Checkpoint/Restore in Userspace (CRIU)
  • Checkpoint containers on VM A
  • Migrate files to VM B
  • Restore on VM B
Simulator

- Rapidly validate migration policies
- Evaluate the influence of policy parameters on results
- Written in about 2000 lines of Java code
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Experimental Setup

• **Proof of concept model (WIP)**
  • Live migrating SPEC benchmarks running in LXC
  • Observed downtime – 30 seconds (depending of process size)

• **Migration Policy Simulations**
  • Used our own random workload generator
  • 2 workloads of each type – static, high variability and low variability
Capping Costs

Number of Migrations

- Single app
- Multiple apps

Max spending limit per day (dollars)

Overcommitment

- Single app
- Multiple apps

Max spending limit per day (dollars)
Constraining Downtime

Total Cost

- **Max migrations per process per day**
  - **Single app**
  - **Multiple apps**

Overcommitment

- **Max migrations per process per day**
  - **Single app**
  - **Multiple apps**
Suppressing Spikes

Number of Migrations

- Median window size: 1, 4, 8
- Single app
- Multiple apps

Overcommitment

- Median window size: 1, 4, 8
- Single app
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Show me the money

• **Baseline**
  • Used same workloads as the simulation
  • Picked from available VMs that would best fit the workloads
  • No migrations!
  • Cost for 3 days - $45.36

• **Our solution**
  • No migration policy requires more than $15 for 3 days
  • 66% money saved!
Conclusions

• Streamlining cloud operations important with increasing scale
• Current IaaS reservation models insufficient
• Better support needed from cloud providers
  • Amazon EC2 Container Service
• Migration policies have to optimize in a multi-dimensional space
  • Simple ones offer savings too!
Questions?
BACKUPS
Single application per VM
Effect of cost per day

Migrations and Cost

Overcommitment
Migrations cap

Migrations and Cost

Overcommitment

Max number of migrations per process per day

Migrations
Cost
Overcommitment
Median window variations

Migrations and Cost

Overcommitment
Multiple applications per VM
Effect of cost per day

Migrations and Cost

Max amount allowed per day (dollars)

- Migrations
- Cost

Overcommitment

Max amount allowed per day (dollars)

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Migrations and Cost

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