Improving Utilization of Infrastructure Clouds

or: How to have your cake and eat it too

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Infrastructure-as-a-Service Clouds

- Typically provided in the form of Virtual Machines
  - Control: install your own software stack
  - Elastic: easy to expand and contract dynamically
  - On-demand: requests are accepted or rejected immediately

![Cloud Icons]
Nimbus IaaS: How It Works
Nimbus IaaS: How It Works

Nimbus publishes information about each VM

Users can find out information about their VM (e.g. what IP the VM was bound to)

Users can interact directly with their VM in the same way they would with a physical machine.

Slide acknowledgement: Kate Keahey, Argonne National Laboratory
If there are not enough resources available to service a request, the request is rejected

Is this really on-demand?

Solution:
- **Overprovision your infrastructure**: ensure you have enough resources available (most of the time) for your user community
Overprovisioned IaaS Cloud
What’s the problem?

Batch Cluster

Overprovisioned Cloud

Utilization on the Fusion cluster @ ANL
courtesy of Ray Bair, LCRC

Utilization → Cost
How can we increase utilization of infrastructure clouds (to lower overall costs) without sacrificing the ability of the cloud to provision resources on-demand?
Backfill Virtual Machines (VMs)

- Generic VMs deployed on idle cloud VMM nodes
- Must be configured by the cloud administrator
- Can be configured to perform any action
- Preempted by on-demand requests
  - Can be provided to users at a lower cost
  - Variable number of backfill VMs may be available at any given time
Backfill Workloads

- Volunteer computing
- Condor
- Many others!
Example Backfill Deployment

Site A
- On-demand User
- Initiate or Terminate Workspaces
- Workspace Service
- Launch Backfill Nodes
- VMM Nodes
- Nimbus Cloud
- VMM 1: User VM, Backfill VM
- VMM 2: User VM
- VMM 3: Backfill VM
- VMM 4: Backfill VM, User VM

Site B
- HTC User
- Submit Job (3 Tasks)
- Join Pool
- Dispatch Tasks
- Condor Pool
- Workers
- Master
- Dispatch Task
- Workers (Unavailable)
What does backfill mean for you?

- **Cloud providers**
  - *Increase* resource utilization, *decrease* costs

- **Cloud users**
  - Another type of resource lease, *cheaper* than on-demand leases

- **Backfill users (volunteer computing users)**
  - *Inexpensive* option for moving workloads to the cloud
Backfill Design Questions

- **Granularity of backfill deployments**
  - One backfill VM per VMM node or one backfill VM per core? Simultaneously deploy multiple backfill VM images? Allow users to deploy backfill VMs?

- **Size of backfill deployment relative to the IaaS cloud**
  - Allow backfill to utilize all available nodes or only a subset?

- **Backfill VM image deployment**
  - Pre-deploy a backfill VM image on all VMM nodes or transfer a fresh backfill VM image each time a backfill VM is deployed?
Amazon’s Solution: Spot Instances

- Users bid on unused EC2 capacity
- Instances run as long as the bid exceeds the current spot price

Slide acknowledgement: Spot price graphic from Amazon, Inc.
Nimbus: Spot Instances + Backfill VMs

- Nimbus 2.7
  - Released February 15, 2011
  - Includes support for spot instances
    - Contributed by Paulo Ricardo Motta Gomes as part of Google Summer of Code 2010
  - Also includes support for backfill VMs
    - Essentially zero-cost spot instances configured by the administrator
    - Preempted by spot instance requests as well as on-demand requests

www.nimbusproject.org
Implementing Backfill

Customizing the open-source Nimbus cloud computing toolkit
Implementation

- Extended Nimbus 2.6
- Configured only by the Nimbus administrator
- Spot instance and on-demand requests trigger the termination of backfill VMs
- Single Backfill VM image per VMM node, predeployed
  - Why?
- Backfill VMs perform a clean shutdown when terminated
  - Why?
Administrator Backfill Configuration

- Enable/disable backfill
- Deploy on specific number of VMM nodes
  - or: Deploy on as many VMM nodes as possible
- Amount of RAM for backfill VMs
- Number of vCPU cores for backfill VMs
- Termination policy
Backfill Termination Policies

- Random
- Most Recent
  - Terminate the backfill VM that has been running for the least amount of time
- Need more advanced termination policies...
User requests resources (spot instance or on-demand)

Are resources available?

Are backfill VMs running?

Terminate Backfill VM (using termination policy)

Deploy user VMs

Reject user request
Evaluation
Deploying Backfill-enabled Nimbus on FutureGrid
Evaluation Infrastructure

Slide acknowledgement: Graphic from futuregrid.org
Deployed backfill-enabled Nimbus service on *hotel* frontend node

Obtained a dedicated set of 16 8-core (128 cores) VMM nodes to integrate with our custom service

Configured a backfill VM image as a Condor worker that automatically joined up with a Condor master

Used a separate 8-core node for the Condor master
Workloads

- Used realistic workload traces
  - **Backfill**: Condor trace from the Condor Log Analyzer at the University of Notre Dame: condorlog.cse.nd.edu
  - **On-demand**: Nimbus trace of on-demand user requests from the University of Chicago Science Cloud (16 cores)

- Backfill: 748 serial jobs
- On-demand: 56 VMs
  - Overprovisioned cloud
  - Single core VMs
  - Scaled by a factor of 8

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Backfill Workload (Condor Jobs)

[Graph showing the number of VMM cores (Vertical) against time (Second) on the X-axis. The graph compares the number of Backfill VM cores (8 cores/VM), User VM cores (1 core/VM), and Total VMM cores.]

[Graph showing the number of Jobs Submitted, Jobs Complete, and Jobs Running against time (Second).]
On-demand Nimbus Workload
On-demand Workload Utilization

Average utilization: 36.36%  Maximum utilization: 43.75%
Both Workloads (with Backfill VMs)
Utilization with Backfill VMs

Average utilization: 83.82%  Maximum utilization: 100%
Impact on Backfill Workload

Entire backfill workload delayed by 11 minutes and 45 seconds
6.39% overhead

Time jobs first begin executing

Time jobs begin executing for the last time before successful completion
Impact of Backfill VMs on Nimbus Users

Nimbus service response time for on-demand user VM requests

- No Backfill
- Backfill Enabled
Concerns

- Need better on-demand cloud workload traces
  - Amazon or other commercial cloud providers
  - Department of Energy’s Magellan project
  - National Science Foundation’s FutureGrid project
  - You

- Need more advanced backfill termination policies
  - Nimbus is open-source, start experimenting!
Future Work

- Develop and evaluate more advanced backfill termination policies
- Evaluate additional workload traces and models at various scales
  - Include spot instance requests, not just on-demand
- Use multiple backfill VM images, deployed on a more granular level
  - Administrator-defined policies for selecting which to run
- Suspend backfill VMs instead of terminating them
- Energy savings, cost, and pricing research
Concluding Thoughts on Backfill

- Combines existing technologies
  - IaaS clouds and failure-resilient applications (e.g. volunteer computing systems)
- Increases utilization (up to 100%), decreases cost
  - Without sacrificing the ability of the cloud to provision resources on-demand
- Provides additional cloud resource leases to users
  - Cheaper than on-demand leases
- Provides an inexpensive and low-overhead method for backfill users (e.g. volunteer computing users) to move their workloads to the cloud
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Use FutureGrid Today!

- Flexible
  - Deployed a custom Nimbus service
  - Integrated with dedicated backend VMM nodes
  - Evaluated custom IaaS cloud toolkit in a real cloud environment

- Easy to use

Start today

futuregrid.org
Thank You!

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