Towards Scalable and Efficient Scientific Cloud Computing

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Overview

Commercial clouds bring a great opportunity to the scientific computing area. Scientific applications usually need huge resources to run on. However not all of the scientists have access to significant high-end computing systems, such as those found in the Top500 list. Cloud has gained the attention of the scientist as a competitive resource to run HPC applications at a lower cost. But as a different infrastructure, it is unclear whether clouds are capable of running scientific applications with a reasonable performance.

The goal of this project is to assess the ability and the cost of the Amazon EC2 cloud running scientific applications, using customized instances against the local systems with no virtualization. We develop a full set of metrics and conduct a comprehensive evaluation over Amazon EC2 in the following aspects. This work will explore low overhead virtualization techniques (e.g. Palacios VMM), investigate network performance and how it might affect network bound applications, and explore a wide range of parallel and distributed file systems for their suitability of running in a cloud infrastructure.

Finally, we analyze the cost of using cloud for scientific computing and try to find the most cost-effective instances in different use case scenarios

Methodology

Our method evaluates the capability of different instance types of Amazon EC2 cloud for scientific computing and analysis the cost of cloud computing. The method is divided into three parts:

- First: run the micro benchmarks to measure the actual performance and compare with the theoretical peak that we expect to get.
  - also include a non-virtualized system, to understand virtualization effect.
- Second: evaluate the performance of a virtual cluster of multiple instances, running real applications.
- Third: analyze the cost of the cloud based on the actual performance results.

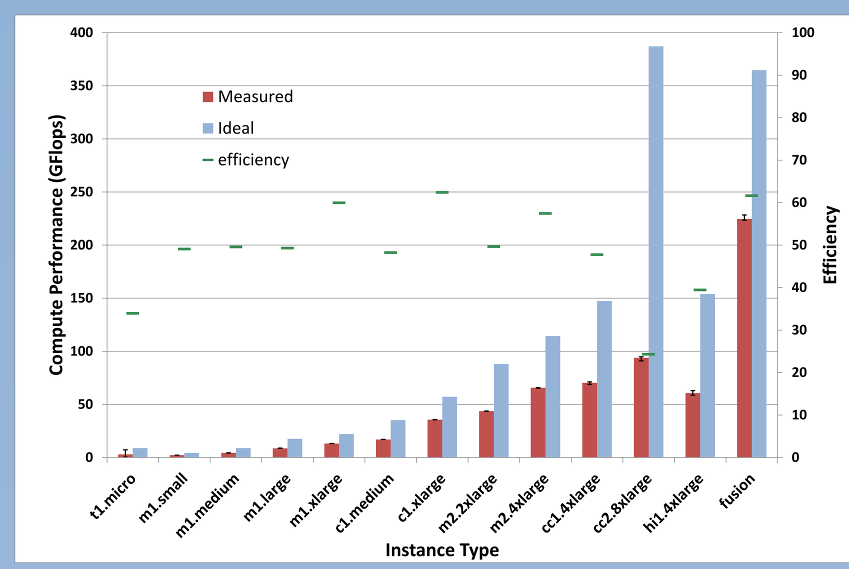
Performance Metrics

The performance metrics for the experiments are based on the critical requirements of the scientific applications. We divide our metrics into different categories:

- CPU:
  - Giga flops (Gflops)
- Memory:
  - Capacity: Giga Bytes (GB)
  - Bandwidth: GB per second (GB/s)
- Network:
  - Bandwidth: Gigabits per sec (Gb/s)
  - Latency: milliseconds (ms)
- I/O:
  - Throughput: Megabytes per sec (MB/s)

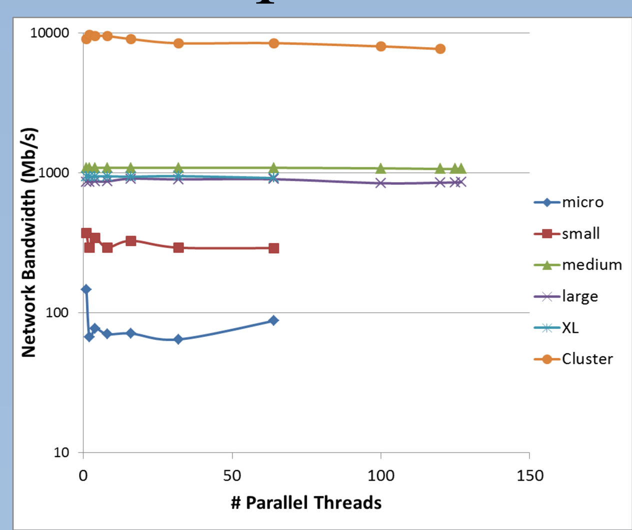
Perforamance Results

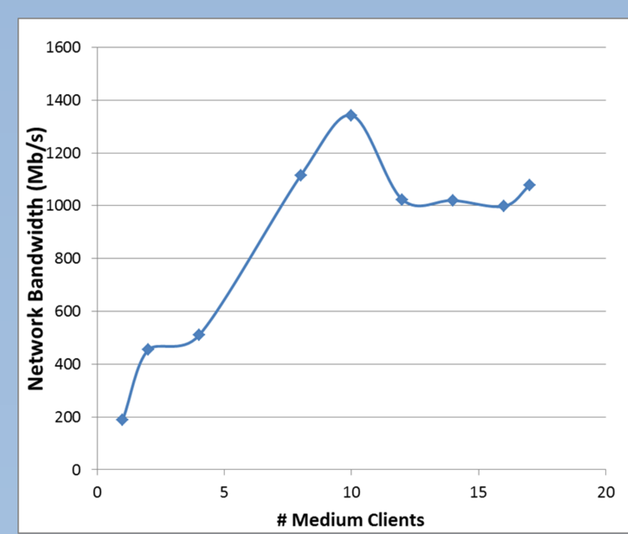
Compute performance



- Low efficiency on compute performance
- High overhead of virtualization on processors

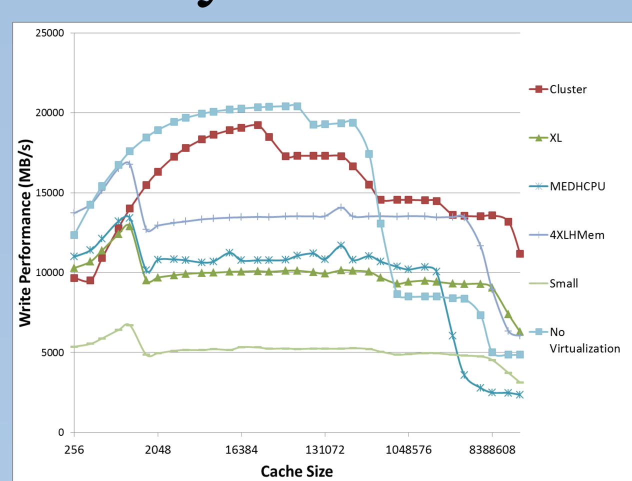
Network performance





- Predictable/stable network performance on single client/server case
- Poor scalability on multiple client case, Not scalable/predictable

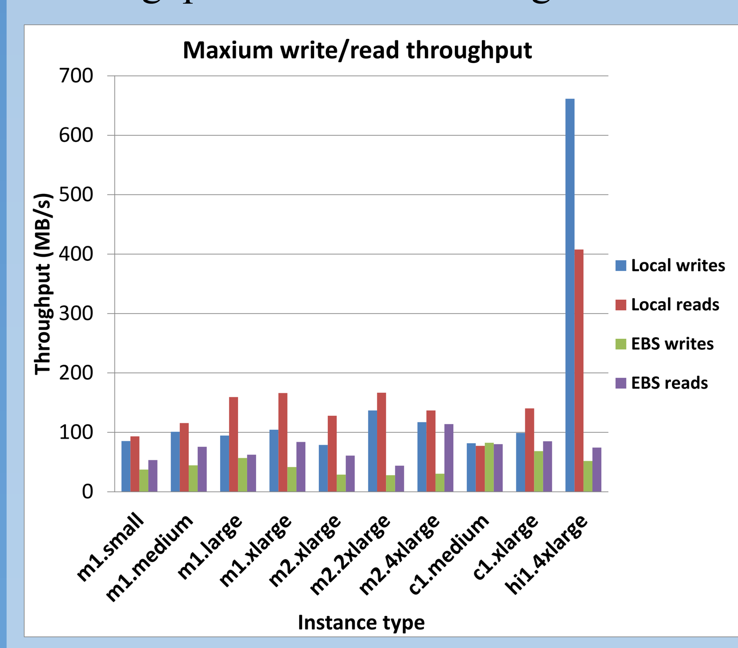
Memory Performance



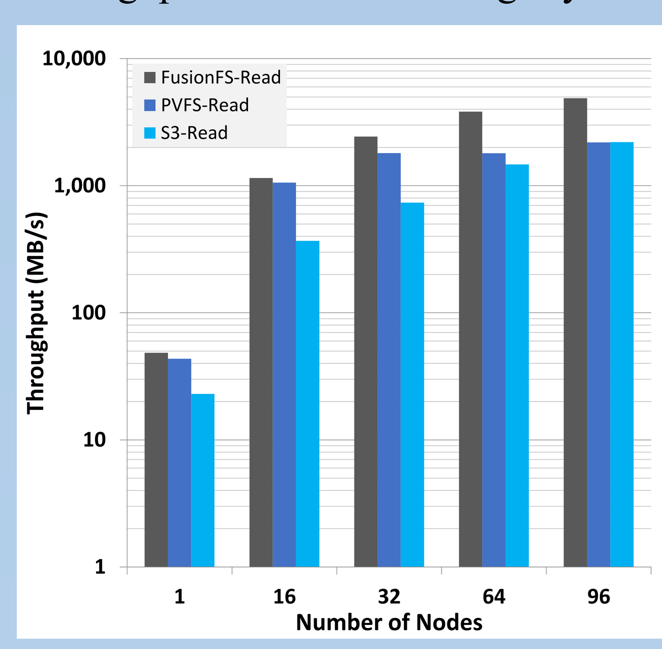
- The memory bandwidth scales perfectly on some instance types. HPC instances beat not-virtualized nodes at large scale
- Unstable write performance, Stable read performance

I/O Performance

Throughput on Instance Storage and EBS

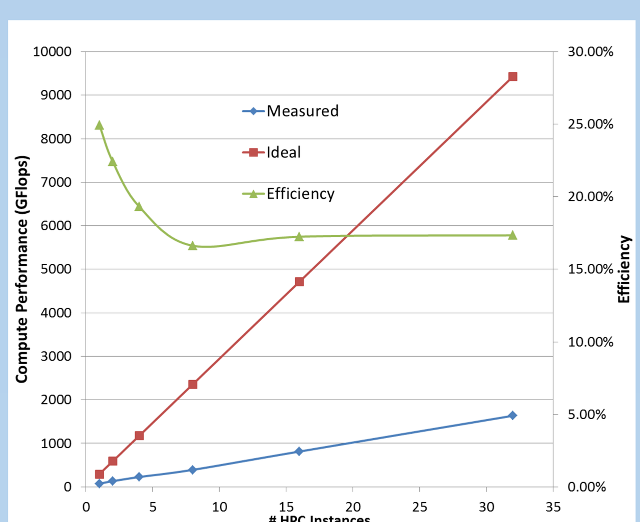


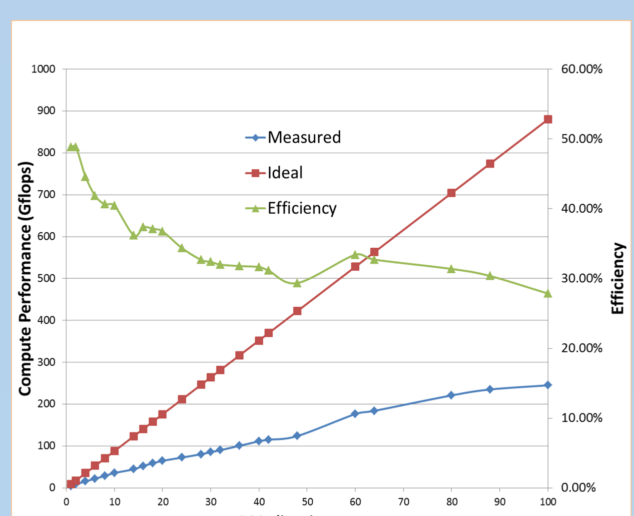
Throughput of different storage systems



- Poor performance on EBS drives because of access over network.
- S3 read throughput is lower than FusionFS and PVFS at smaller scales. The throughput increases linearly with scale. That means it will outperform the other two at larger scales.

Virtual Cluster Performance

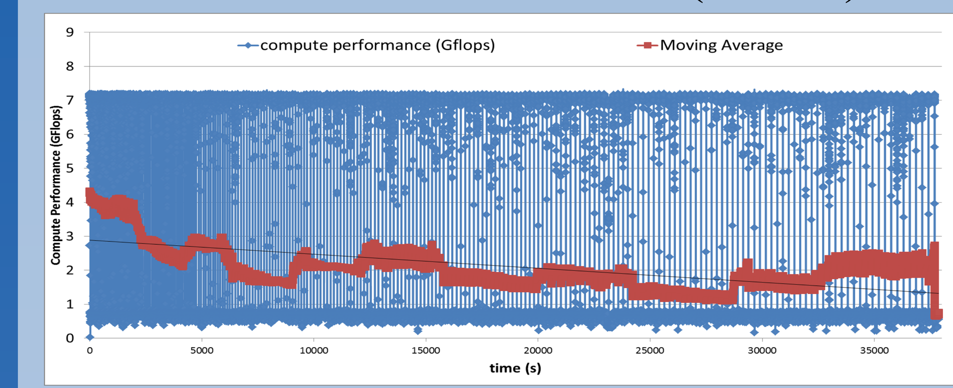




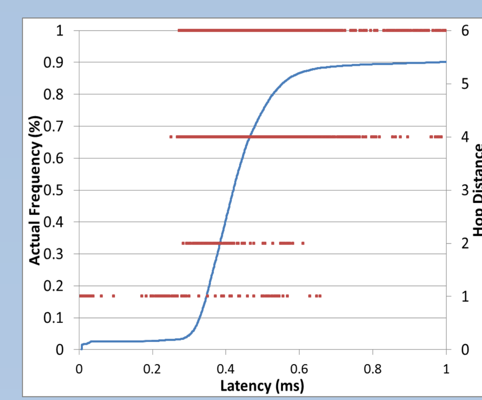
- Poor efficiency at larger scales
- Reason: poor network performance, virtualization effect

Performance Variance

Micro Instance Performance (10 hrs)



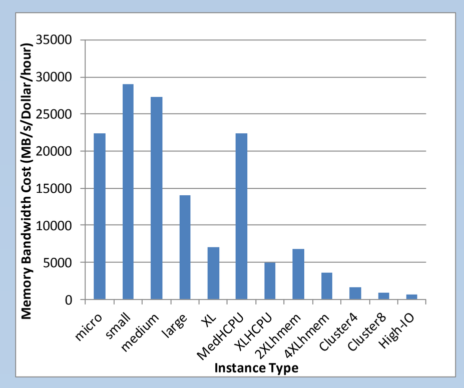
- Performance drop over the time
- Penalize busy instances

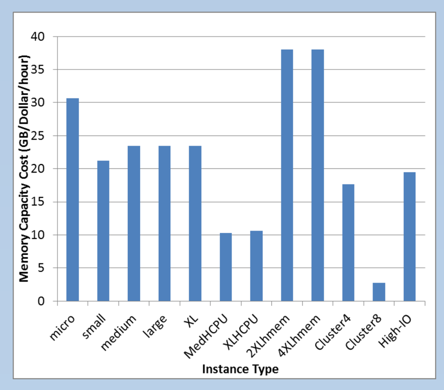


- Latency range: 0.006 - 394 ms, distance: 1 - 6 hops
- Poor correlation between hop distance and latency
- Reason: unstable network, CPU performance. Virtualization effect

Cost Analysis

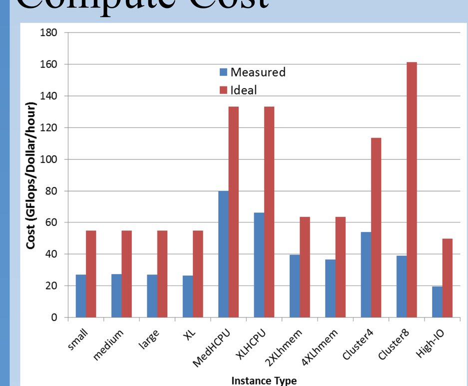
Memory

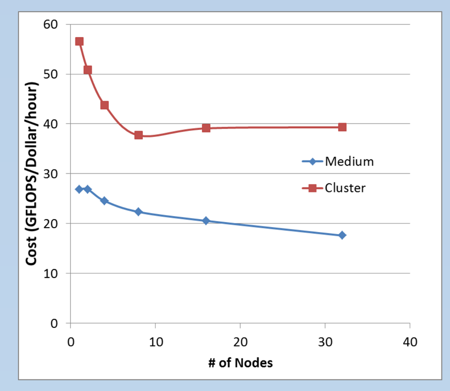




- High-memory instances are the most cost-effective instance in memory capacity. But for the memory bandwidth, smaller instances are more cost-effective

Compute Cost





- Significant difference between measured and ideal cost on HPC instance
- High CPU instances are the most cost-effective ones
- Virtual Cluster: not cost-effective on large scales

Conclusion

- Measured compute performance lower than expected
- Relatively poor and inconsistent interconnect performance inside datacenters
- Need for dedicated resources rather than virtualized, shared resources; need for better isolation of virtualized resources
- Cost effective instances are the smaller instances, poor choice for HPC
- S3 provides a good performance on larger scales.

Future work

- Apply new techniques on the VMM level and evaluate the performance:
  - Pass-through I/O technique
  - Customized Memory Paging technologies
- Evaluate the performance of workflow applications in large scales on Amazon EC2.

References

- Amazon EC2: http://aws.amazon.com/ec2/
- K. Yelick, S. Coghlan, B. Draney, and R. S. Canon, "The Magellan report on cloud computing for science," U.S. Department of Energy, Tech. Rep., 2011.
- Y. Zhao, I. Raicu, S. Lu, X. Fei, "Towards running scientific workflows on Cloud" Tech. Rep., 2012.