**Benchmarking Amazon’s EC2 Cloud Platform**

**Goal of the project:**

The goal of this project is to analyze the performance of an 8-node cluster in Amazon’s Elastic Compute Cloud (EC2). The cluster will be benchmarked and analyzed specifically for the following three metrics: Memory bandwidth, IO performance, and Computational (CPU) performance. These metrics will be required to be measured with increasing number of nodes in the cluster. The benchmarks that measure these metrics are STREAM, IOR (Interleave or Random) and NAS Parallel Benchmarks-Embarrassingly Parallel (NPB-EP) respectively. The Message Passing Interface (MPI) versions of the benchmarks are to be used in the cluster.

To serve as a baseline for comparative purposes, the private cloud based VMs at UNF will also be benchmarked. The results obtained from the private cloud will be compared with the results obtained on the public cloud.

**Description:**

The instance type to be used for this project is micro instance (t1.micro) that is available free of charge for 750 hrs/month for one year per Amazon Web Services (AWS) account. An AWS subscription is required to access this instance.

These benchmarks were written in C and FORTRAN languages. STREAM measures and outputs memory bandwidth in MB/s. IOR measures and outputs input/output performance in MiB/sec (MB/sec = MiB/sec * 1.048). NPB-EP measures and outputs the communication performance. There are two metrics for EP:

i. the execution time measured in seconds

ii. Million operations per second (Mop/s).

When these are run in a cluster they are capable of measuring memory bandwidth, IO performance and communication performance of the entire cluster respectively. Capture the output for these benchmarks by increasing the number of nodes (1, 2, 4, 6 & 8). For example when executing the STREAM benchmark first execute it on 1 node of the micro instance. Then, repeat the process by increasing the number of nodes to 2, then 4, 6 & 8 nodes. Once benchmarking is complete for STREAM benchmark, execute and capture the results for IOR and NPB-EP benchmarks by increasing the number of nodes from 1 to 2, 4, 6 & 8 nodes.

Repeat the above experiments using the 8 VMs assigned to each group on the private cloud at UNF.
Analysis:

1. The results captured for each of these benchmarks must be graphed and analyzed. Be sure to analyze the results obtained as the number of nodes is scaled up for each benchmark and to comment on the scalability of EC2 as observed from the results for each of the benchmarks. For example, compare the memory bandwidth results for 1, 2, 4, 6 & 8 nodes for STREAM benchmark. Perform similar comparison for IOR and NPB-EP benchmarks.

2. You are also required to evaluate the statistical significance of the results obtained for the EC2 cloud vs. the private cloud at UNF using the T-Test function. The built-in function for T-Test in Microsoft Excel outputs a p-value. A p-value of less or equal to 0.05 means the comparison is statistically significant (i.e., the difference in the data sets of the two graphs being compared is statistically significant). A p-value of greater than or 0.05 the comparison is statistically insignificant. You need to document the reasons for why a certain result is statistically significant or statistically insignificant.

3. All groups are also required to carry out following study on Performance Unpredictability in VMs for their projects (for EC2 cloud only):

   For STEAM benchmark, when you capture the memory bandwidth (MB/sec) for 8 VMs, run the STREAM benchmark 6 times on any 2 days (3 runs per day), of week#1 and again on week#2. Then compute the following for week#1 and week#2:
   - mean memory bandwidth,
   - median memory bandwidth,
   - difference between the mean and median as a percentage = \(|\text{mean} - \text{median}| / \text{mean}\)
   - range = max - min
   - standard deviation from the mean both in MB/sec and as a percentage.

   Next, create a box plot for week#1 and week#2 in a graph. A sample box plot is shown below. Note, the Inter Quartile Range (IQR) = \(3^{rd}\) quartile – \(1^{st}\) quartile.
You can download a template to draw this graph in Excel from [http://www.vertex42.com/Files/download2/excel.php?file=box-plot.xls](http://www.vertex42.com/Files/download2/excel.php?file=box-plot.xls)

Your graph for performance variability for two weeks will resemble this graph:

Report this with the rest of your graphs at the time of the first demo. Be sure to include this information in the CD that you turn in at the time of the demo. Refer to slide 40 in the presentation titled A View of Cloud Computing that is available at the website for this class to see what this study is about and what is expected from your study.
Note on drawing conclusions: performance variability is considered to be low if
the range is small, if the difference between the mean and median is < 10%, and if
all individual sample values are within 2 standard deviations of the mean.

Perform a similar study for the IOR benchmark. Refer to slide 41 in the
presentation titled A View of Cloud Computing that is available at the website for
this class to see what this study is about.

Include the results and analysis of these studies 1 and 2 in the paper that each group
submits at the end of the semester.

The following is available at the instructor’s website:

i. A handout to assist and guide you with setting up, configuring, and benchmarking
   EC2
ii. The Stream MPI benchmark zipped file (2 programs written in C), since this
   benchmark may be unavailable at the source

**Project 1**
Setup and configure EC2
Complete benchmarking for the STREAM benchmark
Draw the graphs
Complete the statistical analysis of your results
Points: 45

**Project 2**
Complete benchmarking for the IOR and the NPB-EP benchmarks
Draw the graphs
Complete the statistical analysis of your results
Points: 45

You will provide a demo at the end of each project to the instructor.

**Paper Format**
Points: 50
The paper must be well written and must have the sections listed below. It is good idea to
keep writing your paper as each project ends, rather than waiting till the end of the
semester. This will ensure that your experiences with the technology will still be fresh in
your mind.
Abstract
Describe what your project is about and state its goals (i.e. the benchmarking of the EC2 cloud infrastructure from a systems perspective); what experiments were conducted. The abstract must be concise. Try not to exceed 150 words.

1.0 Introduction
First describe your project in greater depth, i.e. explain your goals, and include a high-level explanation of the EC2 (such as it being an IaaS platform for cloud computing as opposed to a PaaS, or a SaaS platform; explain each type).

2.0 Cloud Computing Platform
You will describe Amazon’s EC2 in detail in this section including the architecture, types of instances offered, performance, security, reliability etc. Be sure to provide references when you refer to texts, papers, and websites etc. to describe EC2.

Also provide a short description of how the EC2 is different from the Google App Engine and Microsoft Azure cloud platforms.

3.0 Related Work
You will conduct a literature survey using the IEEE Digital Library and/or the ACM Digital Library which are available by logging in with your n#/password through the UNF library’s web portal. Cite at least two other papers that have done similar work and comment very briefly (no more than 1 paragraph per paper) on the study carried out, benchmark or methodology used, and conclusions made by the author(s). An example is provided below:

Adams et al in [paper reference # here] performed a quantitative comparison of two Hypervisors, namely VMware’s ESX and XenSource’s XEN. The study was carried out on ... and the benchmarks used were ...The authors concluded that....

Towards the end of the section on Related Work, comment on how your study is different from the two (or more) papers you have described in this section. This could include things like having used different benchmarks, or having used different type of EC2 instances, or having used a different research methodology, or having been more comprehensive in some way etc.

4.0 Result and Comparisons

4.1 Test Bed
Describe the platform used for the study including specifics of the EC2 instances used as well as the specifications of the VMs used in the private cloud.

4.2 Benchmarks and Metrics
Describe each of the benchmarks used and describe the metrics for each benchmark used.

4.3 Research Methodology
Describe how the studies carried out and which experiments were conducted.

4.4 Results
Provide the results by referring the reader to your graph(s) which should be embedded in this section. Explain your results. Also include the results of the statistical studies for both studies 1 and 2. Include box plots for performance variability and describe the results. Your results must include a description of the scalability of EC2 instances for each benchmark used in the study.

4.5 Services Offered
Create a table where you compare EC2 in terms of the services it offers vs. the services offered by Google Compute Engine and HP Cloud.

4.6 Economic Model
Compare the cost/economic model used by each of the three major public cloud providers listed in Section 4.5. This must include the type of instances offered by each and the pricing offered for use. Comment on the strengths of each provider and the type of application that each provider may be better suited for.

5.0 Conclusions
Provide your conclusions, insights that you have gained in this section. Include your assessment of the performance of the EC2 instances for CPU-intensive, memory intensive, and IO intensive computational needs. Point out whether EC2 is better suited to one or the other computational needs and why. Comment on the scalability of EC2 as determined by your results. Also comment on the learning curve in working with EC2 and the benchmarks used.

Provide your overall assessment (based on the services offered, architecture, instance types, and the pricing models of each of the three major cloud services providers) of where each cloud platform may be better suited and the type of applications each platform may be better suited to support in the cloud.

References
Use the following format while listing references. Ensure that every reference number listed in this section within your paper is used/cited somewhere in the body of your paper.