Running MOVES in the Cloud

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EPA Rule Making and Air Quality MOVES Requirements

**The Challenge:**
- Run MOVES for 3200+ US counties for rates (rate per vehicle, rate per distance, rate per profile)
- For seven, slightly different scenarios

**Running MOVES for rates for one county for 2 months (January and July) takes 50 – 80 hours, depending on county temperature extremes, and requires 160 to 240 individual MOVES runs**

**The math, if done serially**
- 3200 (counties) * 65 hrs (average) * 7 Scenarios= 1,456,000 hours, or 60,666.67 days, 166.2 years
The Solution: Step 1: “Representative” Countries

- Representative Counties, methodology
  - Resulted in 103 Representative counties
- Adding runs for January and July, resulted in 206 county/month combinations
- Given the SMOKE/MOVES temperature profiles, each county/month required 50 – 120 individual MOVES runs
- For each scenario, 16,604 MOVES Runs were required
- In early testing, processing 1 county/month on average took about 30 hours
The Solution: Step 2: To the Cloud!

- If only we could launch 206 computers on demand, then we could do ALL 206 county/month combinations in parallel in about 30 hours
Through an EPA contractor and based upon their recommendation, we established an account at Amazon Web Services.

Based upon the SMOKE/MOVES requirements, we developed a series of scripts that would allow us to launch 206 instances (virtual computers) in parallel to:

- process all the MOVES runs required for a county/month and then to process
- another 206 instances to “post process” MOVES output for input to EPA Air Quality modeling systems.
MOVES Processing in the Cloud

- **Data organization and management**
  - Scenario (seven in total)
  - Batch (county/month, 206 in total)
  - Jobs (individual runspecs, 16,604 in total)

- **All MOVES code, default data bases, and runspecs would reside in Amazon “buckets” (1 bucket per scenario)**
MOVES Processing in the Cloud – S3
MOVES Processing in the Cloud – local store
MOVES Processing in the Cloud – local store
MOVES Processing in the Cloud

- Operating system is standard Amazon provided Linux (Centos)
- Instance management done by Amazon Elastic Compute Cloud (EC2)
- Storage done by Amazon Simple Storage Service (S3)
- Queueing done by Amazon’s Simple Queue Service (SQS)
Amazon Processing

- **Scripts were developed to**
  - Upload code, databases, batches to a “bucket”
  - Establish queues, 1 set per scenario (1 queue for jobs and 1 queue for stats)
  - Add batches (county/month) to a queue
  - Download results to local shared drive
  - Check status of each batch
  - Re-add jobs for incompletely processed batches

- **An Amazon instance will process all jobs in a batch and then quit**
Amazon Processing

- Scripts are .bat files and are run from a local directory and the command line on a local EPA computer
- The scripts
  - manipulate data and services at Amazon and
  - manage the transfer of data between Amazon and the local EPA file store
Amazon Processing

S:\MODELING\Tier3\SmokeMovesRuns\PopulateAmazonDataStructure

Folder Tasks
- Make a new folder

Places
- SmokeMovesRuns
- My Documents
- My Computer
- My Network Places

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Amazon Processing

- The Amazon AWS console (browser based) is used to initiate instances and monitor instance status
Experiences to date

“...Thy fate is the common fate of all, Into each life a little rain must fall, Some days must be dark and dreary”

- Longfellow
A widespread failure in Amazon.com’s Web services business was still affecting many Internet sites on Friday morning, highlighting the risks involved when companies rely on so-called cloud computing.

(Note that our presence was purely coincidental!!!
Then, Attack of the “Zombies”

- We experience a 10 – 20 percent instance failure rate when launching instances
- Instances stop responding, CPU goes to zero
  - but not “dead”, still “running” and still incurring charges
- Necessitates manually terminating the instance, re-queueing incomplete batches, and launching new instances
- To complete all batches, 3 to 4 re-runs have been required, resulting in 2-3 times the elapsed time 60-90 clock hrs) vs originally envisioned (30 hrs)
- Amazon very concerned and working with us to find the cause of “zombie” instances
## Conclusions to-date

- Keys to effectiveness are data architecture and easy-to-use scripts for management of cloud processes.
- Is attractive versus acquiring local hardware and incurring corresponding support costs.
- Cloud computing an extremely cost effective (and only the feasible) way to process large scale MOVES runs – parallelism is key!
- Reliability issues will be resolved ("zombies" will eventually be defeated).
Conclusions to-date

- In the cloud, there is a cost vs “clock time” tradeoff
- Faster instances may yield shorter elapsed times, However, they are more expensive.
  - Hi-CPU, On-Demand Instances
    - Medium $0.17 per hour
    - Extra Large $0.68 per hour
  - Cluster Compute Instances
    - Quadruple Extra Large $1.60 per hour
  - GPU Instances Quadruple Extra Large $2.10 per hour
- Each user must consider cost/time tradeoff on their own
- Note: application may not take advantage of enhanced instance capabilities
The Future

● Future plans
  - More research, debugging/testing/refinement is required
  - EPA plans to eventually make scripts, MOVES version(s) and default databases “public” in the “cloud”

● Feedback on interest in a cloud version of MOVES would be welcome