Quantifying CGE Performance: A Unified Scalable Pattern Mining and Search System

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Overview

● **Purpose**
  - Demonstrate the ability to architect a scalable multi platform analytics application
  - Quantify the performance of Cray Graph Engine across multiple platforms and contrasts with competing projects e.g. Apache Spark

● **Results**
  - Strong scaling on Cray XC™ systems
  - Equivalent performance between Cray XC™ and Urika-GX™ systems
  - Substantially better performance than Apache Spark on the same systems

● **Summary**

● **Q&A**
Terminology

● **Cray Graph Engine (CGE)**
  ● Scalable parallel graph analytics framework
  ● W3C Standards Based
    ● Uses RDF Data representation
    ● Uses SPARQL as query language

● **Apache Spark**
  ● In memory parallel analytics framework
  ● Originated from UC Berkeley AMPLab
  ● GraphX is their graph analytics component
Architecture - Hardware Differences

- Understand the physical hardware differences upfront
- Analyze how that will impact your application
- **Cray XC™ versus Urika-GX™**
  - Proprietary blades versus commodity blades
  - Typically larger local memory on GX nodes
  - Direct connection to Aries versus PCI-e connection to Aries expansion card
  - Thousands of nodes versus 48 nodes
  - No local storage versus multiple on-board disks (HDD and SSD)
Architecture - Network Throughput

- Iperf3 Point-Point benchmark
- TCP/IP substantial gap of 20 GiB/s
- Spark relies on TCP/IP

TCP/IP Point-Point Performance - GX vs XC

Message size (Bytes)

Gib/s

- 1
- 10
- 100

- 0.1
- 1
- 10

- 0.01

1 16 256 512 1024 2048 4096 8192 16384 32768 65536 131072
Custom global bandwidth benchmark (16x16)

Fast Memory Access (FMA) is equivalent

CGE relies on FMA
Architecture - Software Considerations

- **Target an appropriate portable runtime**
  - We use Coarray C++ which is backed by PGAS/DMAPP

- **Treat network as the bottleneck**
  - Maximize locality to minimize network usage and global synchronization

- **Abstract launch**
  - Provide a wrapper that allows your application to be agnostic to the underlying workload manager

- **Abstract other subsystems as appropriate**
  - We support IO from both POSIX compliant and HDFS file systems
Experiments
Experimental Setup

- **Hardware**
  - Six cabinet XC with mixed node types
    - 36 core Broadwell nodes with 128GB DDR4-2400 RAM
  - 48 Node Urika-GX
    - 32 core Broadwell nodes with 256GB DDR4-2400 RAM

- **Software**
  - CGE 3.0UP00 running 16 processes per node
  - Apache Spark 2.1.0 w/ Cray patches

- **Datasets**
  - Lehigh University Benchmark (LUBM), a synthetic graph representing academic institutions
    - 25k scale is ~3 billion triples, 200k scale is ~24 billion triples
  - Stanford Network Analysis Project (SNAP)
    - US Patent Citations and two online social networks
Graph analysis workloads

- Two main workloads
  - Pattern matching
  - Whole graph analysis

- Typical systems only good at one
- CGE excels at both
Pattern matching workload

- Given a pattern of interest find all instances thereof
Whole graph analysis workload

- What is the ranking of the targeted vertex?
- What's the shortest route from A to B?
Results
Pattern matching scaling

LUBM200K Scaling

- Strong scaling on most queries

CUG 2017

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Whole graph analysis scaling

**CGE Performance: Pagerank (SPARQL w/ BGF extension)**

- **Strong scaling across all datasets**

![Graph showing CGE Performance: Pagerank (SPARQL w/ BGF extension) for different datasets and node counts.](image-url)
Challenges for multi-platform performance

- **Core Affinity & NUMA Binding**
  - Different workload managers provide very different defaults for core affinity
  - Non-HPC workload managers e.g. Apache Mesos\textsuperscript{TM} don't provide this at all

- **Network performance**
  - Need to minimize network usage so that the additional latency doesn't matter too much
Platform Comparison - GX vs XC

- Performance gap is minimal
- Lot of work to reach this point

CGE Performance: Urika-GX vs XC40
LUBM25K on 32 nodes

- Strict query time (seconds)

Query 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Urika-GX
XC-40
Spark Comparison

- We created Spark versions of all the experiments described in the paper
- For pattern matching our codes were taken from past work carried out by Oak Ridge National Lab (ORNL)
- For whole graph analysis we compare 3 approaches:
  1. Spark code using GraphX package
  2. Iterative approach using standard SPARQL
  3. Native Coarray C++ using Cray SPARQL extensions
Pattern matching - Spark Comparison

LUBM25K CGE vs. Spark GraphX Performance
128 Nodes XC-40

CGE 1-2 orders of magnitude faster
Whole graph analysis - Spark Comparison

- CGE order of magnitude faster
- Iterative SPARQL approach equivalent to Spark
Whole graph analysis - Spark Comparison

- CGE order of magnitude better than Spark
- Dataset characteristics affect performance
Summary

- Demonstrated the ability to architect a scalable multi-platform analytics application
- Quantified the performance of Cray Graph Engine across multiple platforms on a variety of workloads
  - Strong scaling on Cray XC™ systems
  - Substantially better performance than Apache Spark for both pattern matching and whole graph analysis workloads
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