CRAY

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^{TM} systems
  - Equivalent performance between Cray XC^{TM} and Urika-GX^{TM} systems
  - Substantially better performance than Apache Spark on the same systems
- **Summary**
- **Q&A**

Terminology

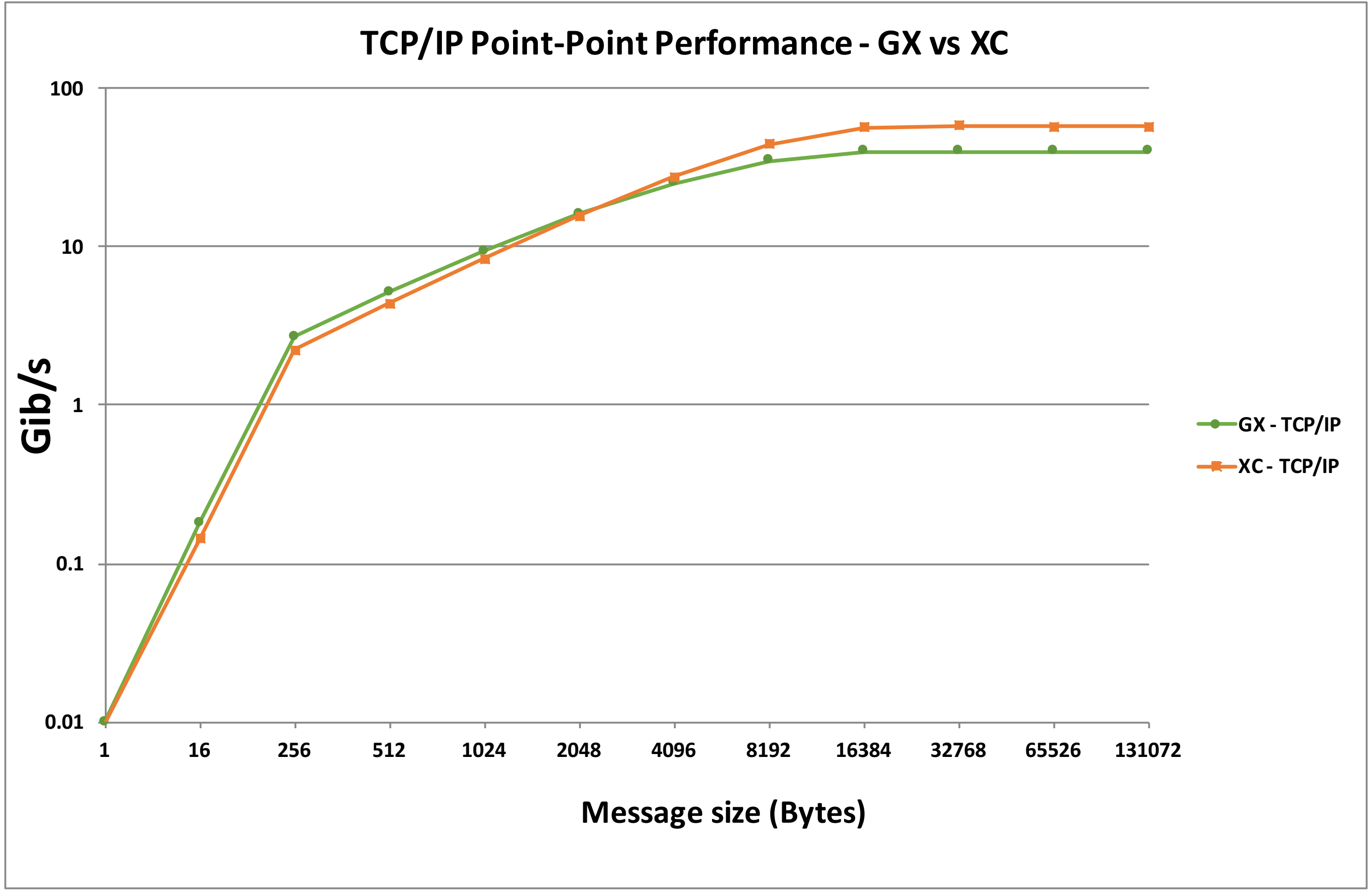
- **Cray Graph Engine (CGE)**
  - Scalable parallel graph analytics framework
  - W3C Standards Based
    - Uses RDF Data representation
    - Uses SPARQL as query language
- **Apache Spark**
  - In memory parallel analytics framework
  - Originated from UC Berkeley AMPLab
  - GraphX is their graph analytics component

Architecture

Architecture - Hardware Differences

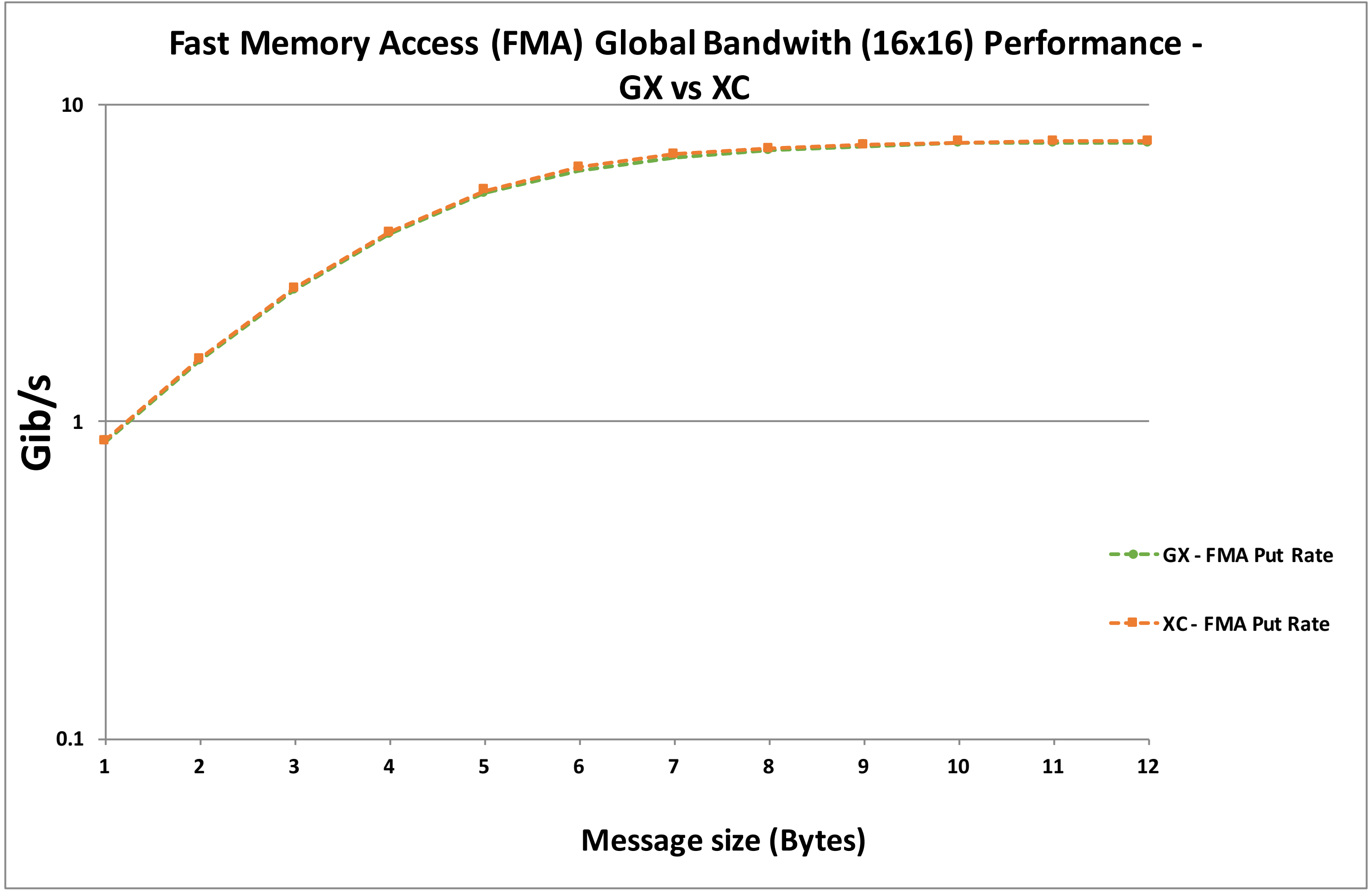
- Understand the physical hardware differences upfront
- Analyze how that will impact your application
- Cray XC™ versus Urika-GX™
  - Proprietary blades versus commodity blades
  - Typically larger local memory on GX nodes
  - Direct connection to Aries versus PCI-e connection to Aries expansion card
  - 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

Architecture - Network Throughput



- Custom global bandwidth benchmark (16x16)
- Fast Memory Access (FMA) is equivalent
- CGE relies on FMA

Architecture - Software Considerations

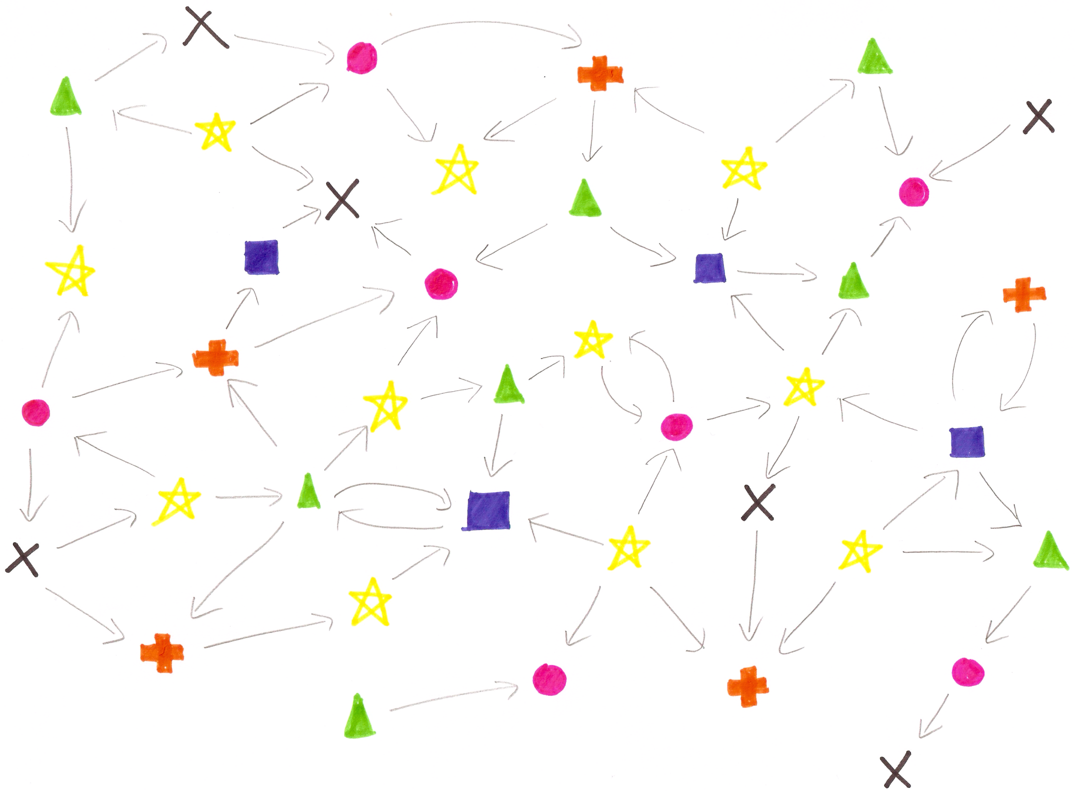
- **Target an appropriate portable runtime**
  - We use Coarray C++ which is backed by PGAS/DMAPP
- **Treat network as the bottleneck**
  - Maximize locality to minimize network usage and global synchronization
- **Abstract launch**
  - Provide a wrapper that allows your application to be agnostic to the underlying workload manager
- **Abstract other subsystems as appropriate**
  - We support IO from both POSIX compliant and HDFS file systems

Experiments

Experimental Setup

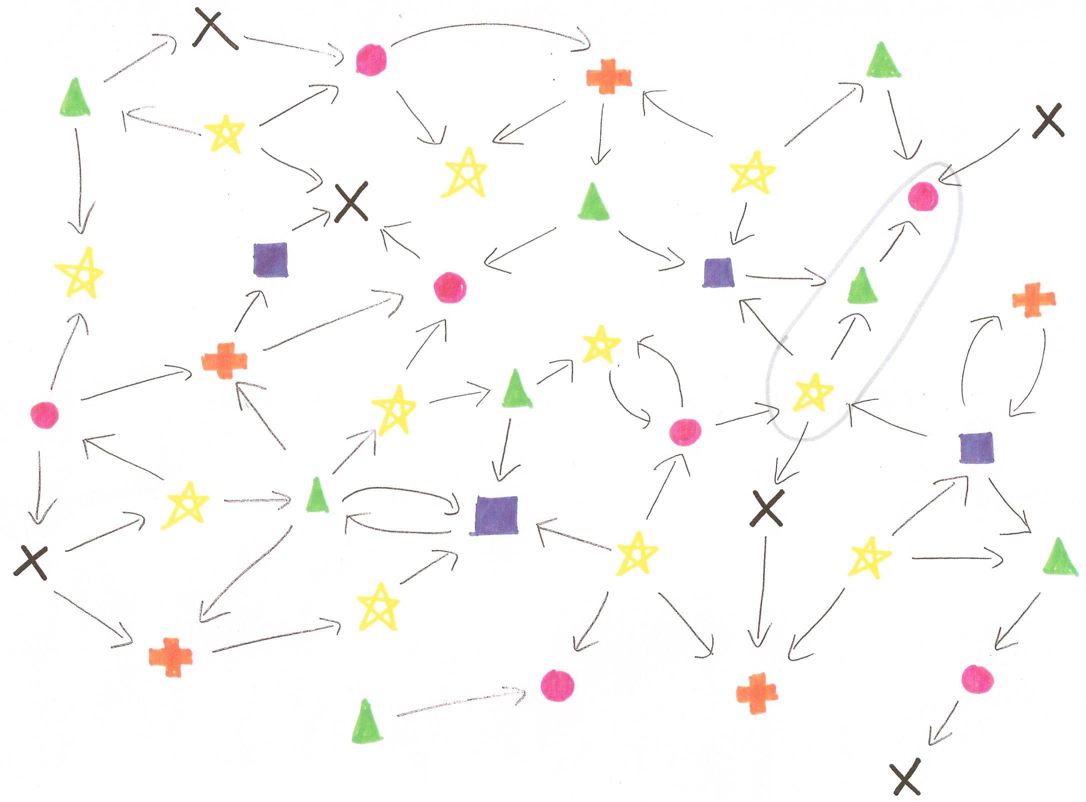
- **Hardware**
  - Six cabinet XC with mixed node types
    - 36 core Broadwell nodes with 128GB DDR4-2400 RAM
  - 48 Node Urika-GX
    - 32 core Broadwell nodes with 256GB DDR4-2400 RAM
- **Software**
  - CGE 3.0UP00 running 16 processes per node
  - Apache Spark 2.1.0 w/ Cray patches
- **Datasets**
  - 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

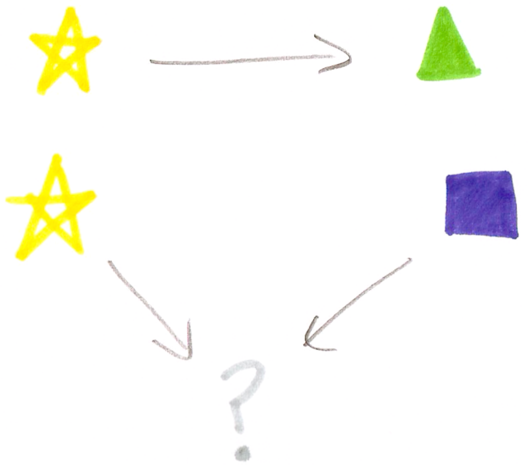


- Two main workloads
  - Pattern matching
  - Whole graph analysis
- Typical systems only good at one
- CGE excels at both

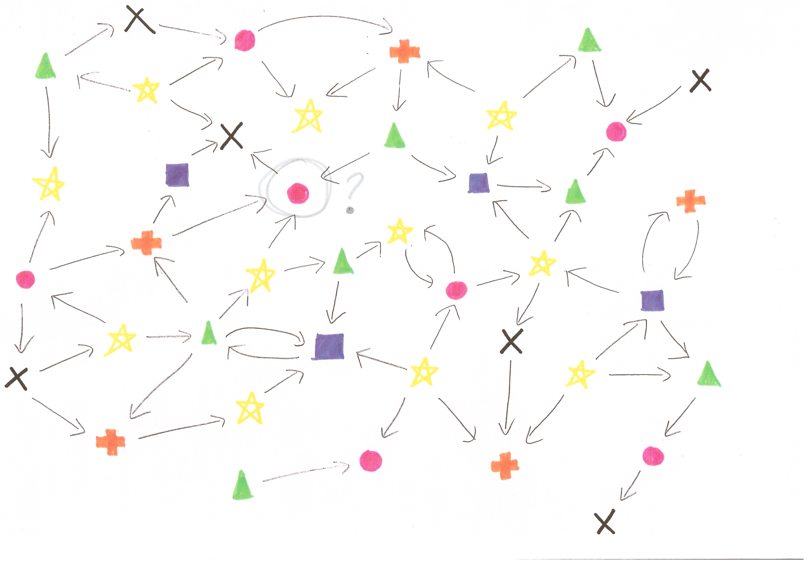
Pattern matching workload



- Given a pattern of interest find all instances thereof

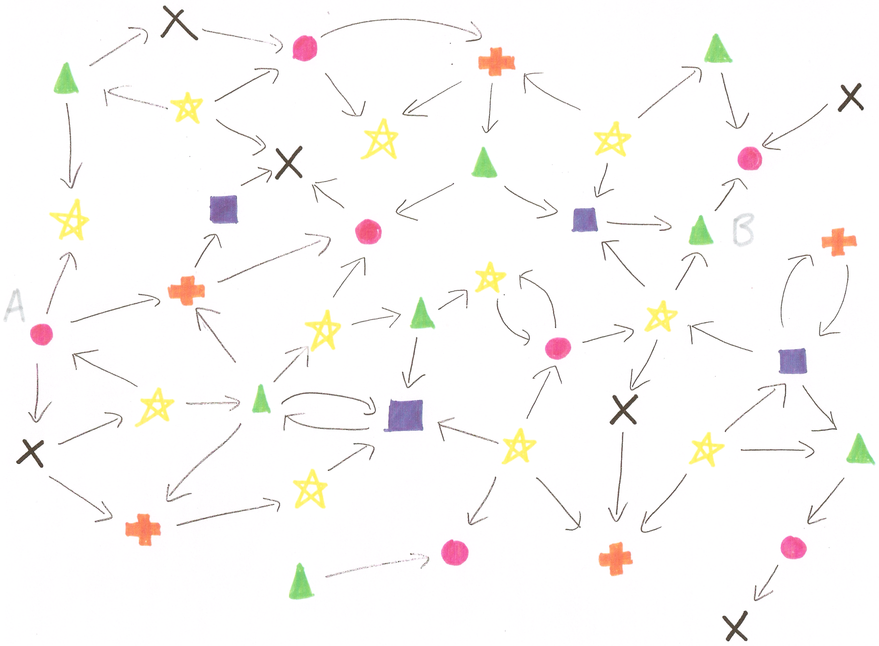


Whole graph analysis workload



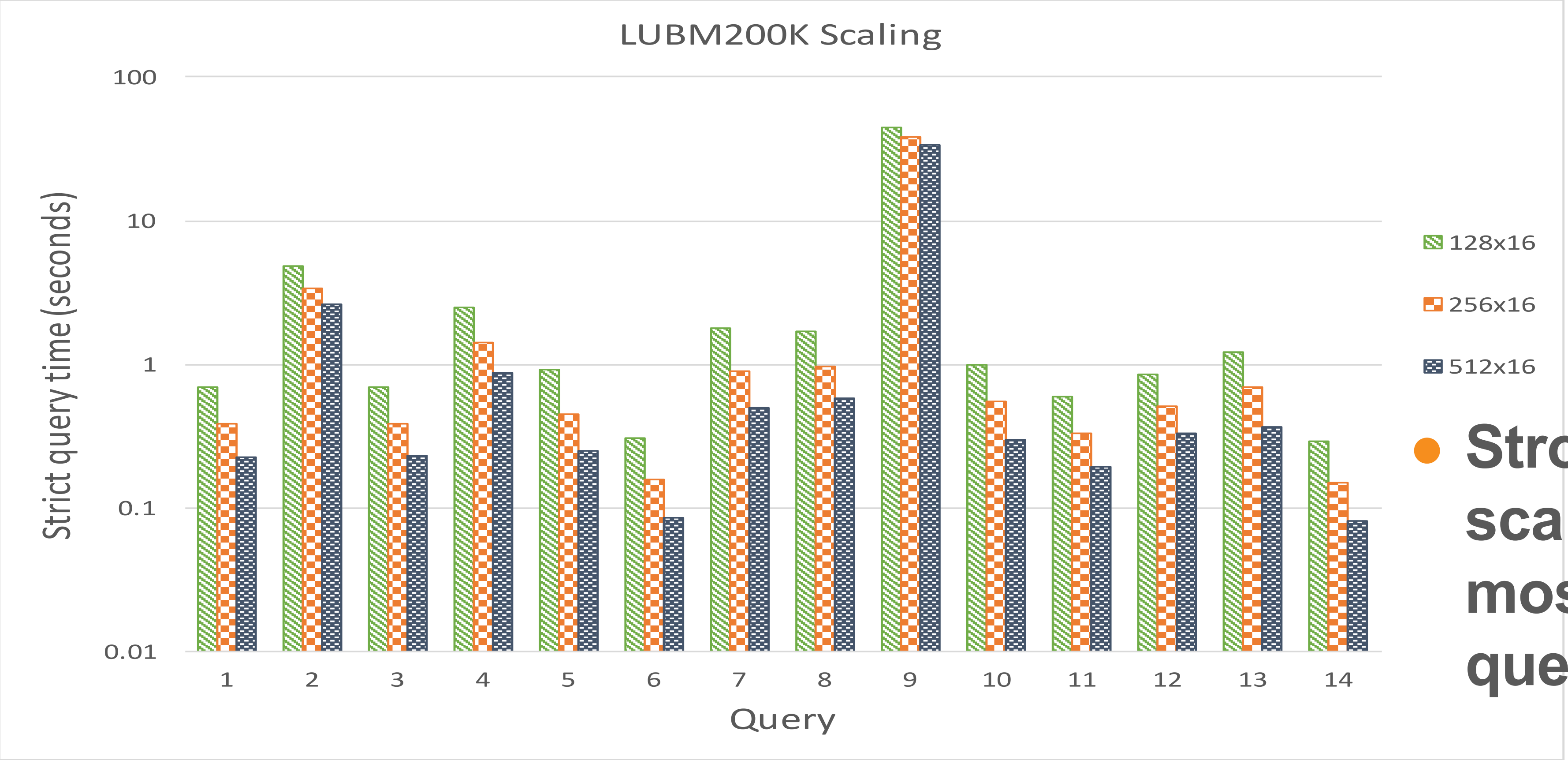
- What is the ranking of the targeted vertex?

- What's the shortest route from A to B?



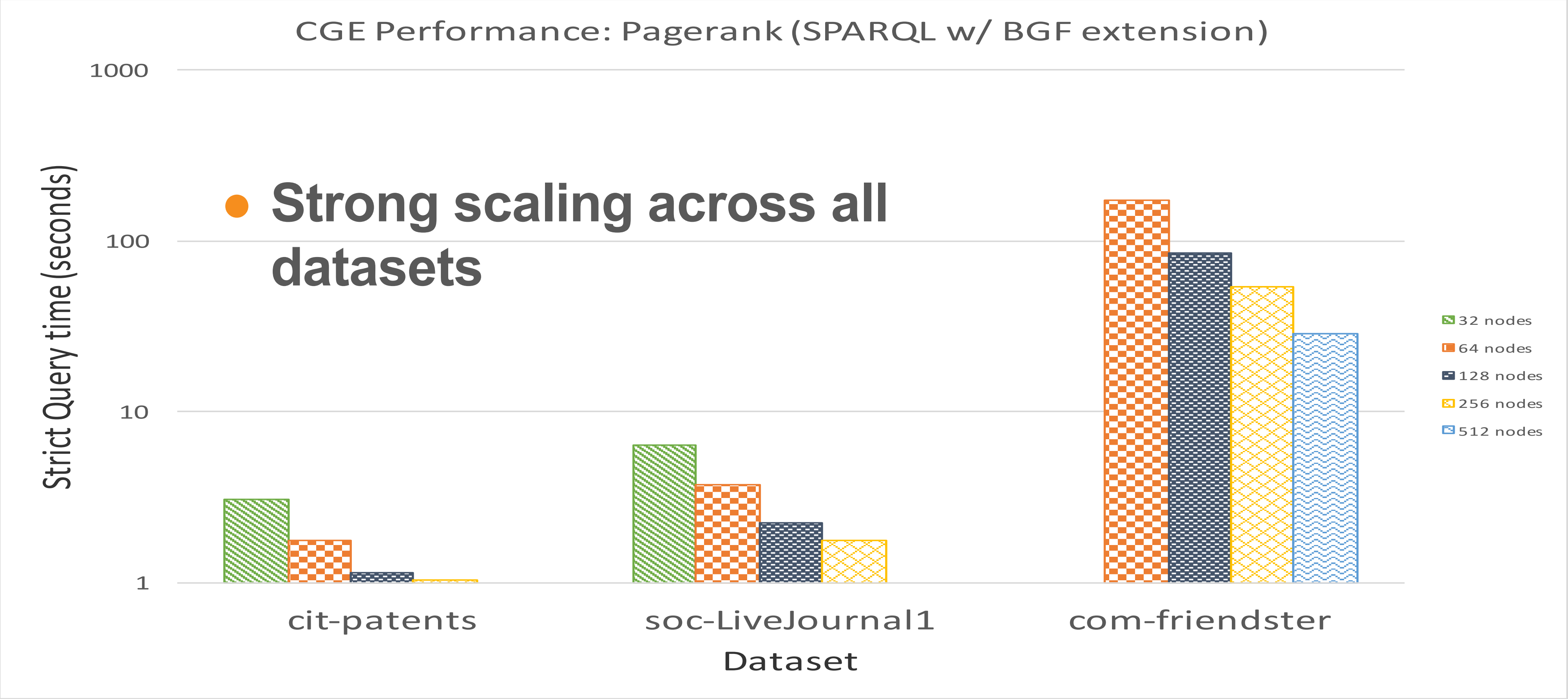
Results

Pattern matching scaling



- Strong scaling on most queries

Whole graph analysis scaling

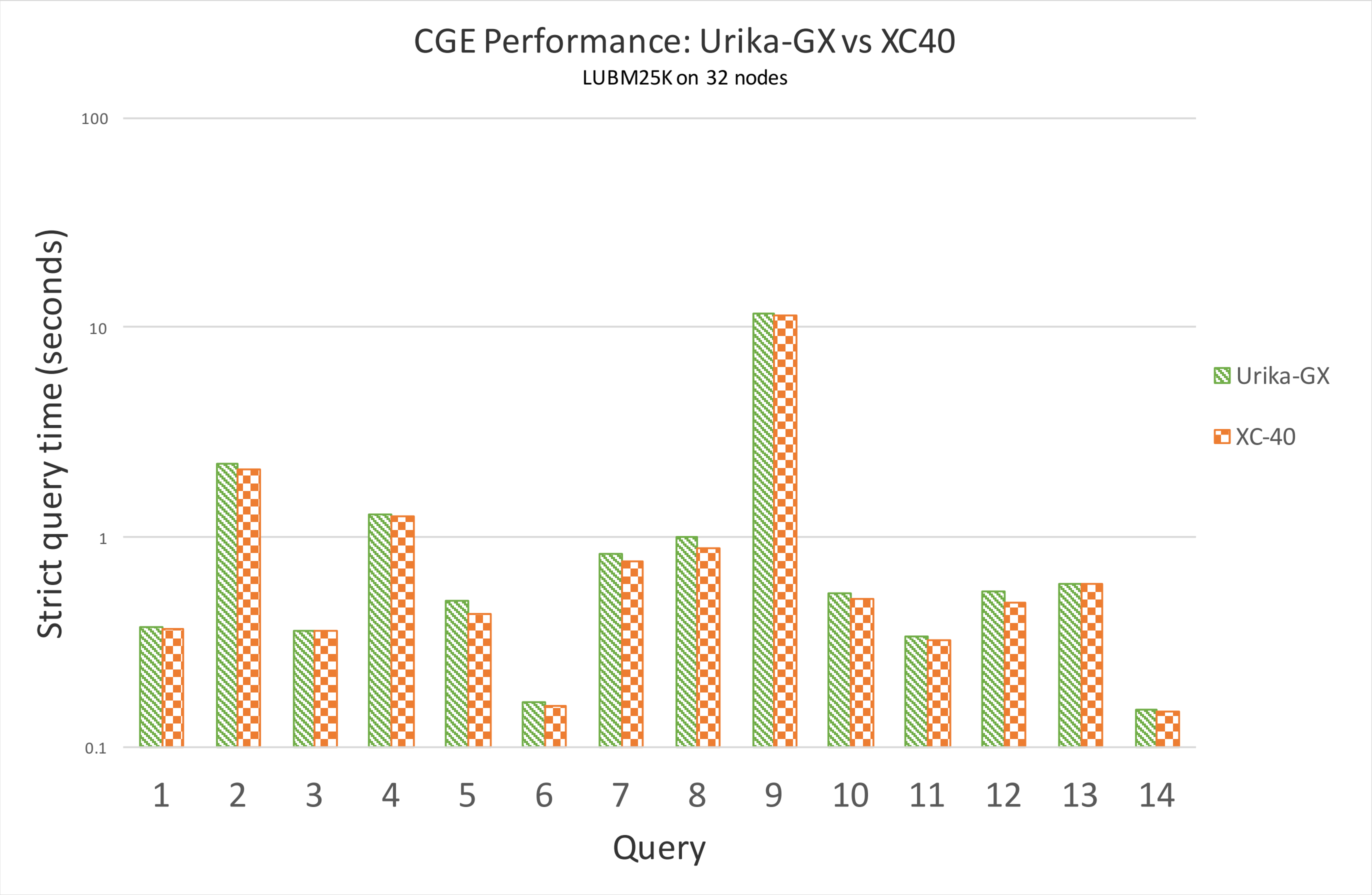


- Strong scaling across all datasets

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^{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

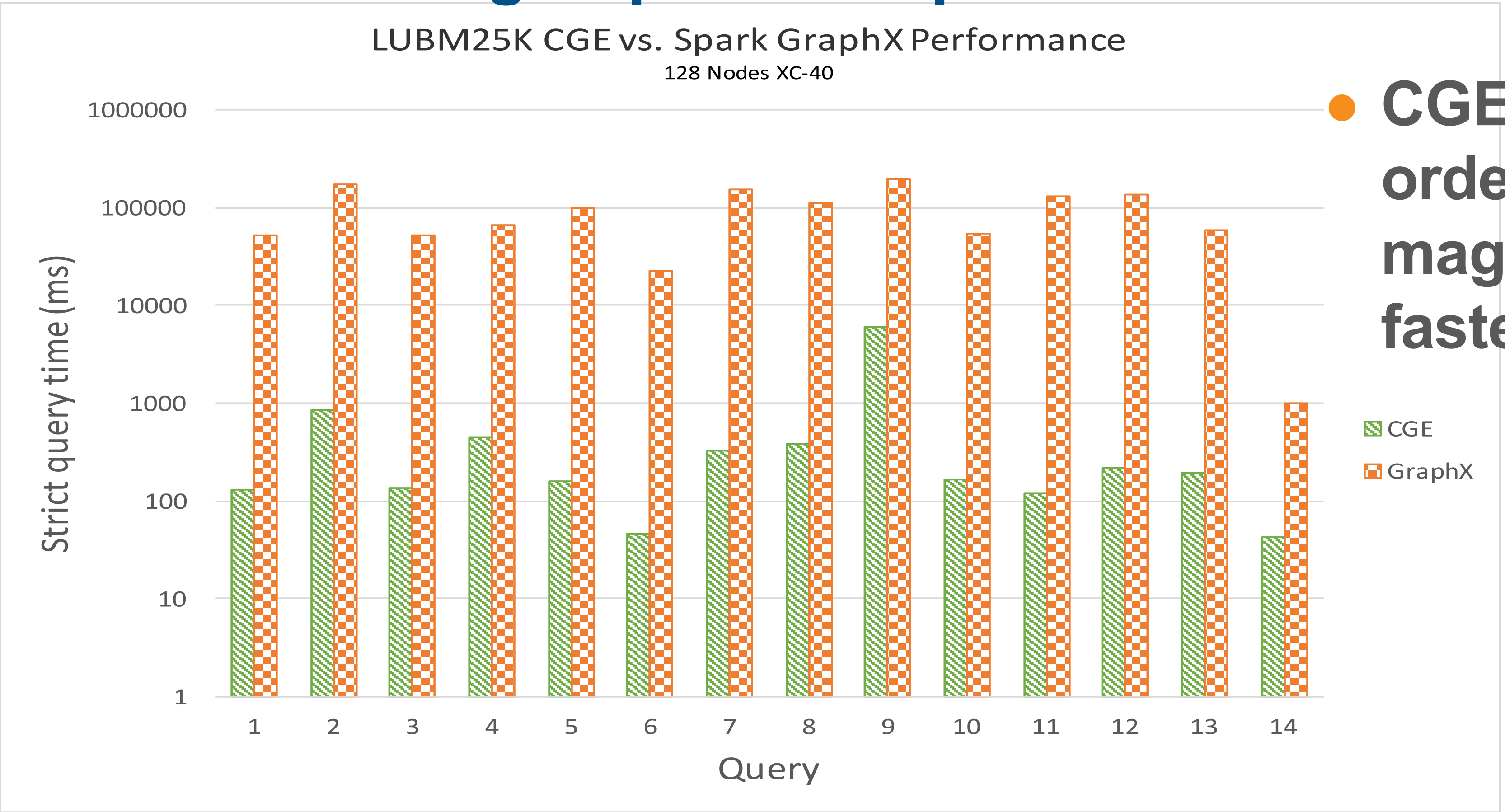


- Performance gap is minimal
- Lot of work to reach this point

Spark Comparison

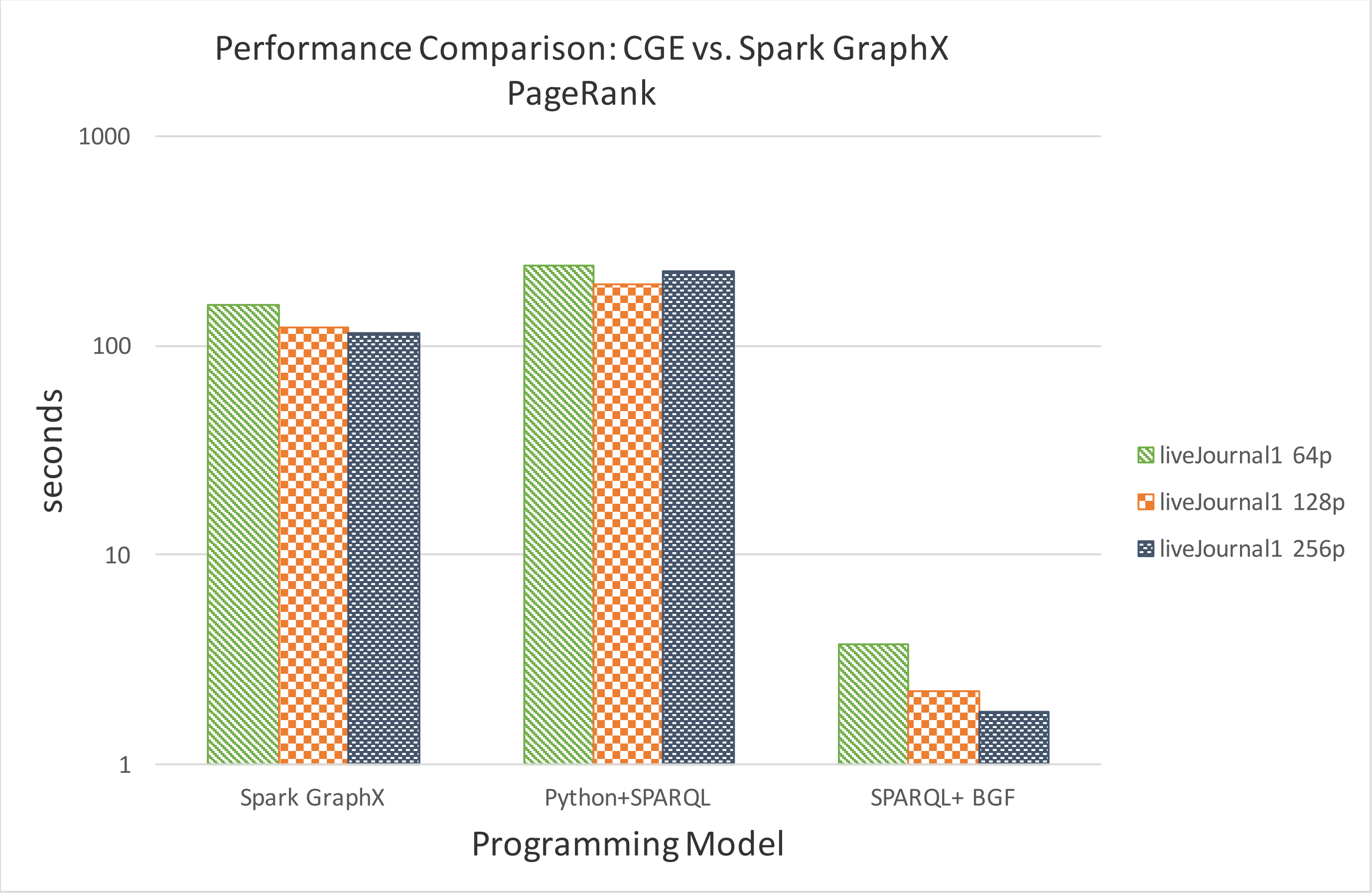
- We created Spark versions of all the experiments described in the paper
- For pattern matching our codes were taken from past work carried out by Oak Ridge National Lab (ORNL)
- For whole graph analysis we compare 3 approaches:
  1. Spark code using GraphX package
  2. Iterative approach using standard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

Pattern matching - Spark Comparison



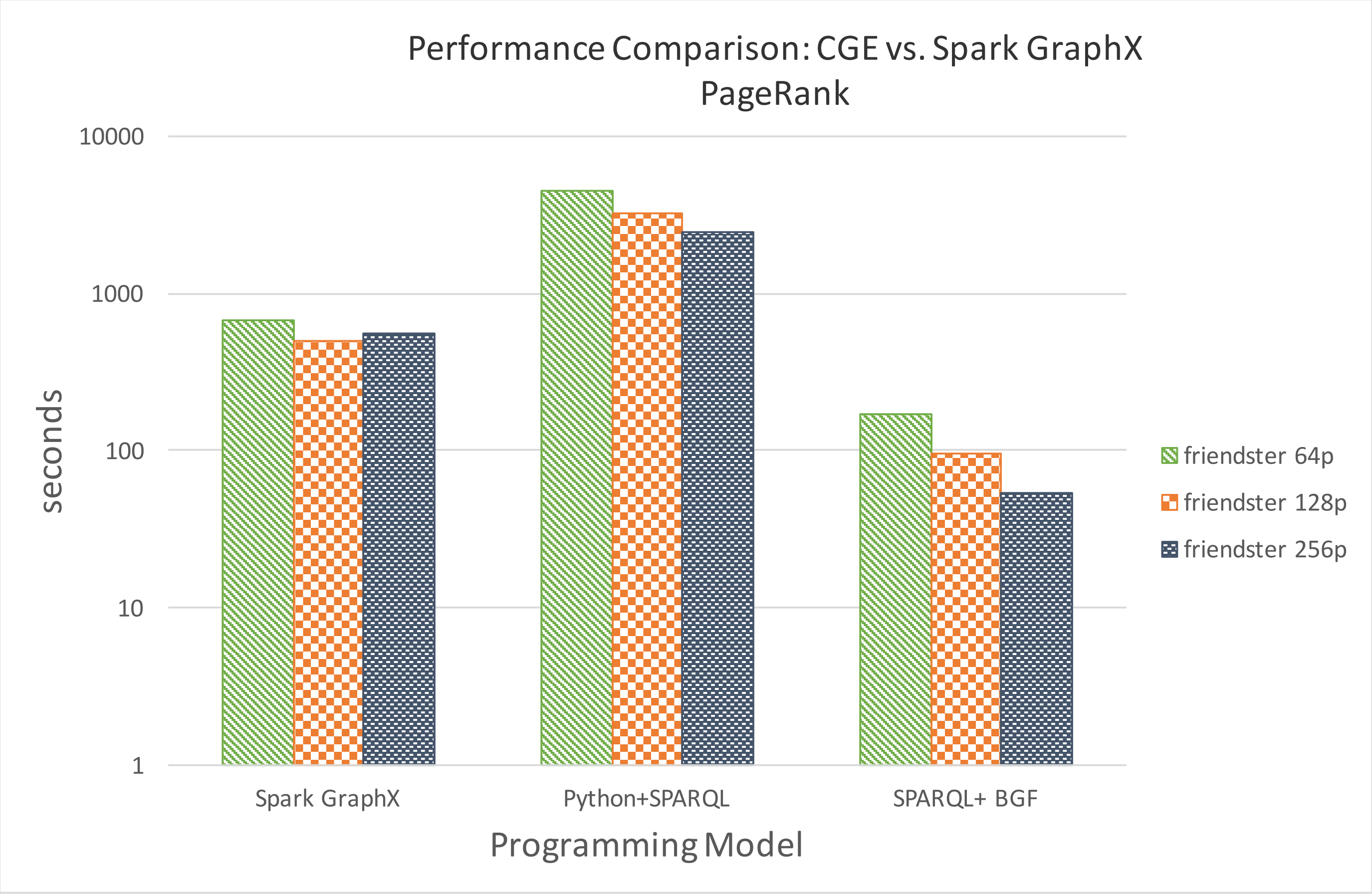
- CGE 1-2 orders of magnitude faster

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^{TM} systems
  - Substantially better performance than Apache Spark for both pattern matching and whole graph analysis workloads

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Q&A

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