Ibis Data Serialization in Apache Spark

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We live in a big data world

- Increase in data generation: IoT, mobile devices, social media, logs from large scale software etc.
- Large and complex data sets
- Beyond ability of traditional software tools.
- Rich analytical potential

Image source: https://towardsdatascience.com/what-is-big-data-lets-answer-this-question-933b94709caf
We live in a big data world

- Big data is essential not only in business but in Science
- Computational Astrophysics, Climate Modeling, Medical and Pharmaceutical research etc.
- Volume 455 Issue 7209, 4 September 2008 of Nature magazine talked about the challenges of dealing with big data.
- Core problem: Explosion of data that cannot be managed speedily using traditional approaches.
**Big data** is high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation.

- *Gartner Glossary*
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- Gartner Glossary
What is Apache Spark

- Is a unified analytics engine for large-scale data processing written in Scala
- Began at UC Berkeley in 2009, Apache project in 2013
- Supports the MapReduce programming model
- Supports both batch and streaming processing of data
- Provides SQL, Machine learning and Graph processing capabilities
- Provides a distributed computing platform that can be run Apache Mesos, Kubernetes, standalone, or in the cloud.
- Has ability to access data in:
  - HDFS (Hadoop Distributed File System)
  - Alluxio, Apache Cassandra, Apache HBase, Apache Hive, and hundreds of other data sources
Common bottleneck in big data processing

- Network bandwidth
- Disk IO
- Memory
- **Serialization**

“...the mechanism for converting (graphs of) data (Java objects) to some format that can be stored or transferred (e.g., a stream of bytes, or XML)…”
Research Questions

- Can Apache Spark's performance be improved by taking advantage of Ibis' serialization techniques?

Sub questions:

- What components of Apache Spark can benefit from Ibis' fast serialization?
- How can Ibis' serialization techniques be integrated into Apache Spark?
- How does the performance of Apache Spark differ when using Java, Kryo and Ibis serialization?
What is Ibis

- Ibis is an open source Java distributed computing software project
- Developed at the Vrije Universiteit Amsterdam
- With the goal of creating an efficient Java-based platform for distributed computing.¹

¹ https://www.cs.vu.nl/ibis/
Related work

- Xiaoyi Lu et al.
  - Improvements to Spark has been made using various methods such as Remote Direct Memory Access (RDMA)
  - Applying zero-copy buffer management in the network stack
- van Nieuwpoort, Rob et al
  - Applied compile-time code generation to improve Java's RMI in Ibis RMI
- Apache Spark has also shown serialization performance can be improved using Kryo serialization.
- But no prior work has been done regarding using Ibis serialization in Spark
Overview of Ibis components
What is Ibis software stack: Component view

Application

RMI   GMI   RepMI   Satin

Ibis Portability Layer (IPL)

Serialization & Communication
  TCP, UDP, MPI, Panda, GM, etc.

Grid Monitoring
  NWS, etc.

Topology Discovery
  TopoMon, etc.

Resource Management
  GRAM, etc.

Information Service
  GIS, etc.
What is Ibis software stack

- Application
  - RMI
  - GMI
  - RepMI
  - Satin

Ibis Portability Layer (IPL)

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  - GRAM, etc.
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  - GIS, etc.
What makes Ibis serialization efficient

- Ibis serialization optimizes:
  - Optimizes object creation
  - Avoiding Data Copying
  - Optionally moves runtime type inspection to compile time
Overview of how Spark works
How Spark Works

Source: https://spark.apache.org/docs/latest(cluster-overview.html)
Spark APIs

- Datasets
- DataFrames
- RDD (Resilient Distributed Dataset)
How Spark executes applications

Source: https://trongkhoanguyen.com/spark/understand-rdd-operations-transformations-and-actions/
Methodology
Methodology

- Identifying Spark components using serialization.
- Extracting the serialization component in Ibis
- Modify spark to use the serialization from Ibis
- Measure performance difference
Identifying Spark components using serialization

- We analysed the source code of Spark
- We found 17 instances of direct serialization calls
  - Internal operations
  - Network operations
  - Persistence operations (Disk and Memory)
- Available serialization mechanisms:
  - Native Java serialization
  - Kryo serialization

[1] https://github.com/EsotericSoftware/kryo
Modifying Spark to use Ibis serialization

- 17 different components using serialization.
- We managed to replace 15 of those.
Unresolved Incompatibilities.

- Incompatibility with NettyBlockRpcServer and NettyBlockTransferService
  - Uses Zero-copy I/O
  - Off heap network buffer management
  - Making a drop in replacement harder
- Incompatibility with deserializing from Hadoop filesystem.
Resolved Incompatibilities.

- Modification to support serialization of Scala’s Option type
- Modification to support serialization of Enum with constant method
  - Thanks to the Ibis maintainer: Ceriel Jacobs from the Vrije University Amsterdam
- Modification to support ByteBuffer
Measuring the performance differences
Benchmark setup

- We now have a:
  - A modified version of Spark
  - Original Spark version to test Kryo and Native Java serialization
- Two worker nodes, directly connected
- Both running a HDFS DataNode
- Using Hadoop Yarn as resource manager
Benchmark setup
Benchmarking method

- Single test results may not be conclusive
- To get more reliable results we perform each benchmark 50 times
- Take the mean of all results
- Test environments are reset between test runs
- Also comparing Ibis and Ibisc
Benchmark types

- Mostly use standardized benchmarks

- TeraSort:
  - Distributed sorting algorithm
  - Measures shuffling performance

- SparkPi:
  - Computes an approximation of Pi
  - Measures computing performance

- Memory persistence
  - Measure memory persistence performance
Results
Figure 3: TeraSort time to completion
Conclusion

- Research question:
  - Can Apache Spark's performance be improved by taking advantage of Ibis' serialization techniques?

- 15 out of 17 components could be replaced
- Ibis was 15-20% faster in benchmarks that extensively use serialization
- Ibis was 10-15% more efficient in memory usage in benchmarks that extensively use serialization
- There was no noticeable performance difference in purely computational benchmarks
Future Work

- Replace remaining two components with Ibis serialization
- Measure performance using other benchmarks
- Research performance on a larger scale
- Apply Ibis rewriter to Spark
- Compare Ibis against dataset encoders
- Experiment with Ibis' networking implementations in Spark
- Investigate Ibis serialization performance in other distributed applications
Questions?