An Experimental Comparison of Complex Object Implementations for Big Data Systems

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Join work with

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Introduction

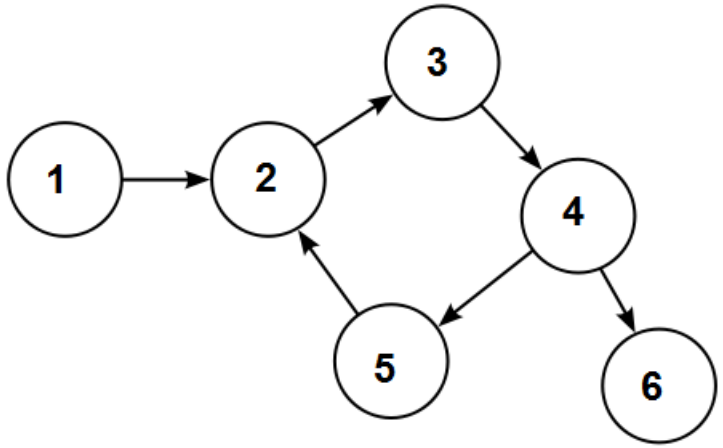
- Relational databases store records made of flat types.
  - integer, float, boolean, char etc.
- All the records have fixed size.

- Example: A student database.

Last Name	First Name	Student ID	Net ID	SSN	…
Doe	John	S012141*	jd*	*4768	…
Roe	Jane	S012142*	jr*	*4321	…
…					
…					

Introduction

- How do relational databases store complex objects?
  - Complex Objects have variable size and are highly nested.



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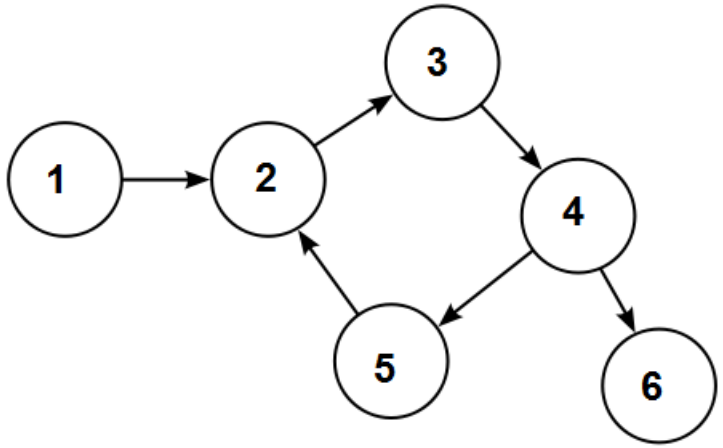


Graph ID	…
1	…
…	…

Graphs

Graph ID	Vertex ID	…
1	1	…
1	2	
…		

Vertices

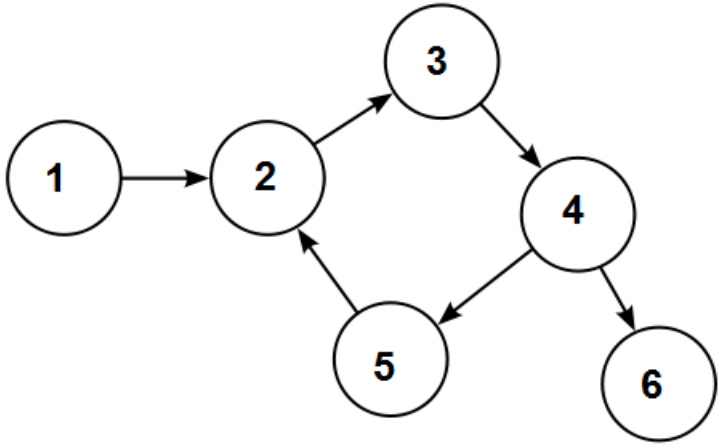
Graph ID	from	to	…
1	1	2	…
1	2	3	
1	3	4	
…			

Edges

Introduction

- Modern programming languages provide a lot of useful features.
  - Generics (in Java), Templates (in C++).

- Outside relational database -




```
public class Graph {
    // Set of nodes
    private Map<Integer, Vertex> vertices;

    // Set of directed edges
    private Map<Integer, List<Edge>> edges;
}
```

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Big Data System:

There are costs associated with -

- Objectification
- Serialization
- Garbage Collection

Key Questions

Any big data system designer faces some important choices:

- Which data model to use?
- Which implementation for data model to use?
- Which runtime environment to use?

Goal

Across a variety of data management tasks, experimentally compare the costs associated with various choices of complex object implementations.

Complex Object Models

- Host Language Objects
- Self-Describing Documents
- Custom Data Models

1. Host Language Objects

- Which runtime environment to use?
  - Automatic memory managed vs Not
  - Managed(Java) vs Unmanaged (C++)

- Which serialization framework to use?
  - Serialization: Conversion from in memory to on disk representation.

1. Host Language Objects

Java

C++

Java Default

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Java	C++
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1. Host Language Objects

Java

Java Default

Java ByteBuffer

Java Kryo

C++

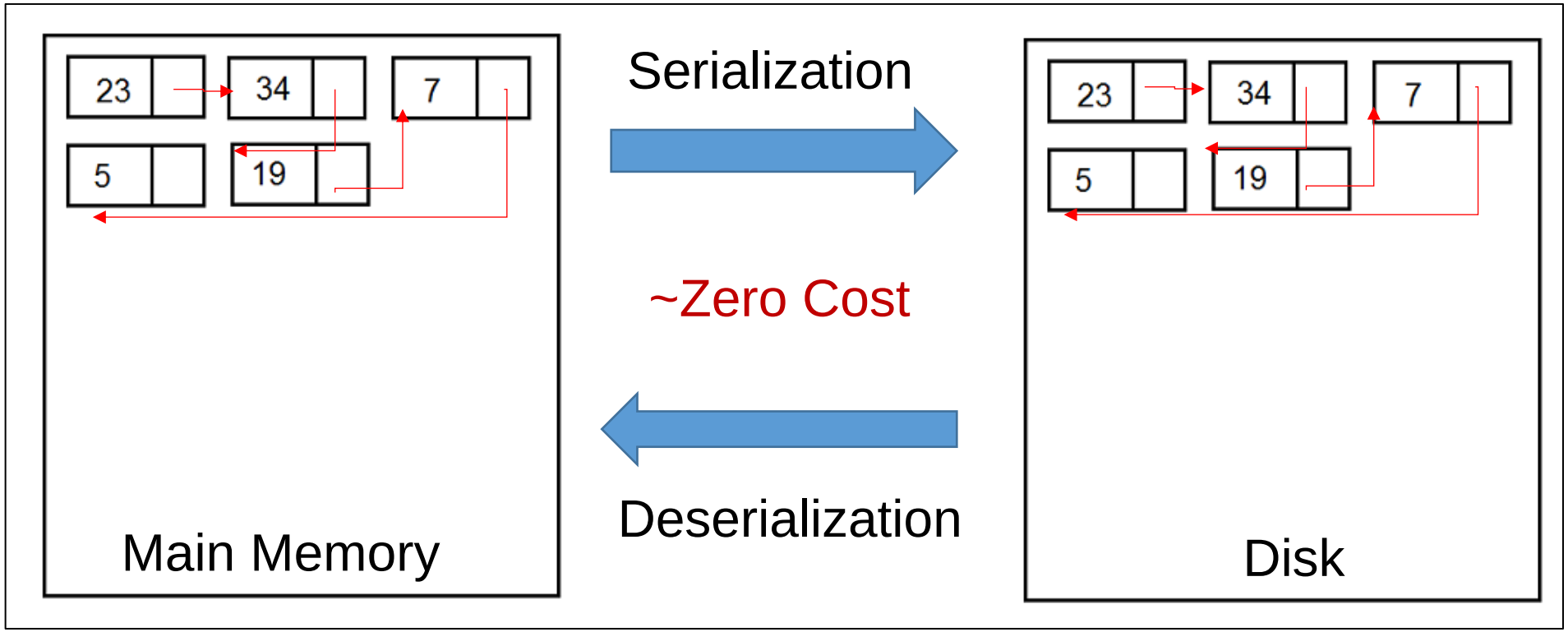
C++ Hand-Coded

C++ Boost

C++ InPlace

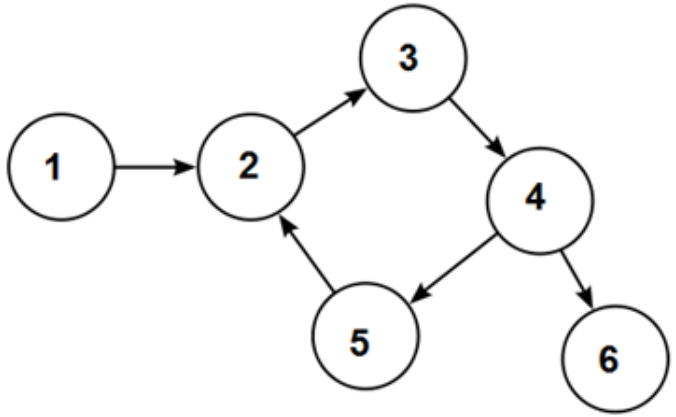
C++ InPlace

- We borrow the idea from relational database.
  - On disk representation = In memory representation.



2. Self-Describing Documents

JSON + gzip




```
{
    "Graph": {
        "Vertices": [1, 2, 3, 4, 5, 6],
        "Edges": {
            "1": [2],
            "2": [3],
            "3": [4],
            "4": [5, 6],
            "5": [2]
        }
    }
}
```

JSON

BSON

```
¨....Graph.œ....Vertices./....0..
....1.....2.....3.....4.....5.....
Edges.W....1.....0.....2.....0.
.....3.....0.....4.....0.....1.....
..5.....0.....
```

BSON

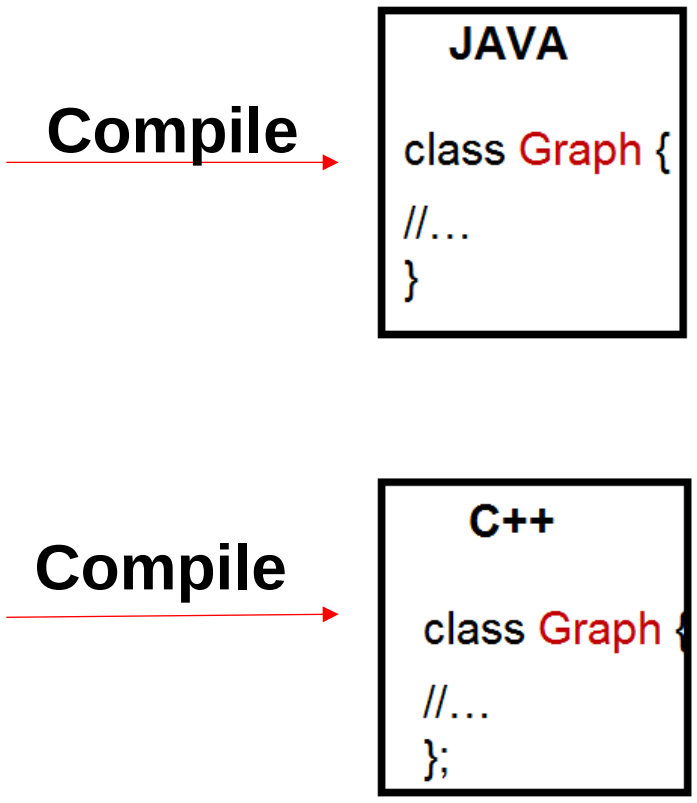
3. Custom Data Models

Java Protocol Buffers

C++ Protocol Buffers

```
message Graph {
    message Vertex {
        required int32 vertexID = 1;
        //...
    }
    message Edge {
        required int32 fromVertex = 1;
        required int32 toVertex = 2;
        //...
    }
    message AdjacencyList {
        repeated Edge edges = 1;
    }
    map <int32, Vertex> vertices = 1;
    map <int32, AdjacencyList> edges = 2;
}
```

Graph representation in DSL



Summary: Object Implementations

Host-language objects
Java Default
Java Kryo
Java ByteBuffer
C++ Boost
C++ HandCoded
C++ InPlace

Self-Describing Documents
JSON
BSON

Custom Nested Models
Java Protocol Buffers
C++ Protocol Buffers

Experiments

- Read from Local Disks
  - Sequential Read
  - Random Read
- Networked Reads
  - Read from RAM
  - Read from Disk
- External Sort
- Distributed Data Aggregation

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Dataset

- Average size of a TPC-H Customer object on disk:

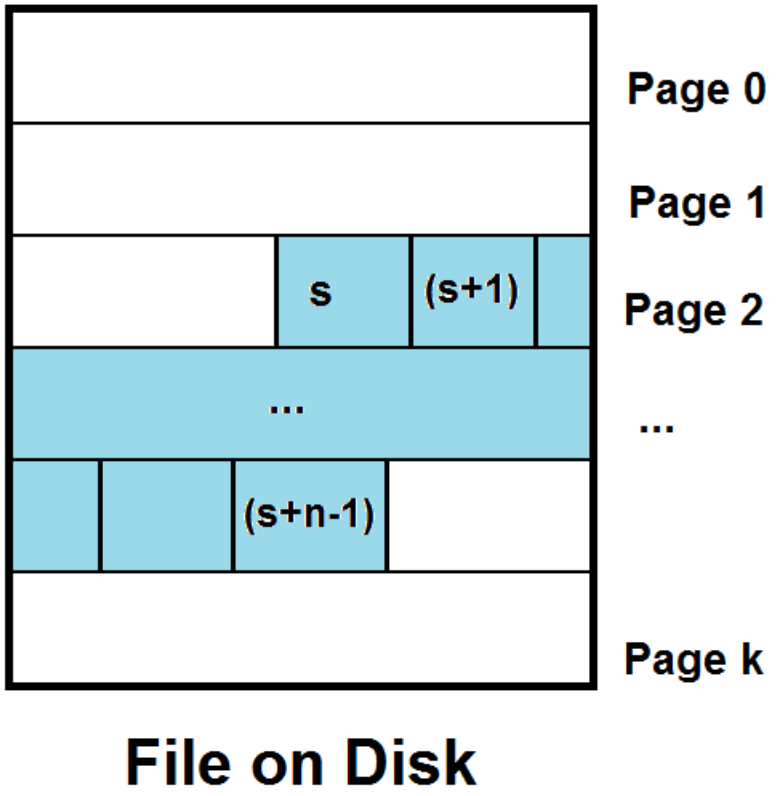
Implementation	Size (Bytes)	
Java JSON + gzip	8508	Data + Schema + Compression
Java Kryo	16176	
Java Protocol Buffers	17305	Data + Light-weight encoding
C++ Protocol Buffers	17931	
C++ HandCoded	19275	
Java ByteBuffer	19478	Data
Java Default	19556	
C++ Boost	21004	Data + Headers
C++ InPlace	25127	Memory Representation of Data
Java BSON	33879	Data + Schema

1. Sequential Read

Goal:
Test the ability to support fast retrieval of objects.

Task:
3 million TPC-H Customer objects.

Read 100K objects sequentially.



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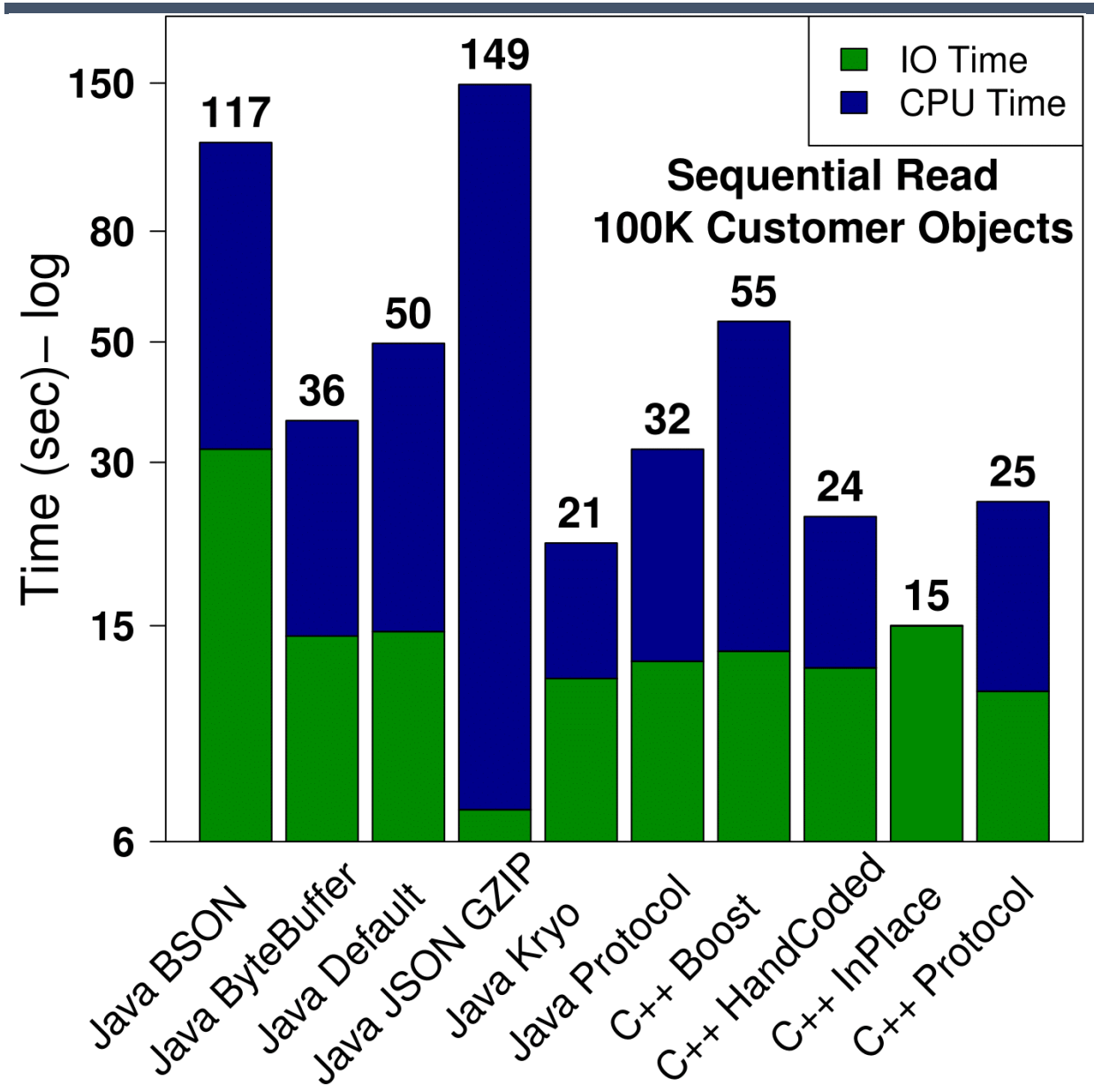

- The fastest C++ implementation (InPlace) is at least 1.5x faster than fastest Java implementation (Kryo) for larger reads.

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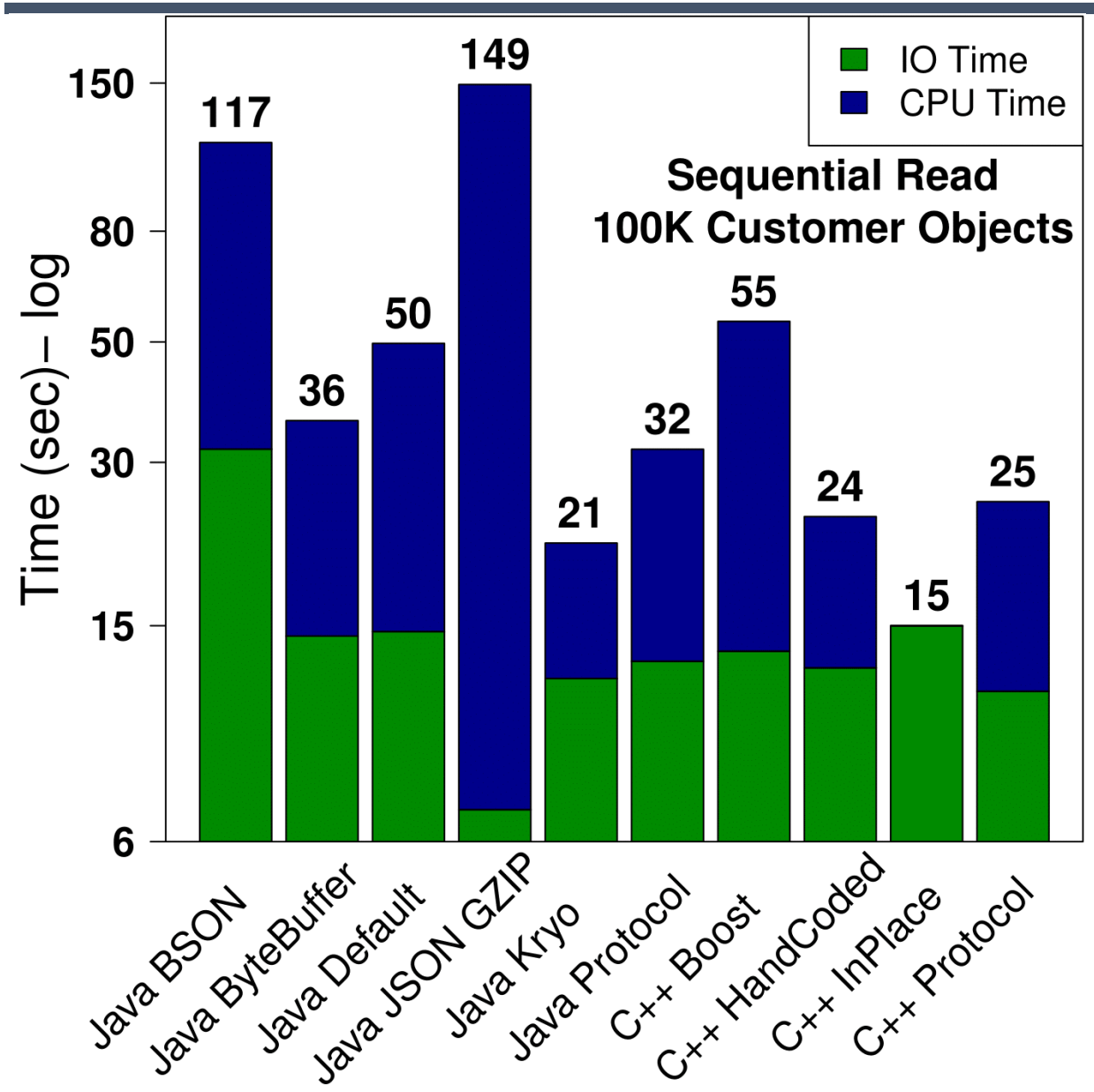

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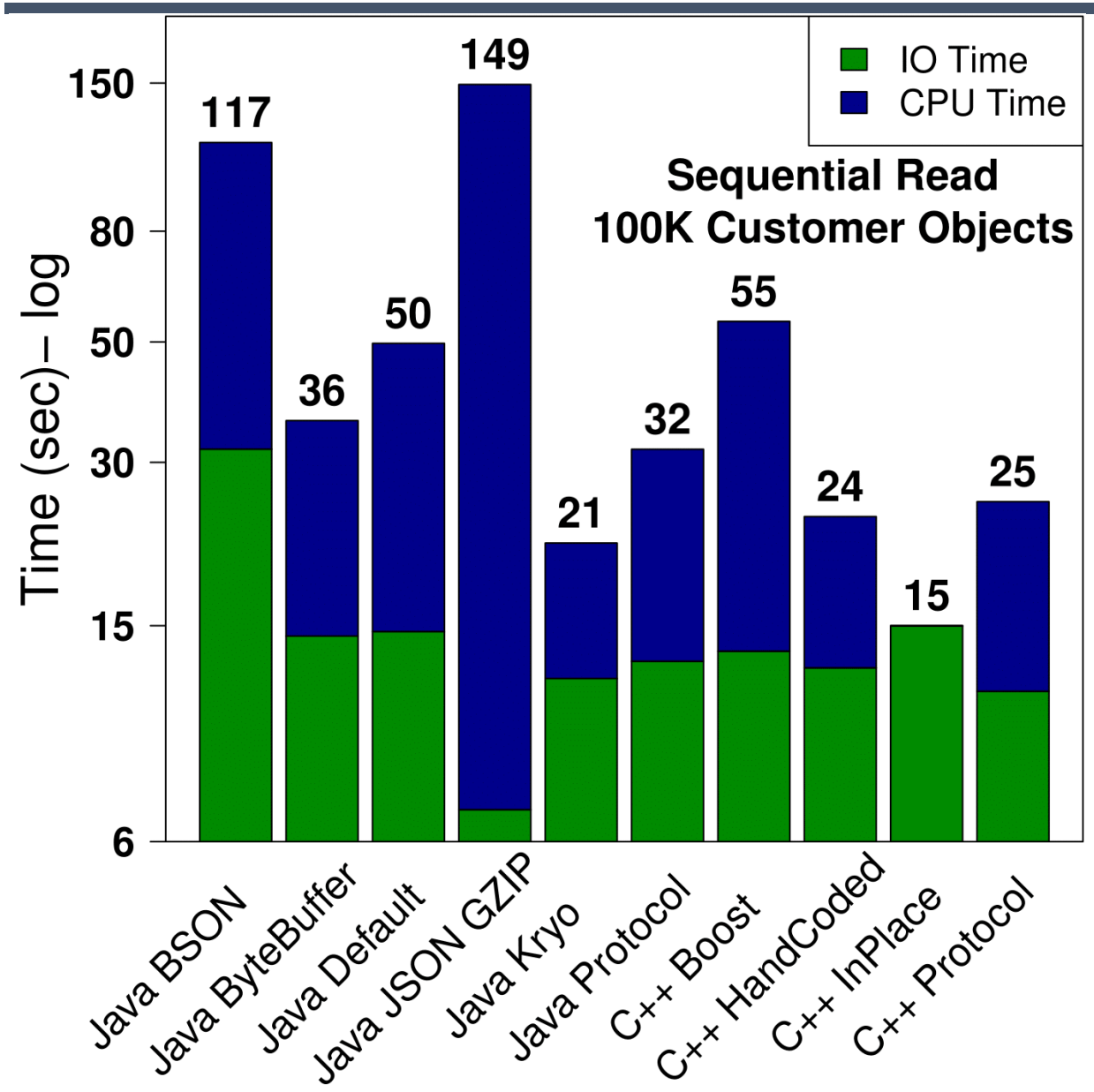

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- C++ InPlace is IO bound.
- JSON + gzip is CPU bound.

2. External Sort

Goal:

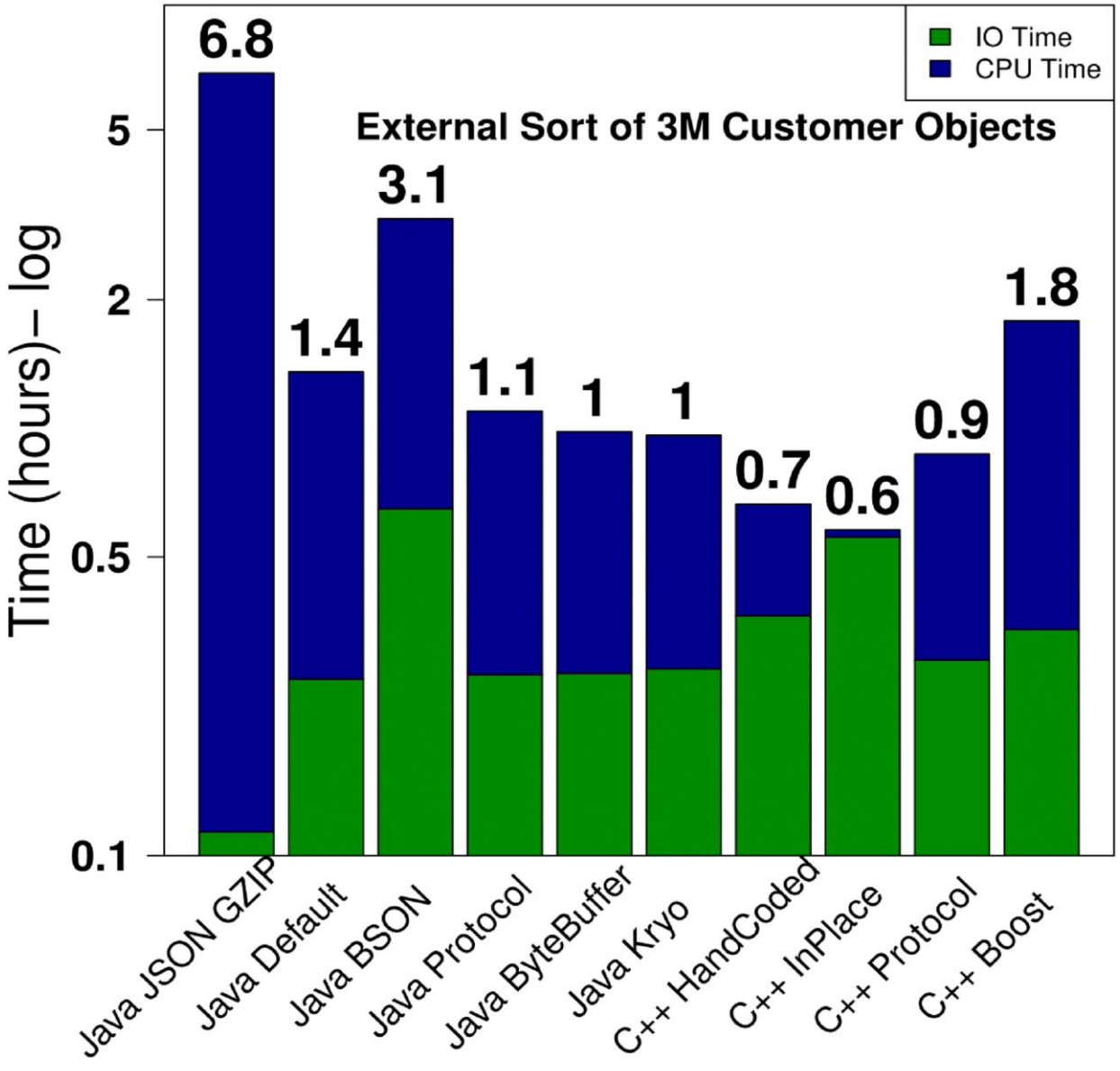
Sorting is common workflow in data management system.

Details:

Sorting 3 million TPC-H Customer objects (~ 60GB).

Compute machine has 30GB RAM.

2. External Sort



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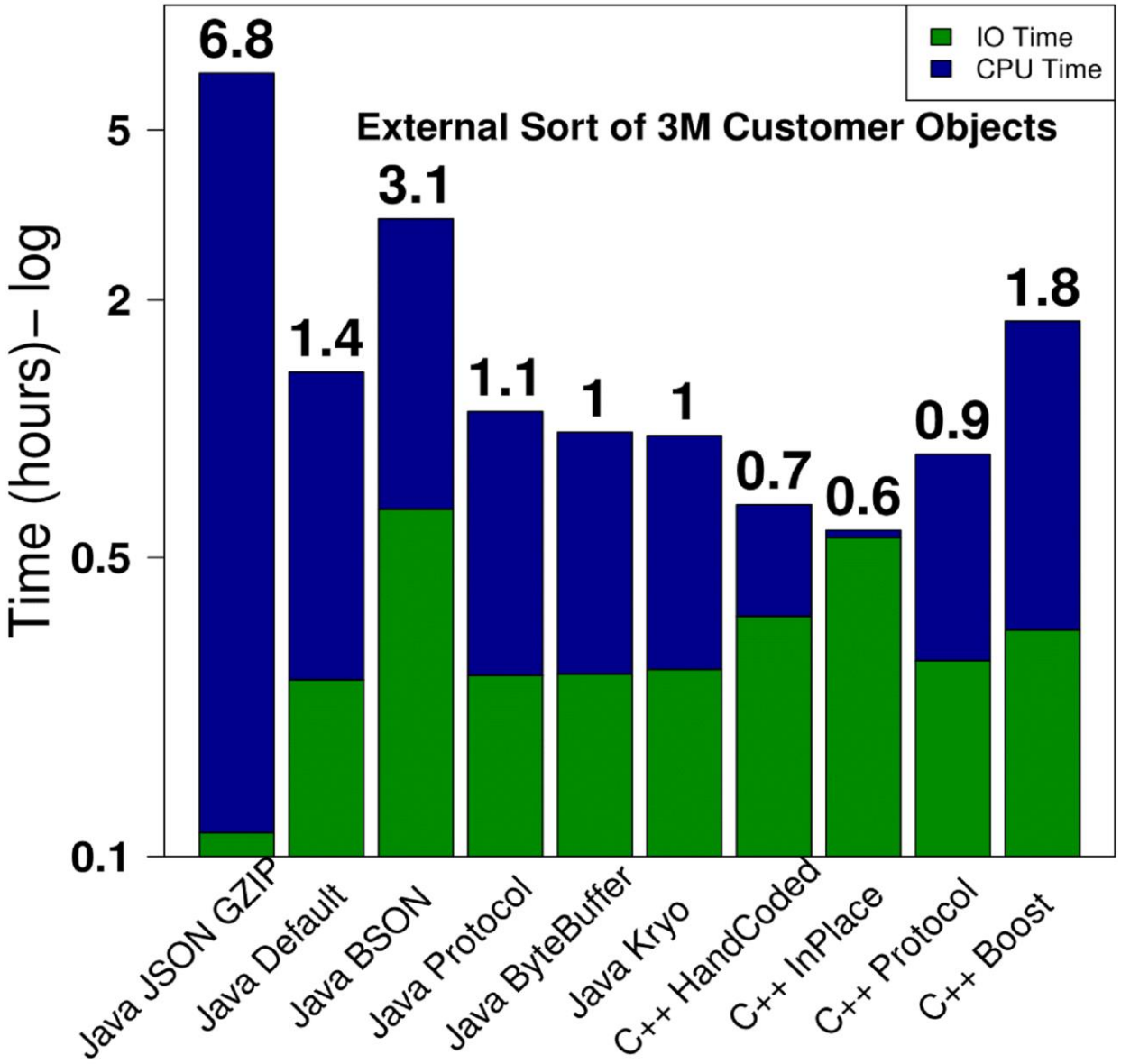

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- The execution time in a memory managed environment (Java) is significantly higher than an un-managed environment (C++ on Linux).
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Thank You

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