MATE-EC2:
A Middleware for Processing Data with Amazon Web Services

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The 4th Workshop on Many-Task Computing on Grids and Supercomputers: MTAGS'11

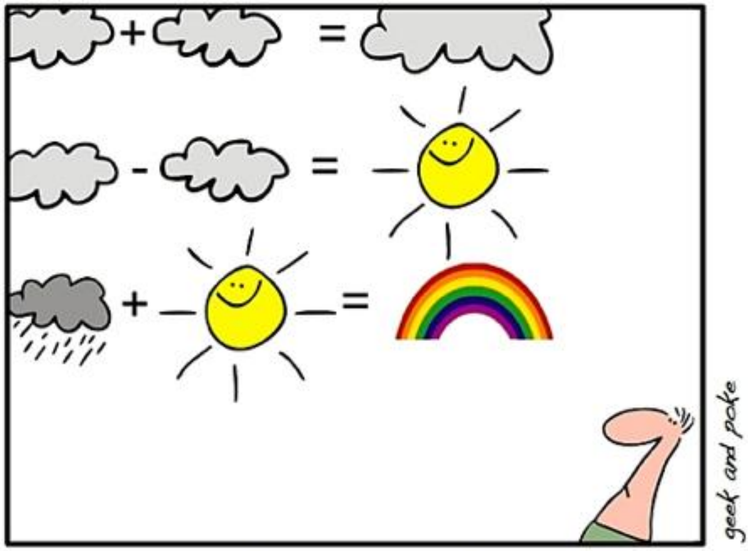
The Problem

- Today’s applications are increasingly data and compute intensive
- Many-Task Computing paradigms becoming pervasive: WF, MR
- E.g., Map-Reducible applications are solving common problems
  - Data mining
  - Graph processing
  - etc.

Clouds

- Infrastructure-as-a-Service
  – Anyone, anywhere can allocate "unlimited" *virtualized* compute/storage resources

- Amazon Web Services:
  – Most popular IaaS provider
  – Elastic Compute Cloud (EC2)
  – Simple Storage Service (S3)



SIMPLY EXPLAINED – PART 17:
CLOUD COMPUTING

Amazon Web Services: EC2

- On-Demand Instances (Virtual Machines)
  - Types: Extra Large, Large, Small, etc.
- For example, Extra Large Instance:
  - Cost: $0.68 per allocated-hour
  - 15GB memory; 1.7TB disk (ephemeral)
  - <u>8 Compute Units</u>
  - <u>High I/O performance</u>

Amazon Web Services: S3

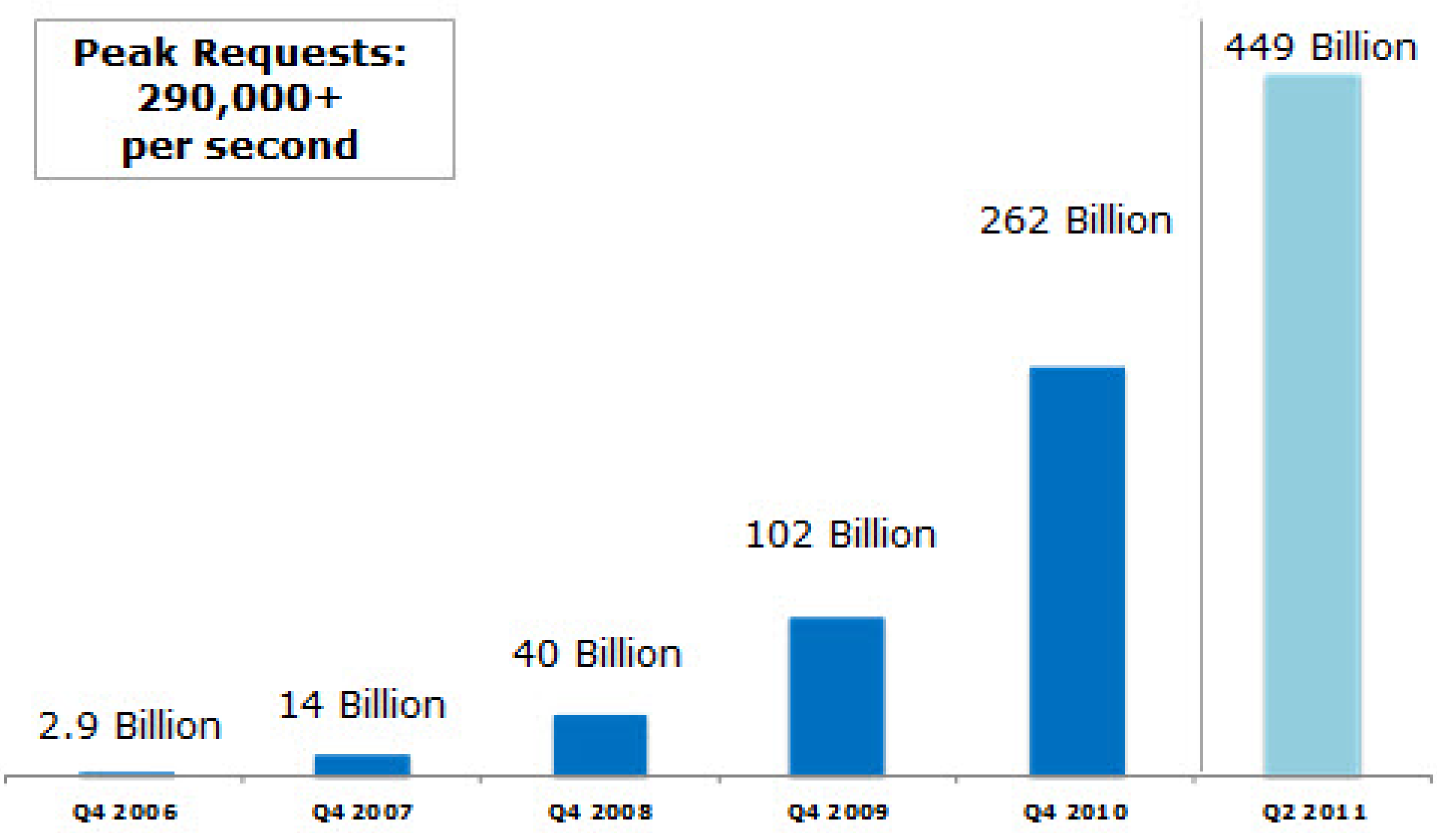
- Accessible anywhere. High reliability and availability
- Objects are arbitrary data blobs
- Objects stored as `(key,value)` in *Buckets*
  - 5TB of data per object
  - Unlimited objects per bucket

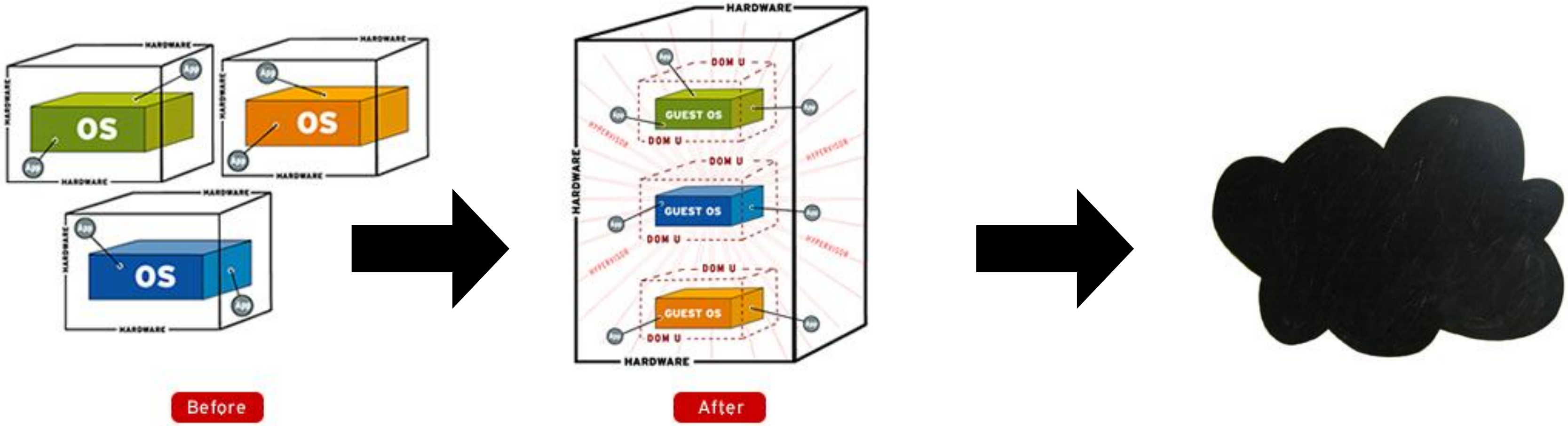
Amazon Web Services: S3 (Cont.)

- Simple FTP-like interface using web service protocol
  - Put, Get (Partial Get), and Delete
  - SOAP and REST
- High throughput (~40MB/sec)
  - Scales well to multiple clients
- Low costs

Amazon Web Services: S3 (Cont.)

- 449 billion objects in S3 as of July 2011
  - Doubling each year





- Virtualization is characteristic of any cloud environment: Clouds are **black boxes**

- Storage and elastic compute services exhibit performance variabilities we should leverage

Goals

- As users are increasingly moving to cloud-based solutions for computing....

- We have a need for services and tools that can…
  - Get the most out of cloud resources for data-intensive processing
  - Provide a simple programming interface

Outline

- Background
- System Overview
- Experiments
- Conclusion

MATE-EC2 System Design

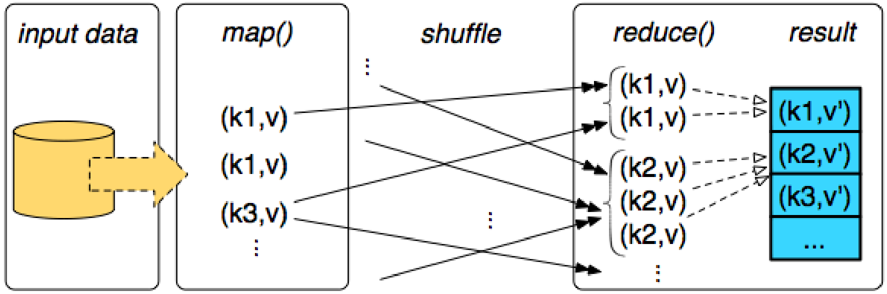
- Cloud middleware that is able to
  - Use a set of possibly heterogeneous EC2 instances to *scalably* and *efficiently* process data stored in S3

- MATE is a ***generalized reduction*** PDC structure like Map-Reduce

MATE and Map-Reduce

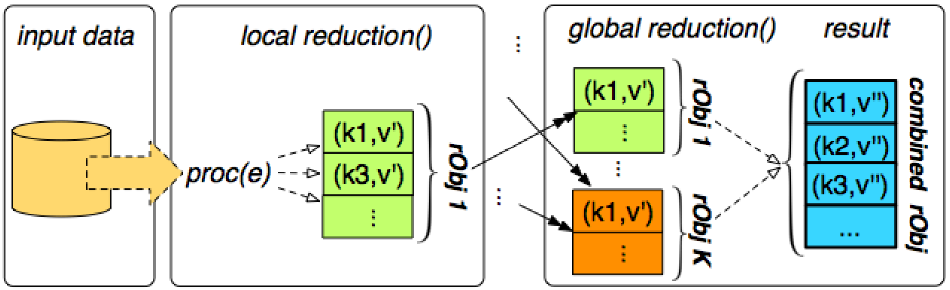
Map-Reduce

```
// outer sequential loop
while () {
   // reduction loop
   for each (element e) {
      (i, val) := process(e);
   }
   sort (i, val) pairs over i
   reduce to compute each rObj(i)
}
```

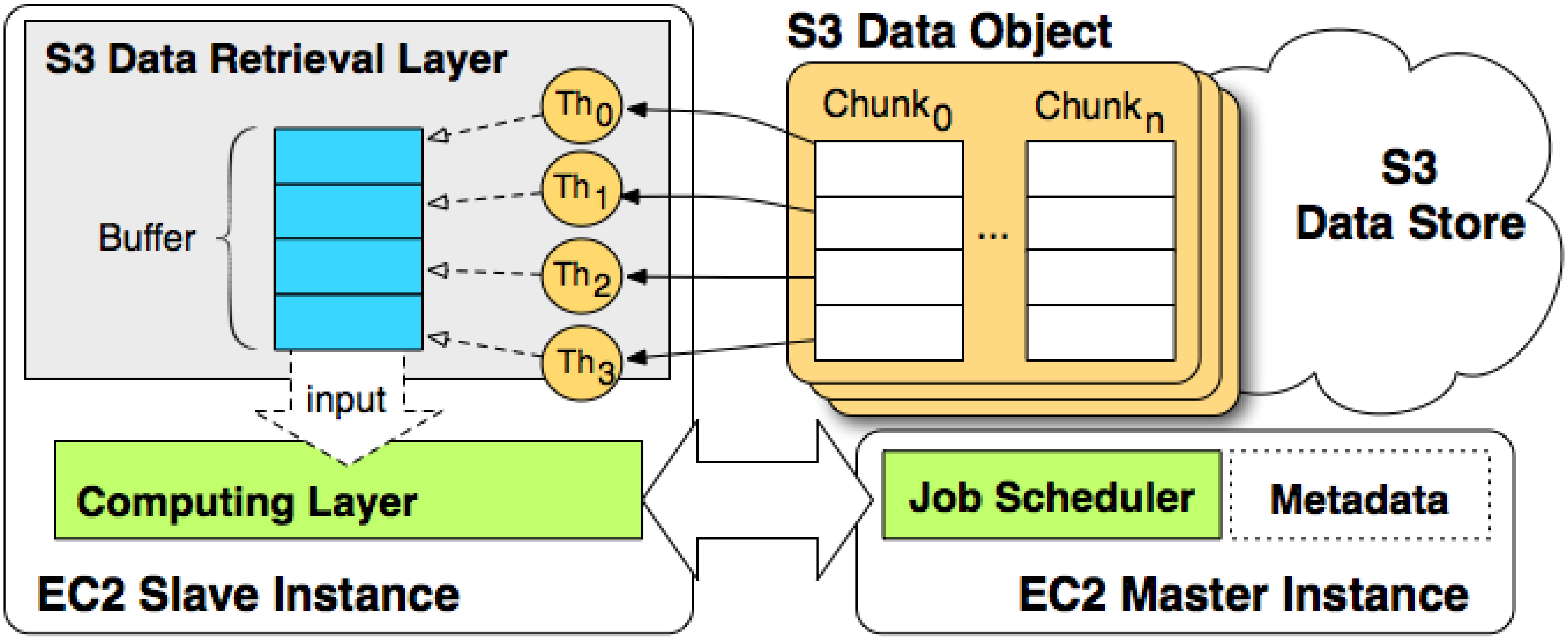


MATE

```
// outer sequential loop
while () {
   // reduction loop
   for each (element e) {
      (i, val) := process(e);
      rObj(i) := reduce(rObj(i), val);
   }
   global reduction to combine rObjs
}
```

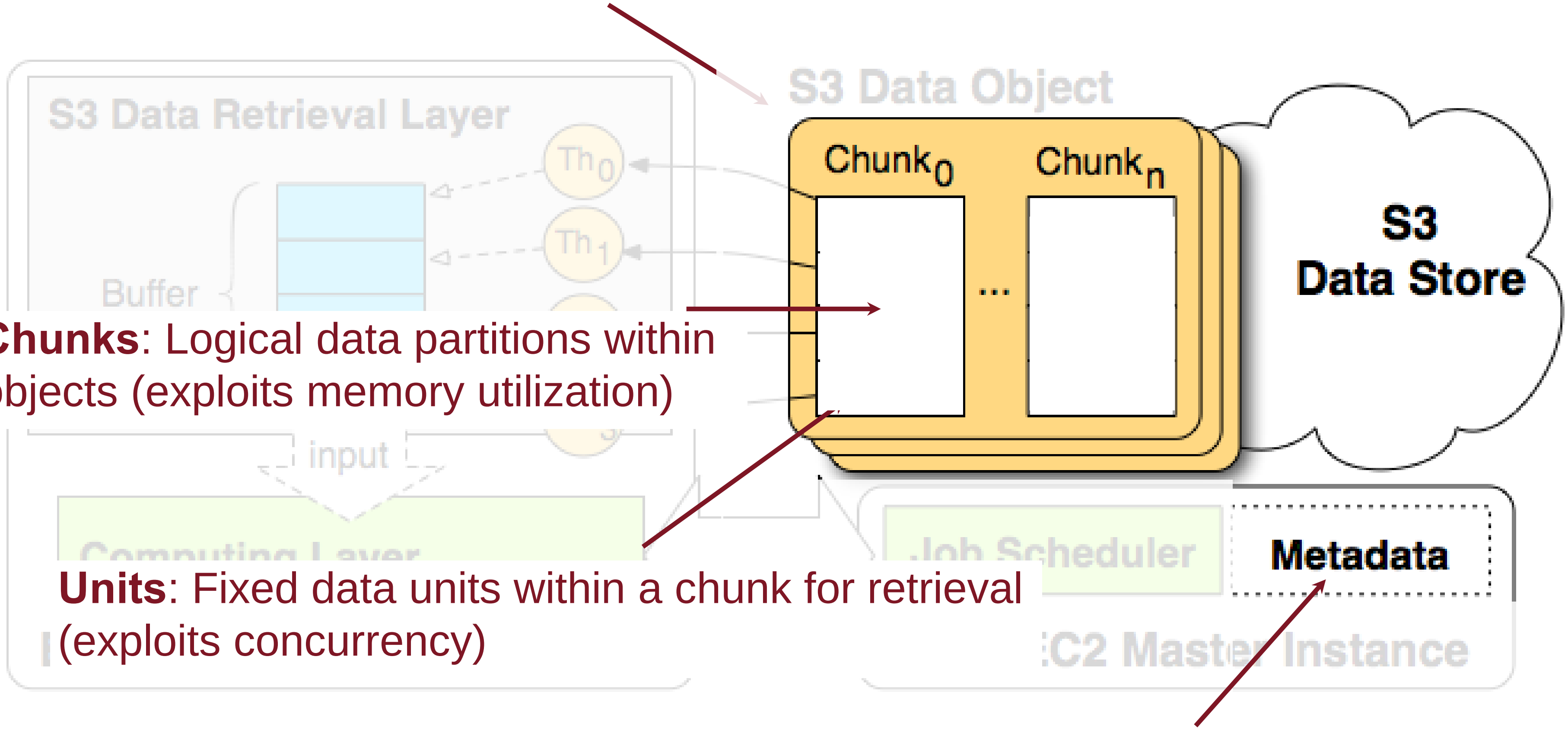


MATE-EC2 Design



MATE-EC2 Design: Data Organization

Objects: Physical representation of the data in S3

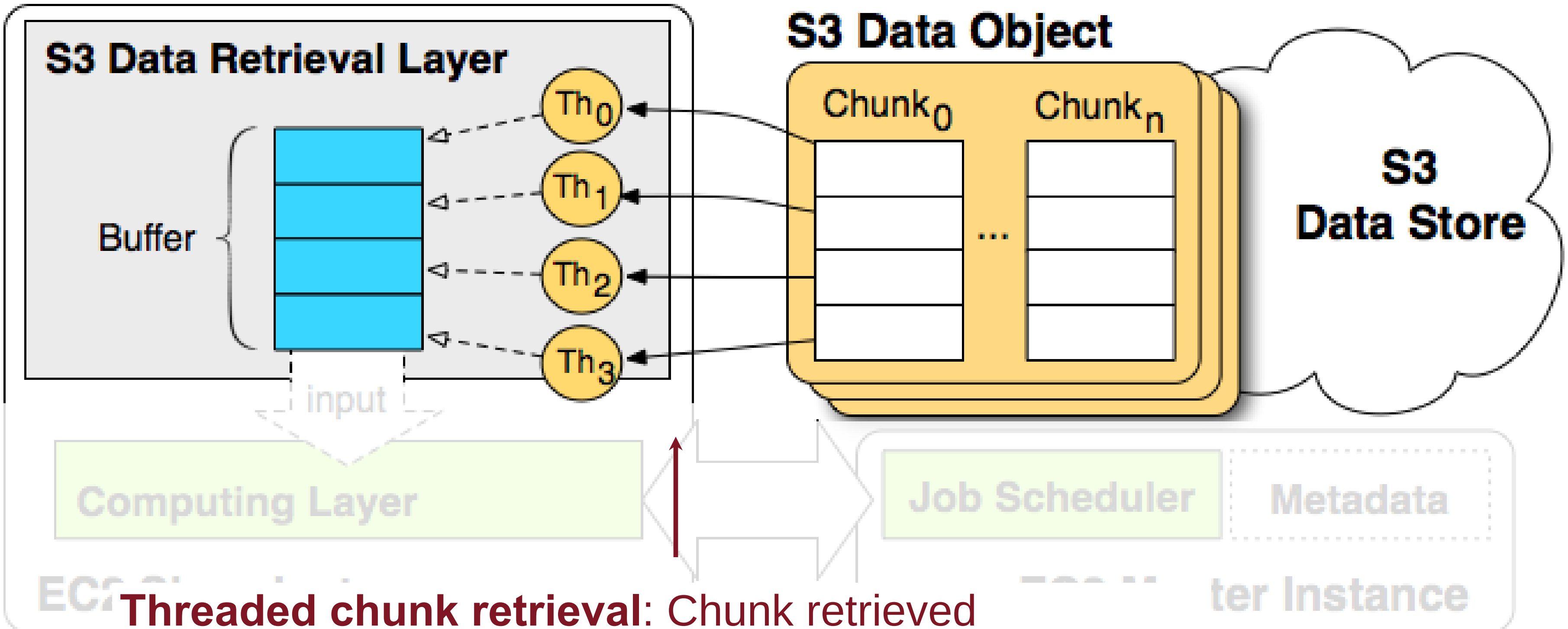


Chunks: Logical data partitions within objects (exploits memory utilization)

Units: Fixed data units within a chunk for retrieval (exploits concurrency)

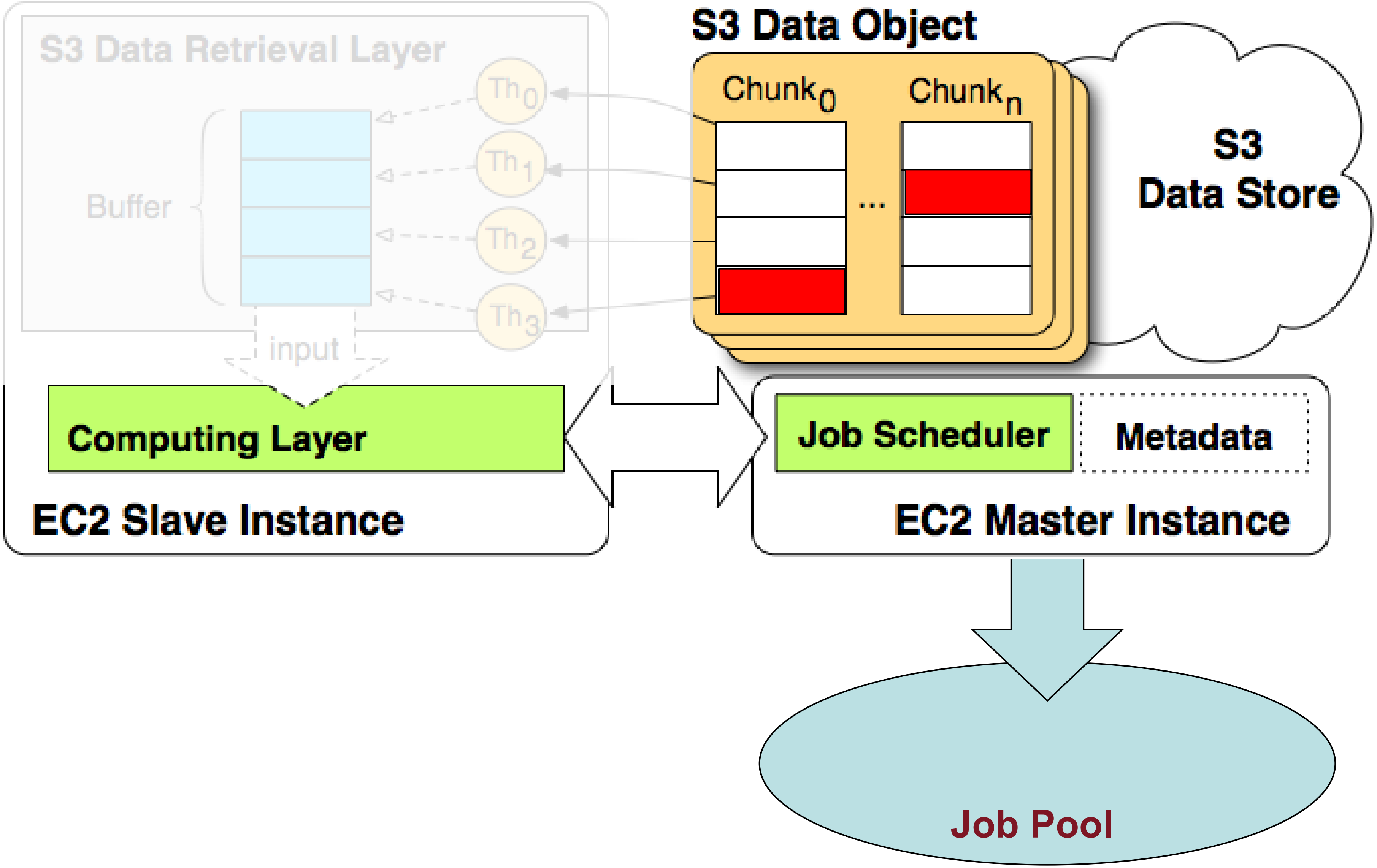
Metadata: chunk offset, chunk size, unit size

MATE-EC2 Design: Data Retrieval

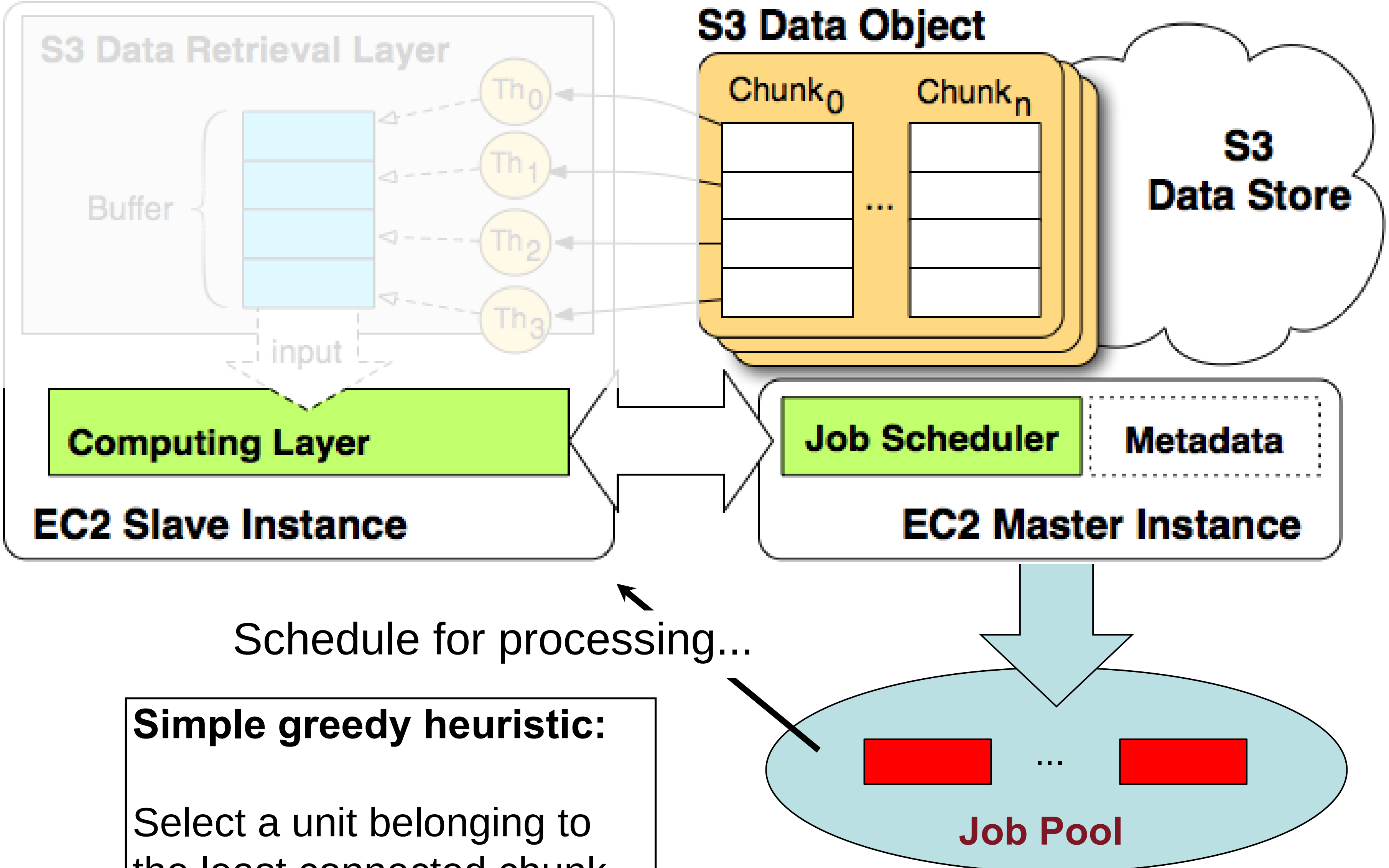


Threaded chunk retrieval: Chunk retrieved concurrently with a number of threads

Dynamic Load Balancing



Dynamic Load Balancing

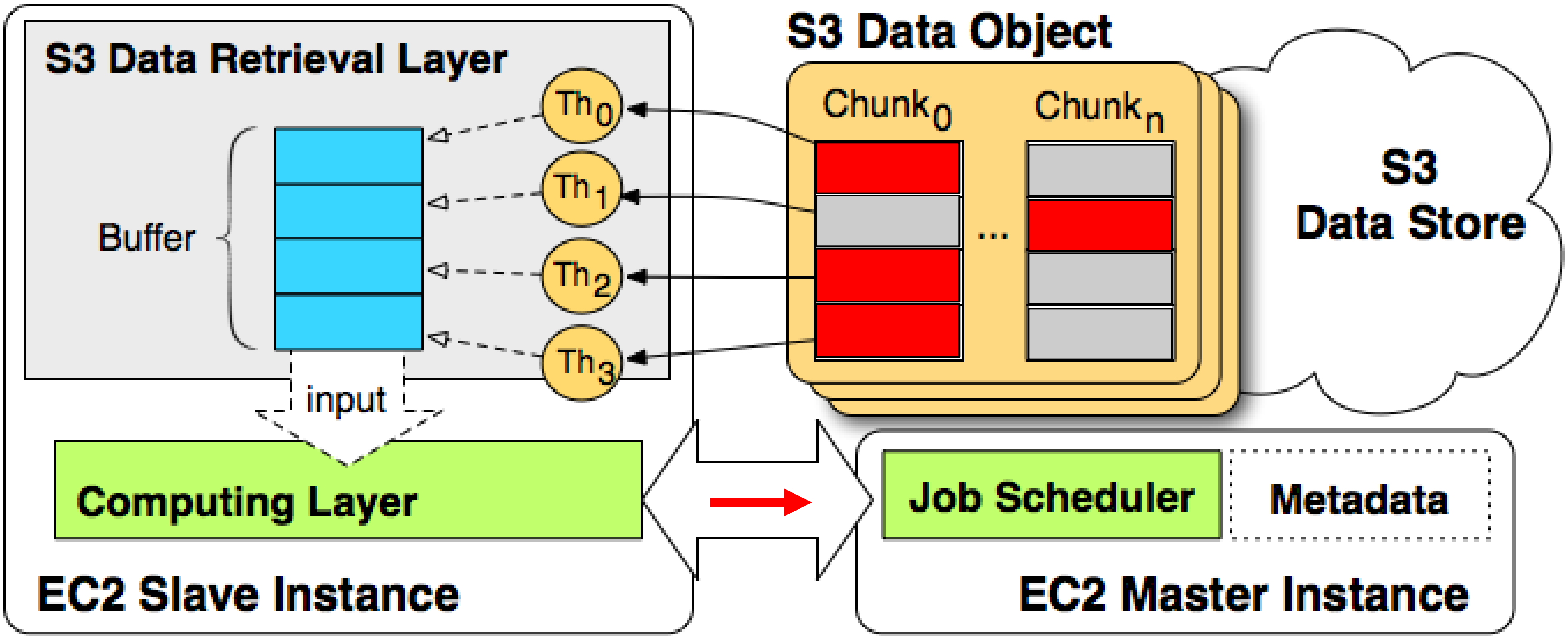


Schedule for processing...

Simple greedy heuristic:

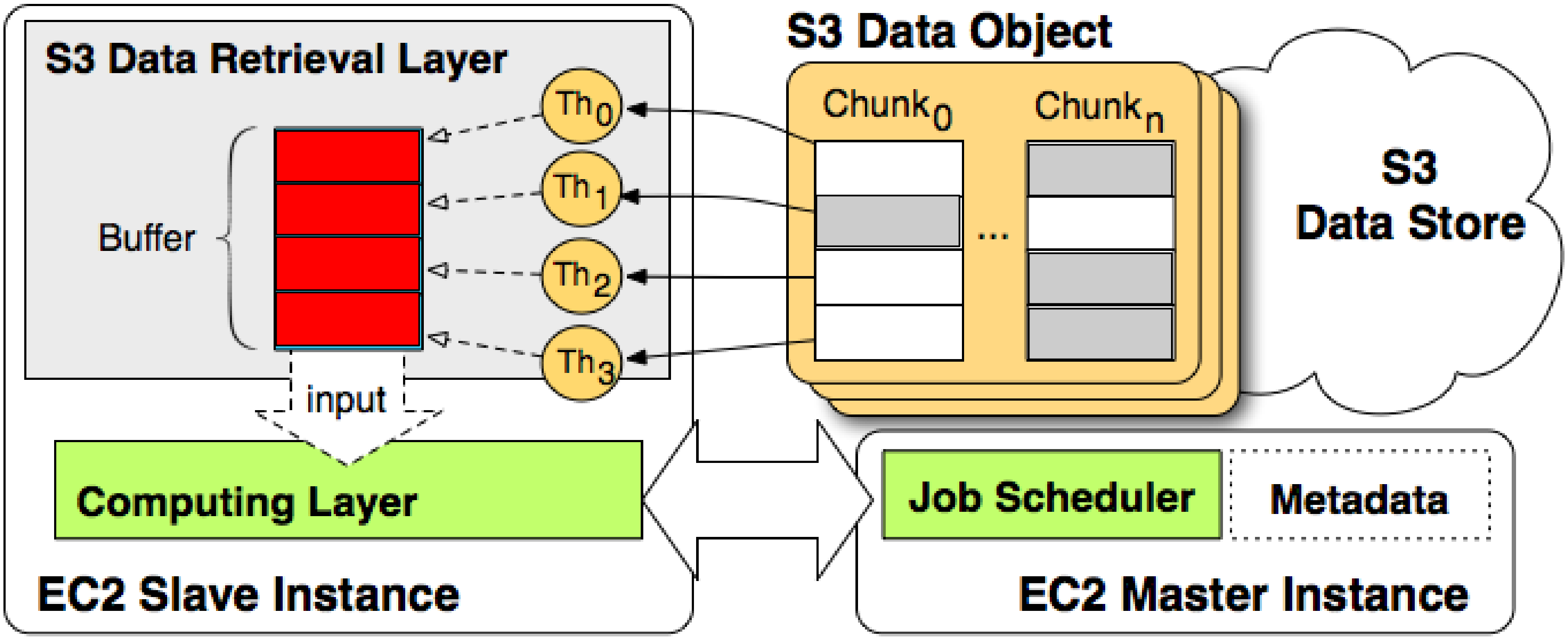
Select a unit belonging to the least connected chunk

MATE-EC2 Processing Flow



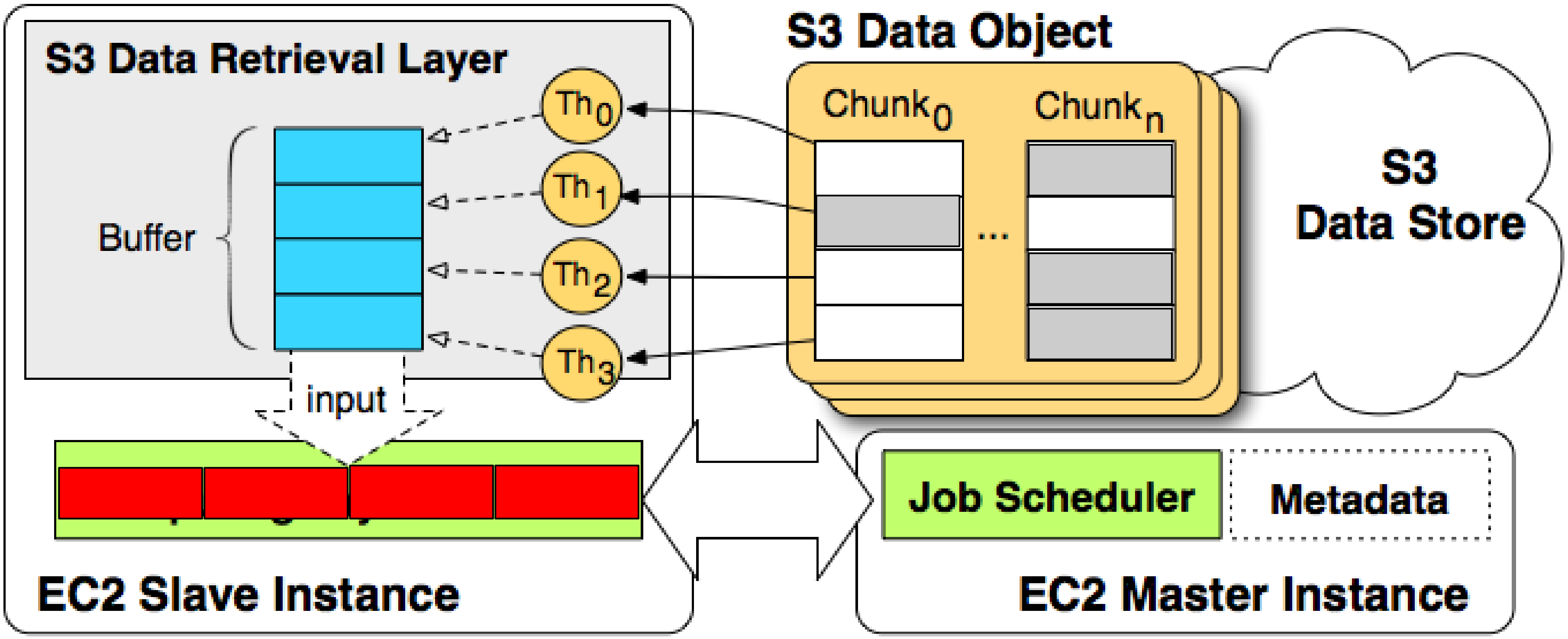
(1) Compute node requests a job from Master

MATE-EC2 Processing Flow



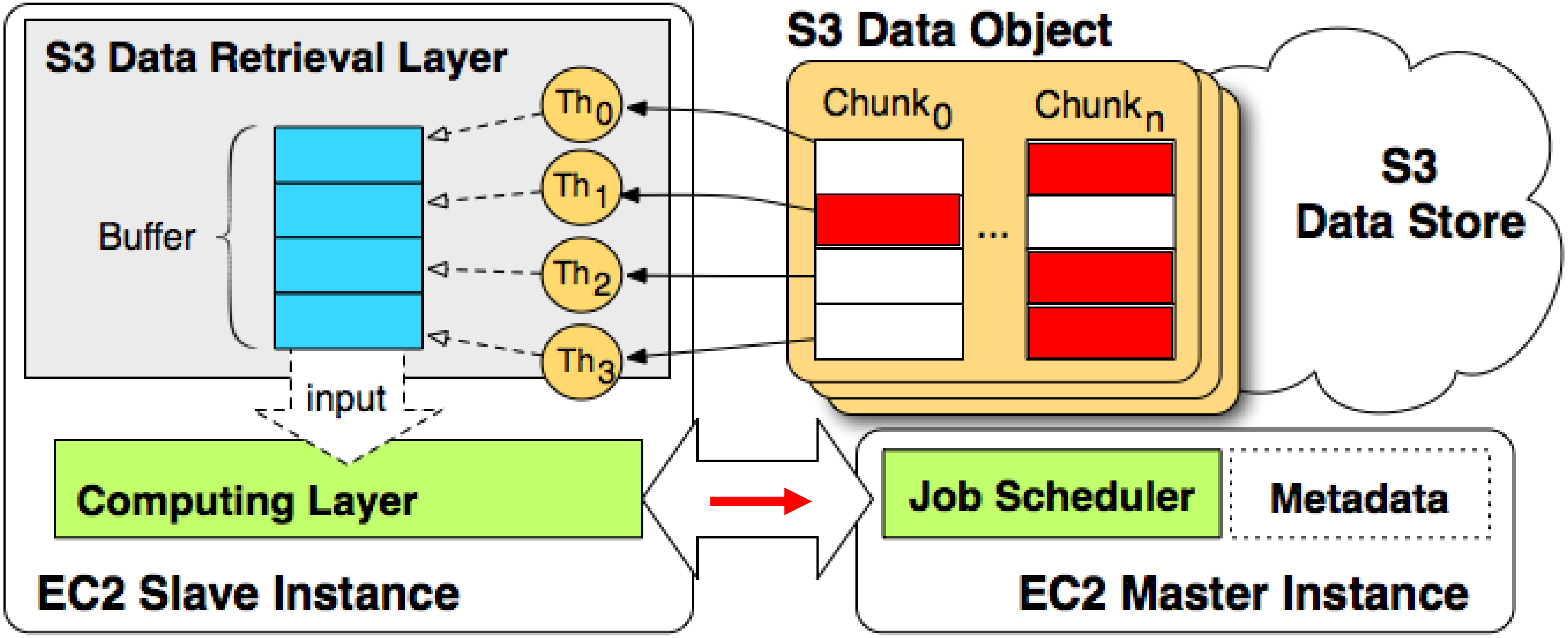
(2) Chunk retrieved in units

MATE-EC2 Processing Flow



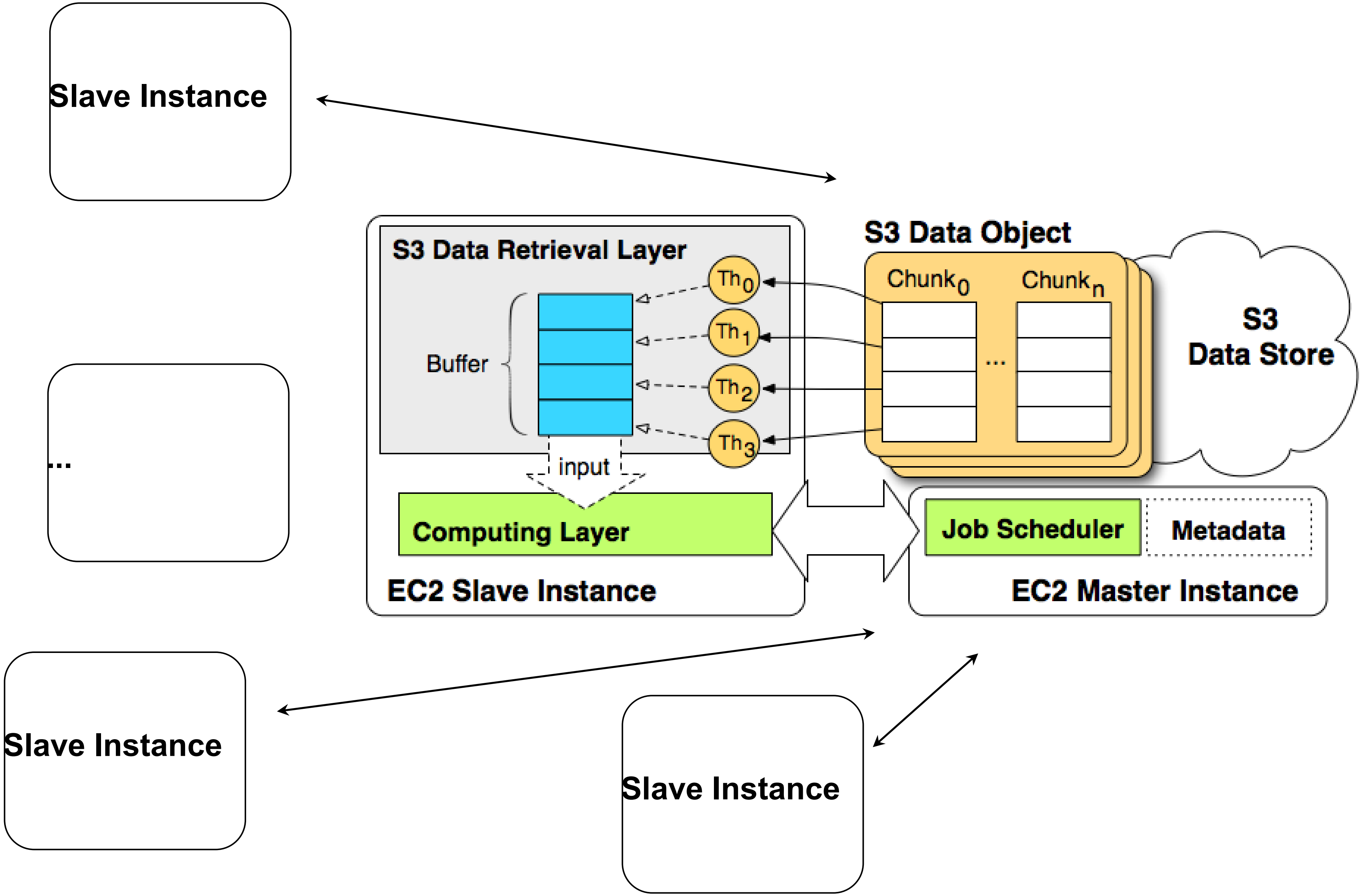
(3) Pass to Compute Layer, and process

MATE-EC2 Processing Flow



(4) Request another job from Master

MATE-EC2 Processing Flow



Experiments

- Goals
  - Finding the most suitable setting for AWS
  - Performance of MATE-EC2 on heterogeneous and homogeneous compute environments
  - Performance comparison of MATE-EC2 and Map-Reduce

Experiments (Cont.)

- Setup:
  - 4 Large EC2 *slave* instances
  - 1 Large instance for *master* instance
  - For each application, the dataset is split into16 data objects on S3

- Large Instance:
  - 4 compute units (each comparable to 1.0-1.2GHz)
  - 7.5GB (memory)
  - 850GB (disk, ephemeral)
  - High I/O

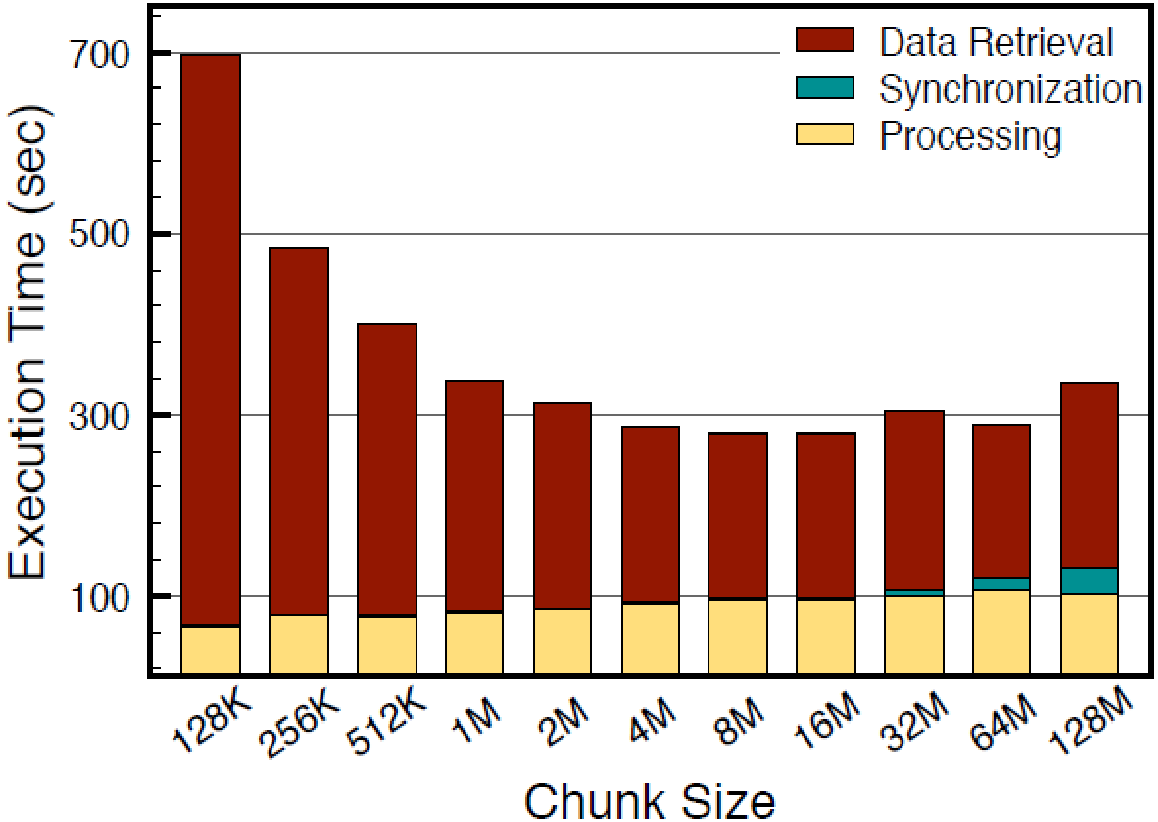
Experiments (Cont.)

App	I/O	Comp	RObj Size	Dataset
KMeans Clustering	Low/Med	Med/High	Small	**8.2GB** 10.7 billion points
PCA	Low	High	Large	**8.2GB**
PageRank	High	Low/Med	Very Large	**1GB** 9.6M nodes, 131M edges

Effect of Chunk Sizes (KMeans)

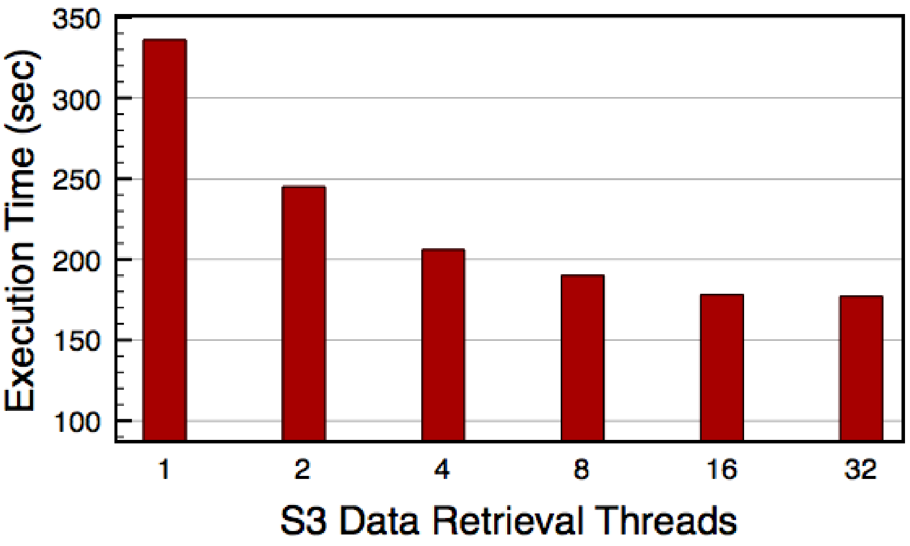
- Performance increase:
  - 128KB vs. >8M
  - 2.07x to 2.49x speedup

1 Data Retrieval Thread



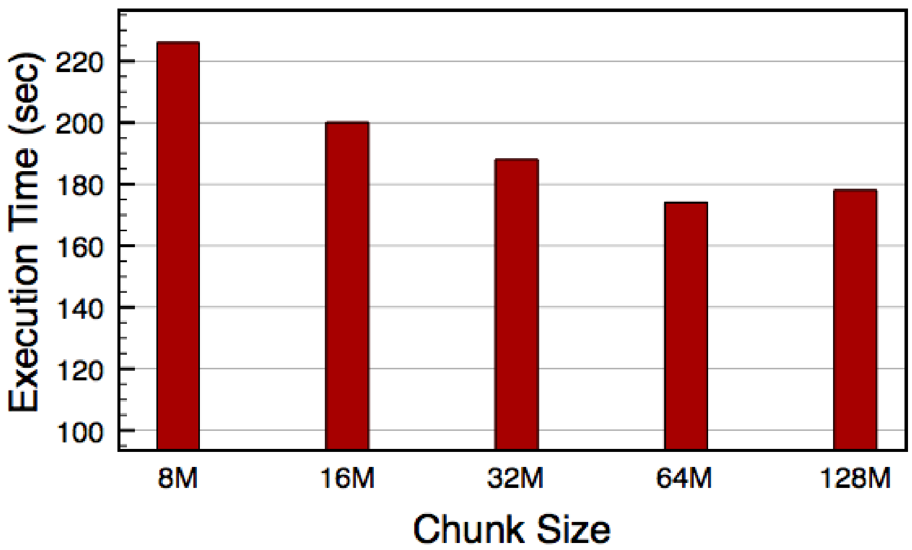
Data Retrieval (KMeans)

128M Chunk Size



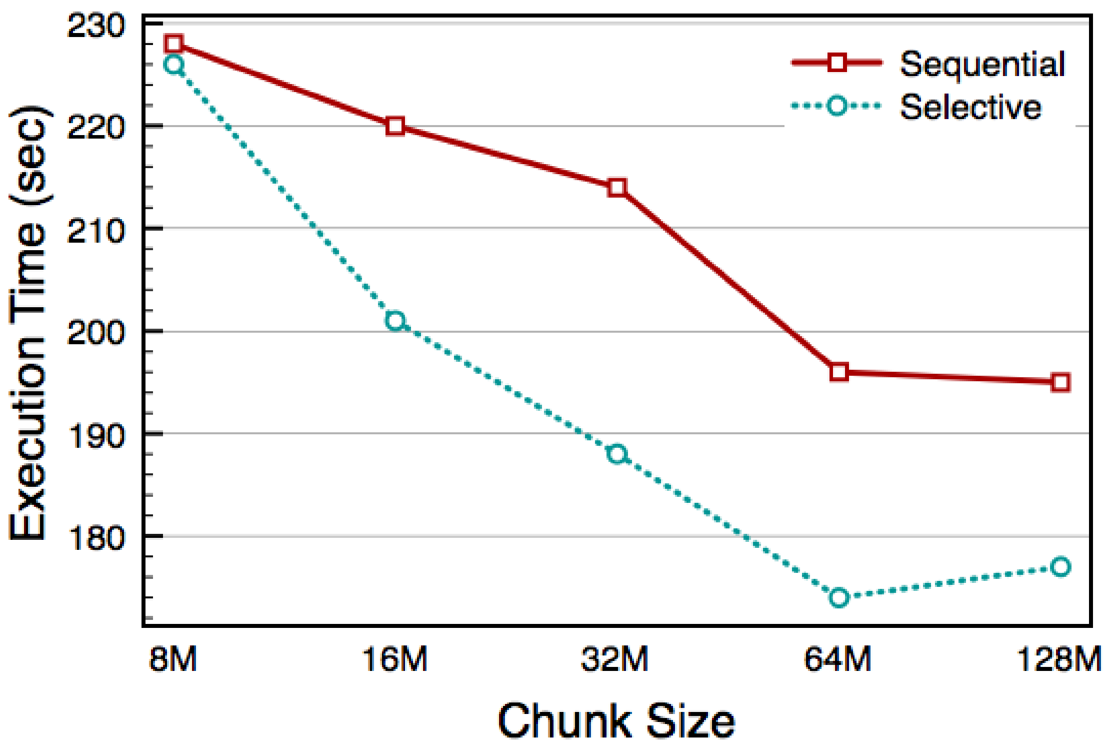
- One Thread vs. others: 1.37x - 1.90x

16 Data Retrieval Threads



- 8M vs. others speedup: 1.13x - 1.30x

Job Assignment (KMeans)

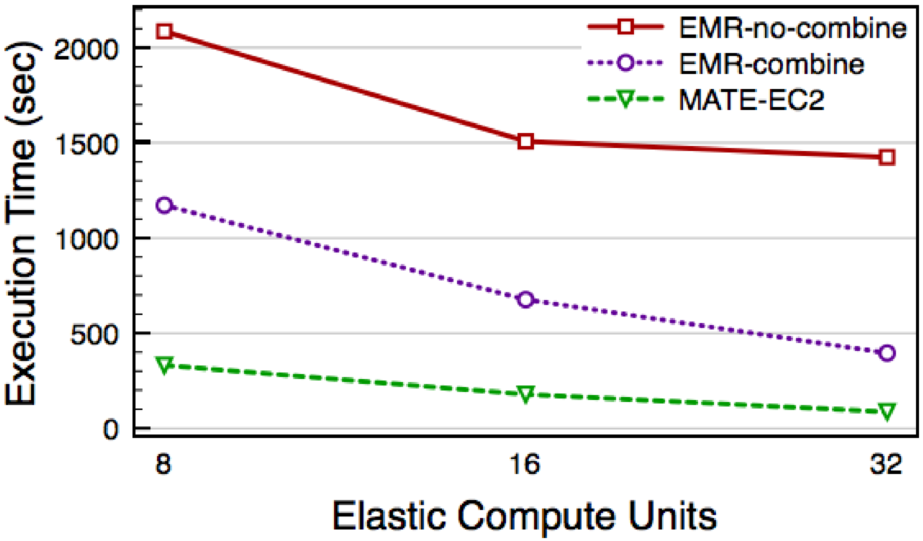


- Speedup:
  - 1.01x for 8M
  - 1.1x to 1.14x for others

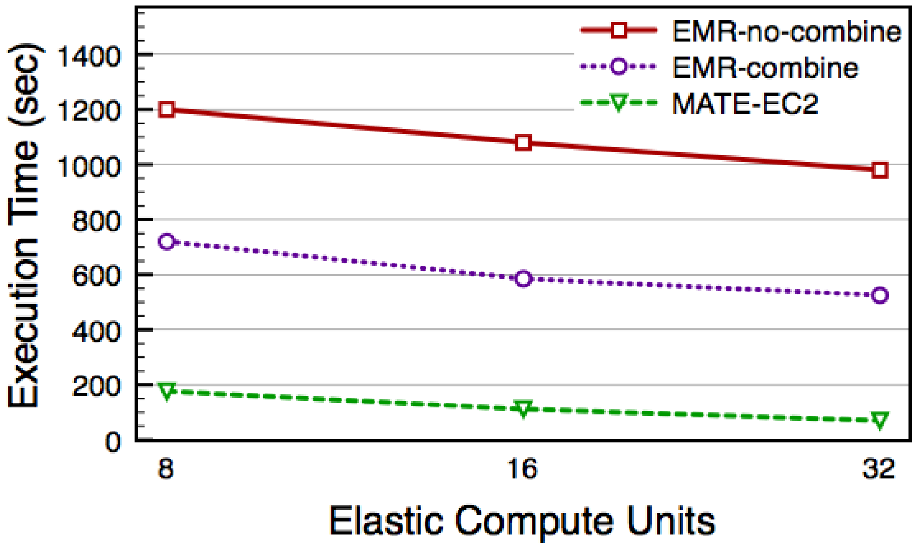
MATE-EC2 vs. Elastic MapReduce

Chunk Size: 128MB
Data retrieval Threads: 16

KMeans



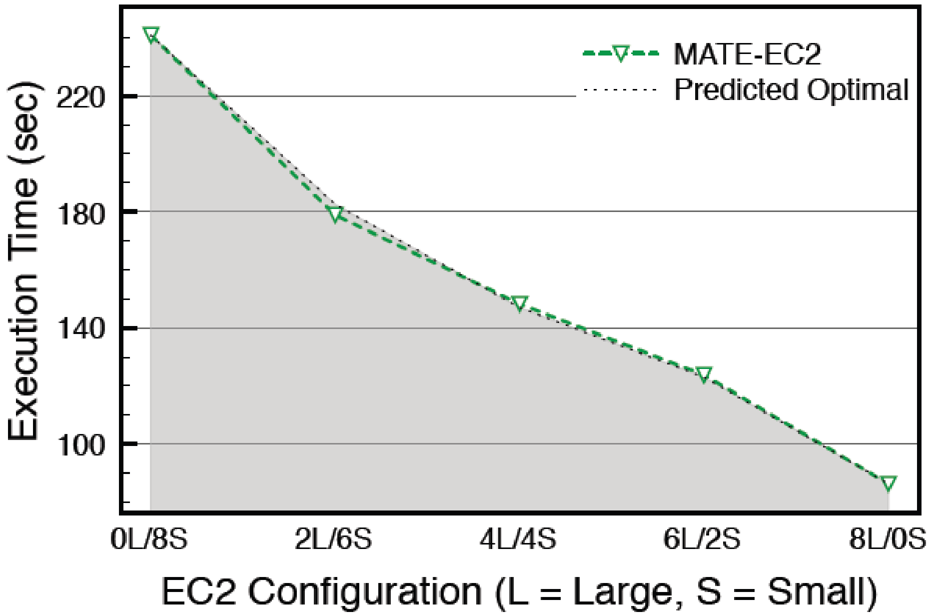
PageRank



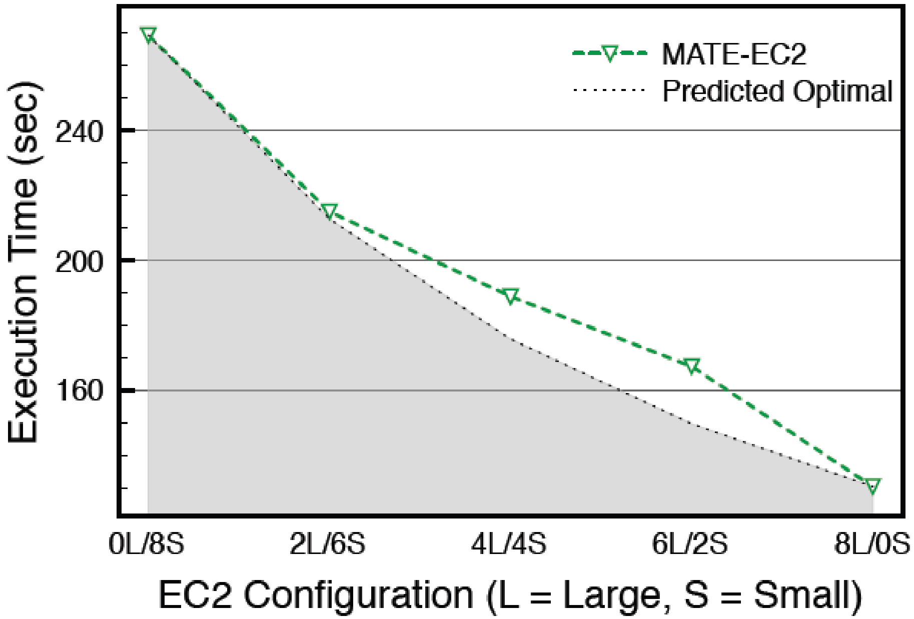
Speedups vs. EMR-combine
3.54x to 4.58x

Speedups vs. EMR-combine
4.08x to 7.54x

MATE-EC2 on Heterogeneous Instances



(a) KMeans – 128MB Chunk Size, 16 Data Retrieval Threads



(b) PCA – 128MB Chunk Size, 16 Data Retrieval Threads

- Overheads
  - KMeans: 1%
  - PCA: 1.1%, 7.4%, 11.7%

In Conclusion...

- AWS environment is explored for data-intensive computing
  - 64M and 128M data chunks w/ 16 data retrieval threads seems to be optimal for our middleware
- Our data retrieval and processing optimizations significantly improve the performance of our middleware
- MATE-EC2 outperforms MR both in scalability and performance

Thank You

- Questions & Discussion

- Acknowledgments:
  - We want to thank the MTAGS’11 organizers and the reviewers for their constructive comments
  - This work was sponsored by: