HiTune

Dataflow-Based Performance Analysis for Big Data Cloud

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Big Data

"Industrial Revolution of Data"

- The heartbeat of mobile, cloud and social computing
- Expanding faster than Moore's law
  - E.g., Internet of Things

What is Big Data?

- Too large to work with using traditional tools (e.g., RDBMS)
- Require a new architecture
  - Massively parallel software running on 100s~1000s of servers

Dataflow Model for Big Data Analytics

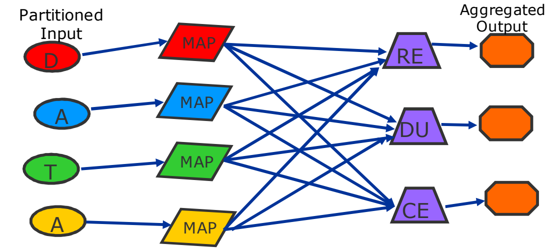
User

- Applications modeled as dataflow graphs
- Write subroutines running on the vertices
- Abstracted away from messy details of distributed computing

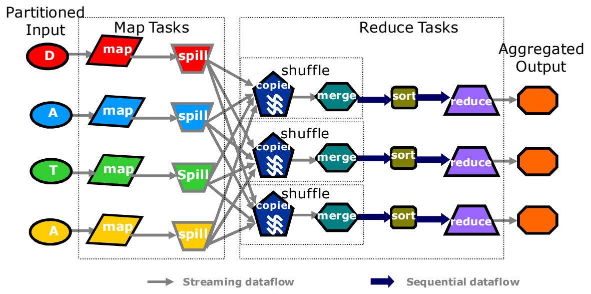
System runtime

- Dynamically map dataflow graphs to the cluster
- Handles all the low level details
  - Data partitioning, task distribution, load balancing, node communications, fault tolerance, …

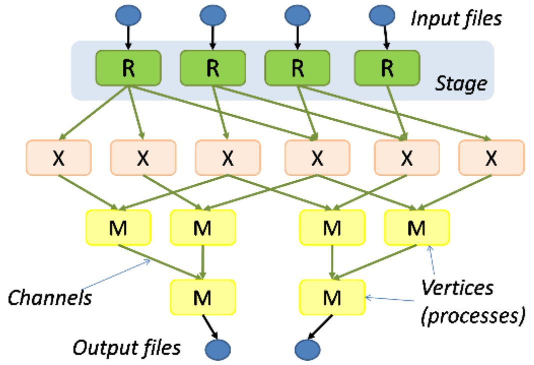
MapReduce



Hadoop



Dryad



What Worked

Parallel programming is hard

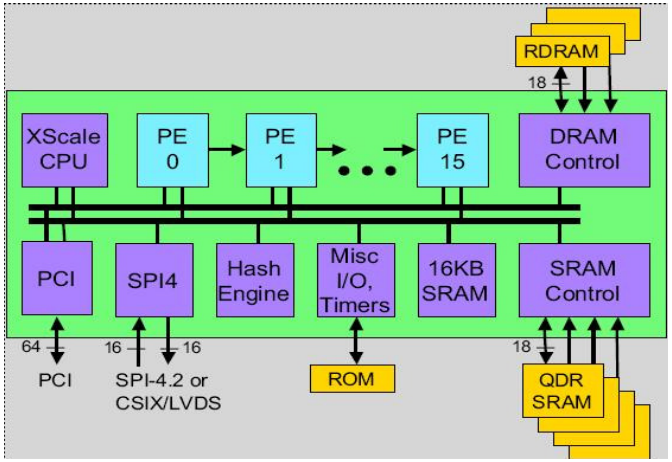
- Distributed programming is harder
- Dataflow model makes it a lot easier

> **Nontrivial software written with *threads*, *semaphores*, and *mutexes* are incomprehensible to humans.**
>
> **Edward A. Lee**
> **CGO 2007, March 2007**

An appropriately high level of abstraction

- User required to consider data parallelisms exposed by the dataflow
- Runtime distributes executions of subroutines by exploiting data dependencies encoded in the dataflow

Auto-Partitioning Compiler for Intel Network Processor (IXP)



What Didn’t Work

Dataflow abstraction makes Big Data system appear as a “black box”

- Very difficult for the user to understand runtime behaviors
- Performance analysis & tuning remain a big challenge

Key challenges of performance analysis for Big Data

- Massively distributed system
  - How to correlate concurrent performance activities (across 10000s of programs and machines)?
- High level dataflow abstraction
  - How to relate low level performance activities to high level dataflow model?

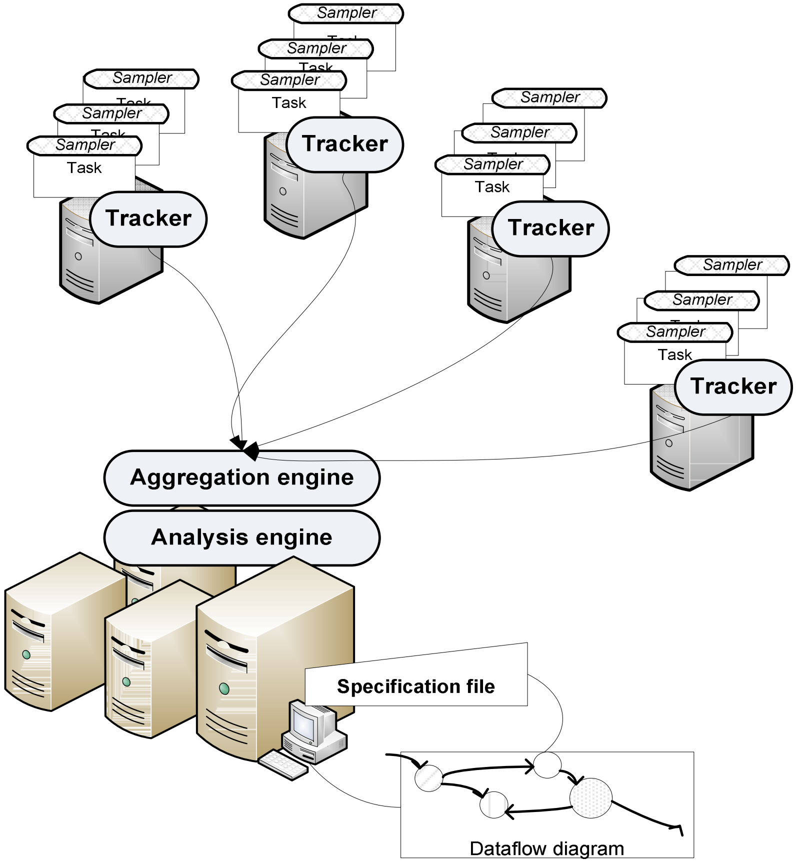
HiTune: "Vtune for Hadoop"

Distributed instrumentations

- Lightweight sampling using binary instrumentation
  - No source code modifications
- Implemented using Java programming language agents
  - Generic sampling information collected

Dataflow-driven analysis

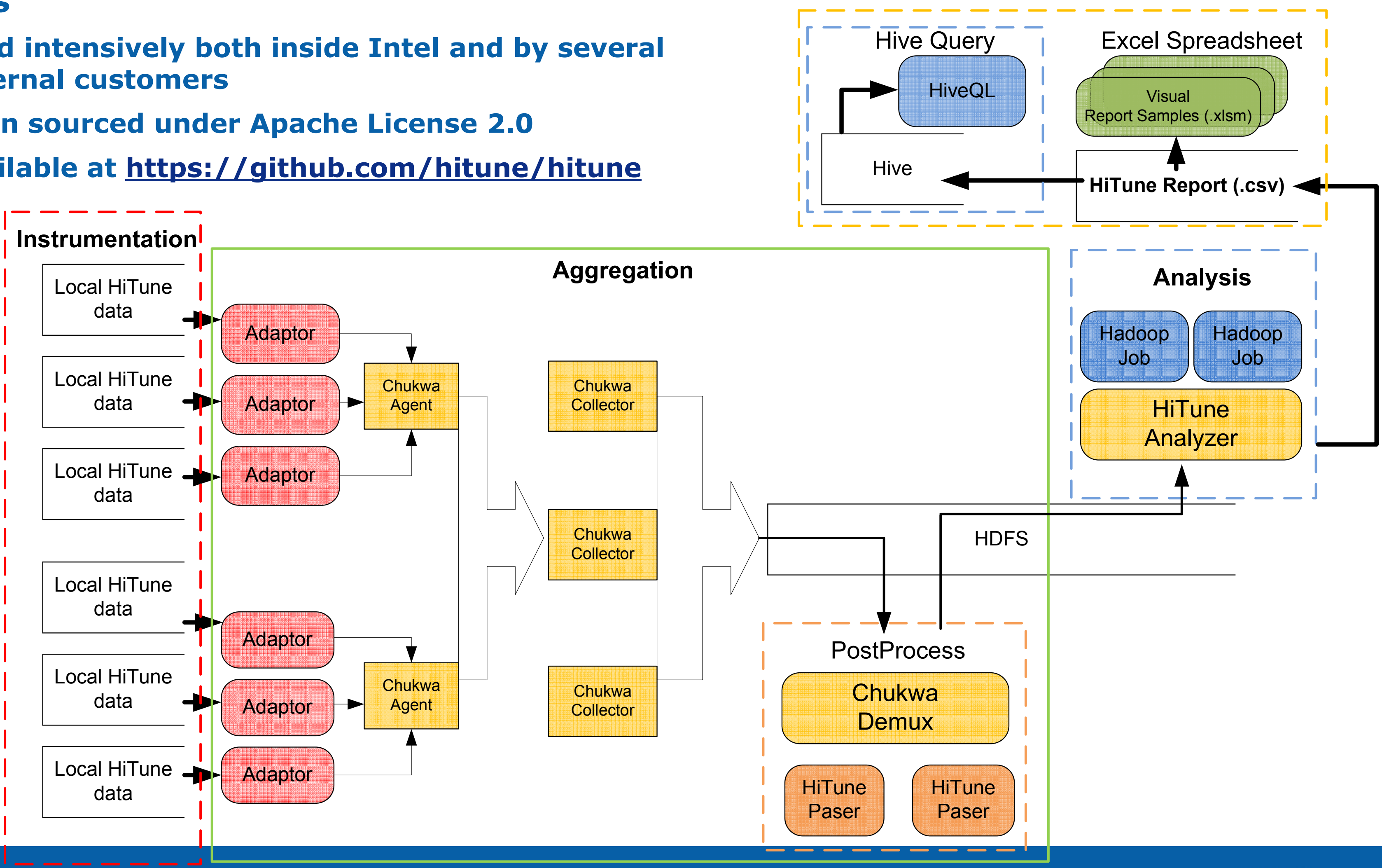
- Re-constructing dataflow execution process using low level sampling information
  - Based on a dataflow specification
- Implemented as several Hadoop jobs



HiTune 0.9

Status

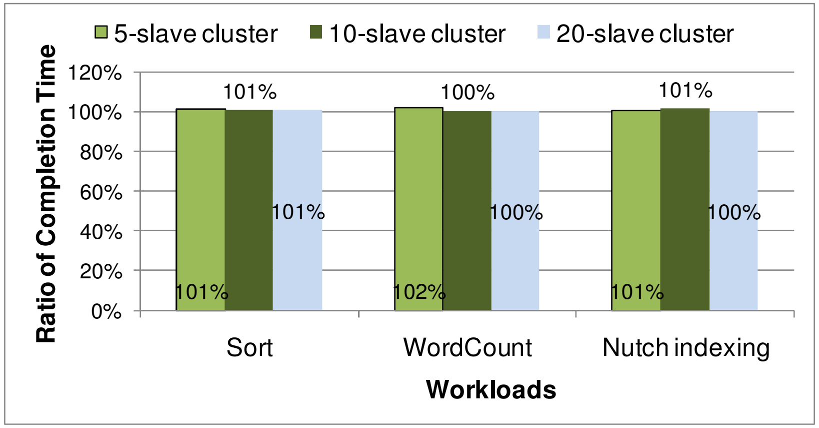
- Used intensively both inside Intel and by several external customers
- Open sourced under Apache License 2.0
- Available at https://github.com/hitune/hitune

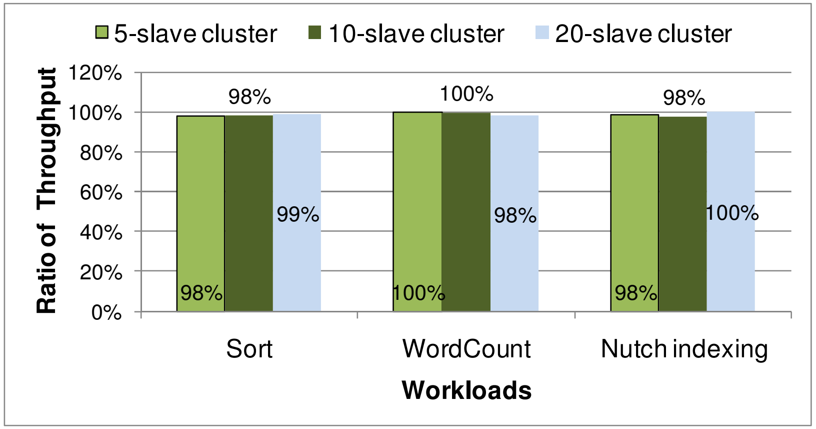


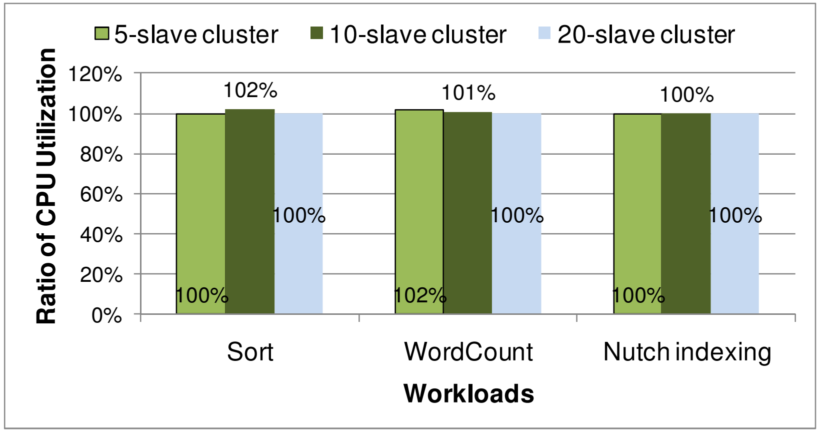
Overhead

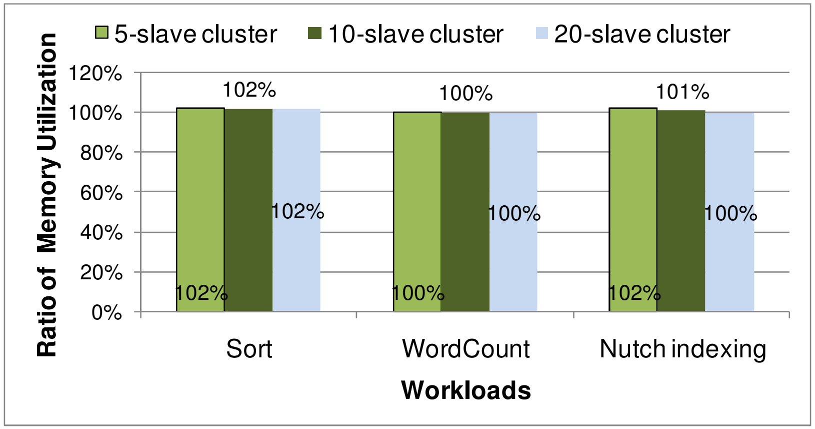
Ratio of instrumented vs. uninstrumented clusters

- **Less than 2% runtime overhead due to instrumentation**

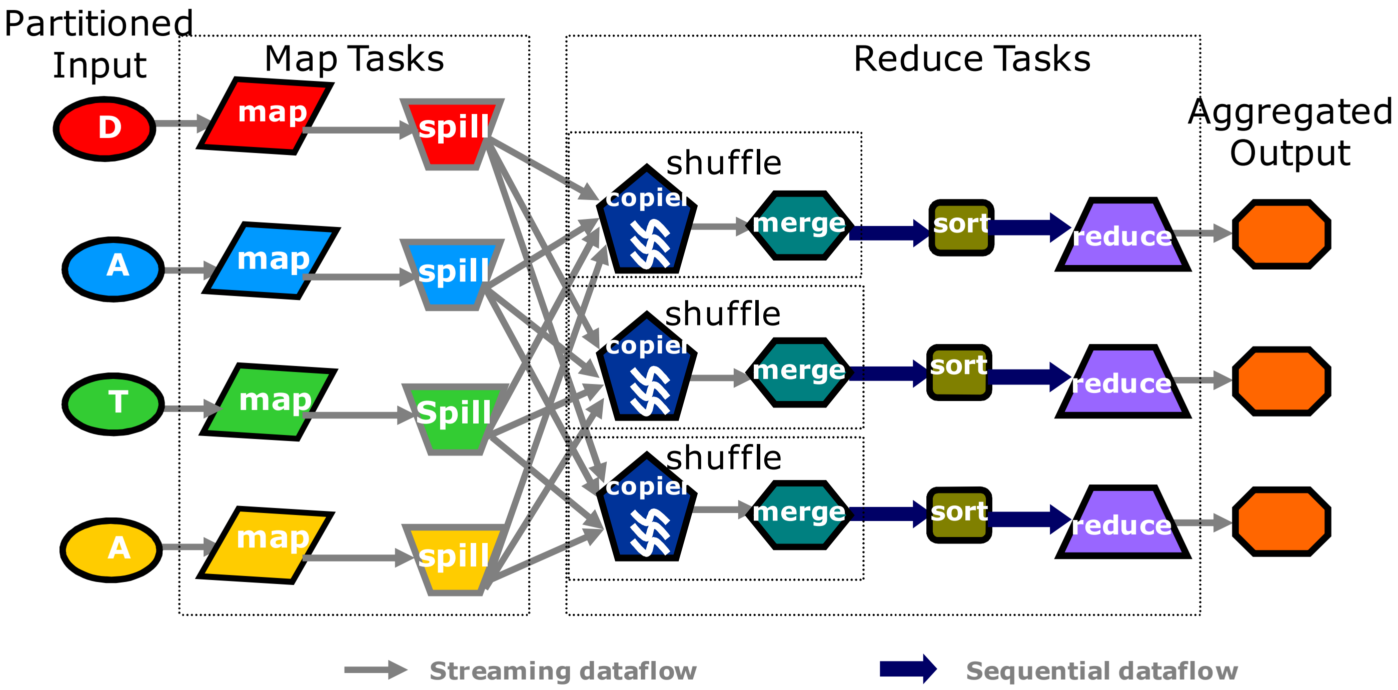








The Hadoop Dataflow Model



Case Study: Limitation of Traditional Tools

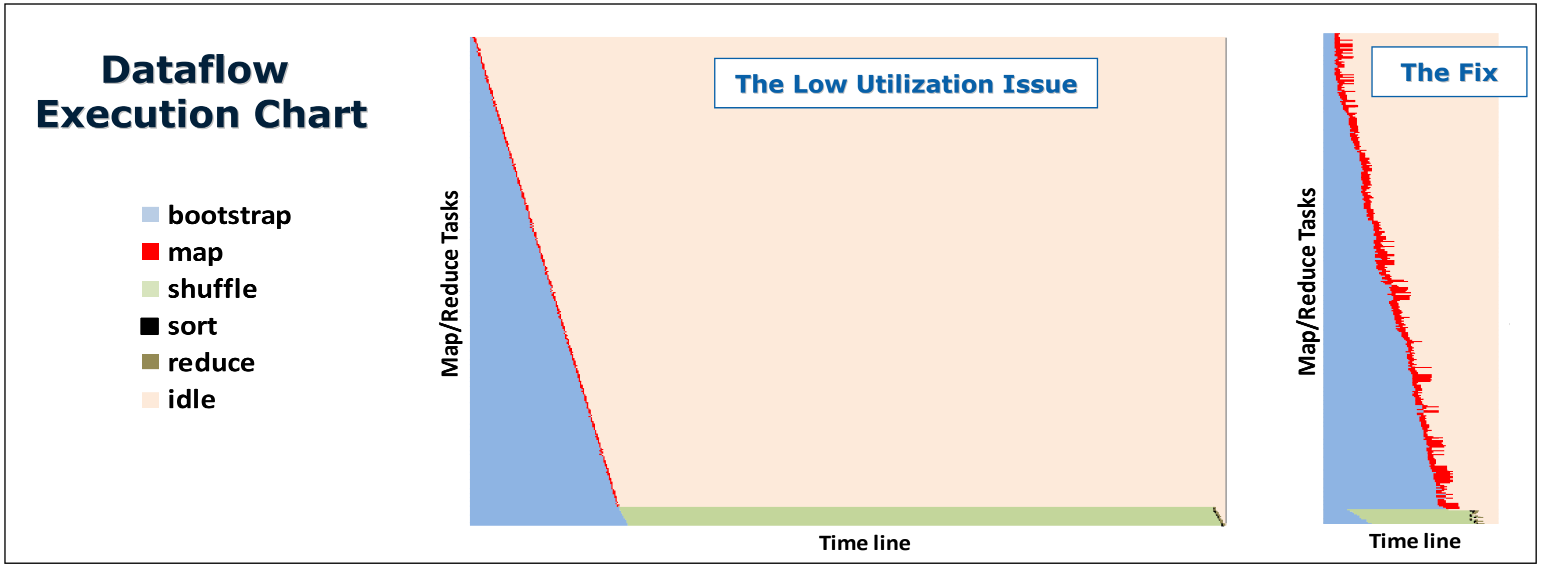
Sorting many small files (3200 500KB-sized files) using Hadoop 0.20.1

- ***Cluster very lightly utilized (extremely low CPU, disk I/O and network utilization)***
- **No obvious bottlenecks or hotspots in the cluster**
- **Traditional tools (e.g., system monitors and program profilers) fail to reveal the root cause**

Case Study: Limitation of Traditional Tools

HiTune results (dataflow execution) reveal the root cause

- Upgrading to “Fair Scheduler 2.0” fixes the issue



Dataflow Execution Chart

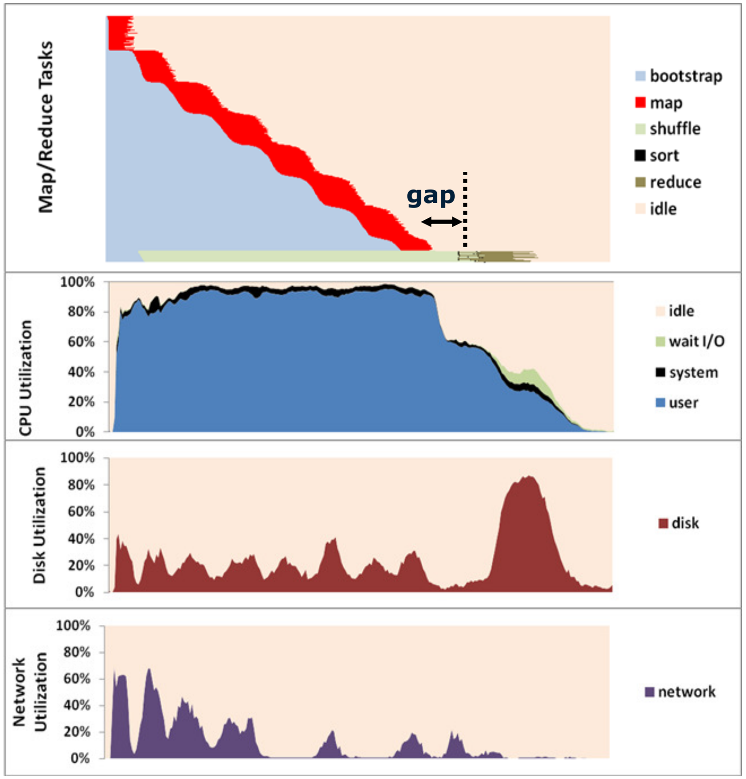
The Low Utilization Issue

The Fix

Case Study: Limitation of Hadoop Logs

TeraSort

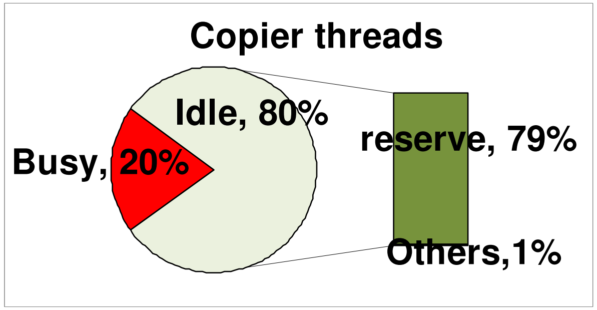
- ***Large gap between end of map and end of shuffle***
  - None of CPU, disk I/O and network bandwidth are bottlenecked during the gap
- **"*Shuffle Fetchers Busy Percent*" metric reported by Hadoop is always 100%**
  - Increasing the number of copier threads brings no improvement
- **Traditional tools or Hadoop logs fail to reveal the root cause**

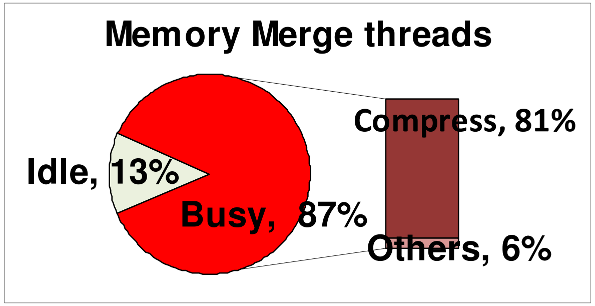


Case Study: Limitation of Hadoop Logs

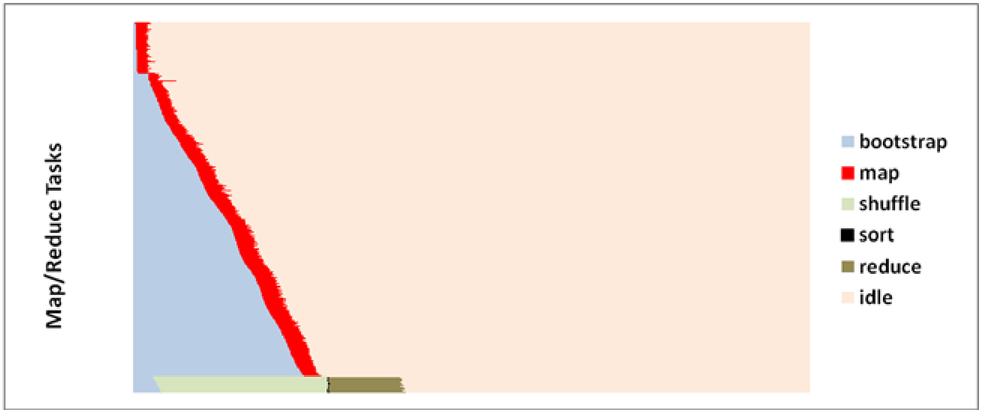
HiTune results (dataflow-based hotspot breakdown) reveal the root cause

- *Copier* threads idle 80% of the time, waiting for *memory merge* thread
- *memory merge* thread busy mostly due to compression





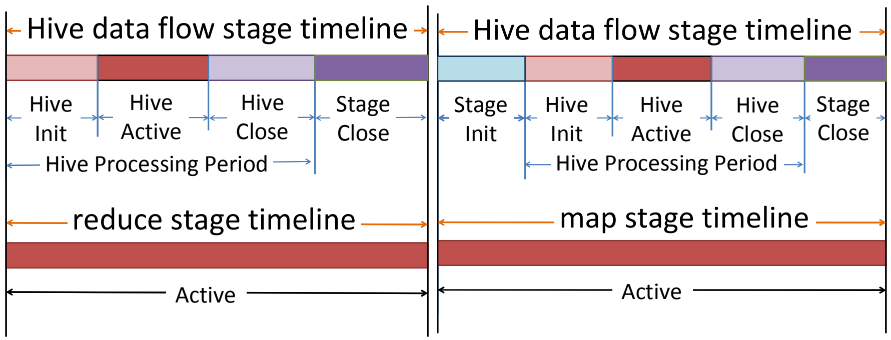
- Changing compression codec to LZO fixes this issue



Case Study: Extensibility

Easily extended to support Hive

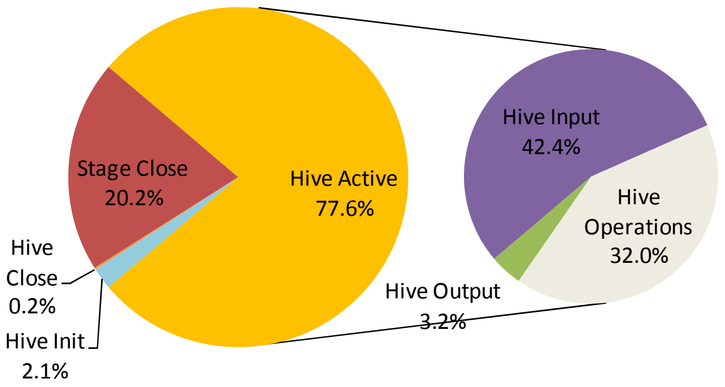
- Simply changing the dataflow specification



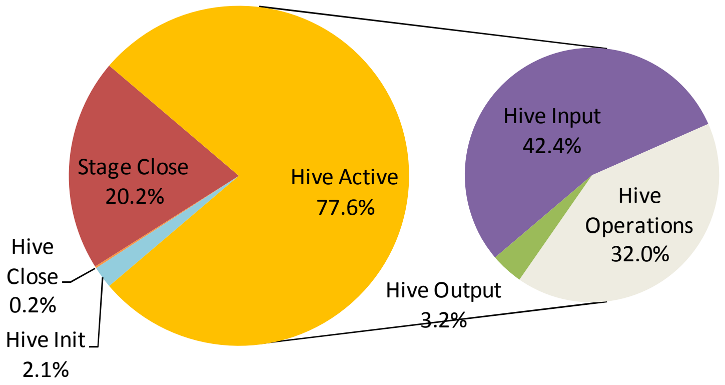
Aggregation query in Hive performance benchmarks

- 68% of time spent on data input/output, Hadoop/Hive initialization & cleanup
- Critical to reduce intermediate results, improve data input/output, and reduce Hadoop/Hive overheads

Map Tasks



Reduce Tasks



Summary

HiTune - “VTune for Hadoop”

- Better insights on Hadoop runtime behaviors
  - Dataflow-based analysis
- Extremely low runtime overheads
- Very good scalability & extensibility
- v0.9 open sourced under Apache License 2.0
  - See https://github.com/hitune/hitune

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