Result Integrity Check for MapReduce Computation on Hybrid Clouds

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Agenda

- Problem Statement
- System Design
- Theoretical Analysis
- Experiment Result

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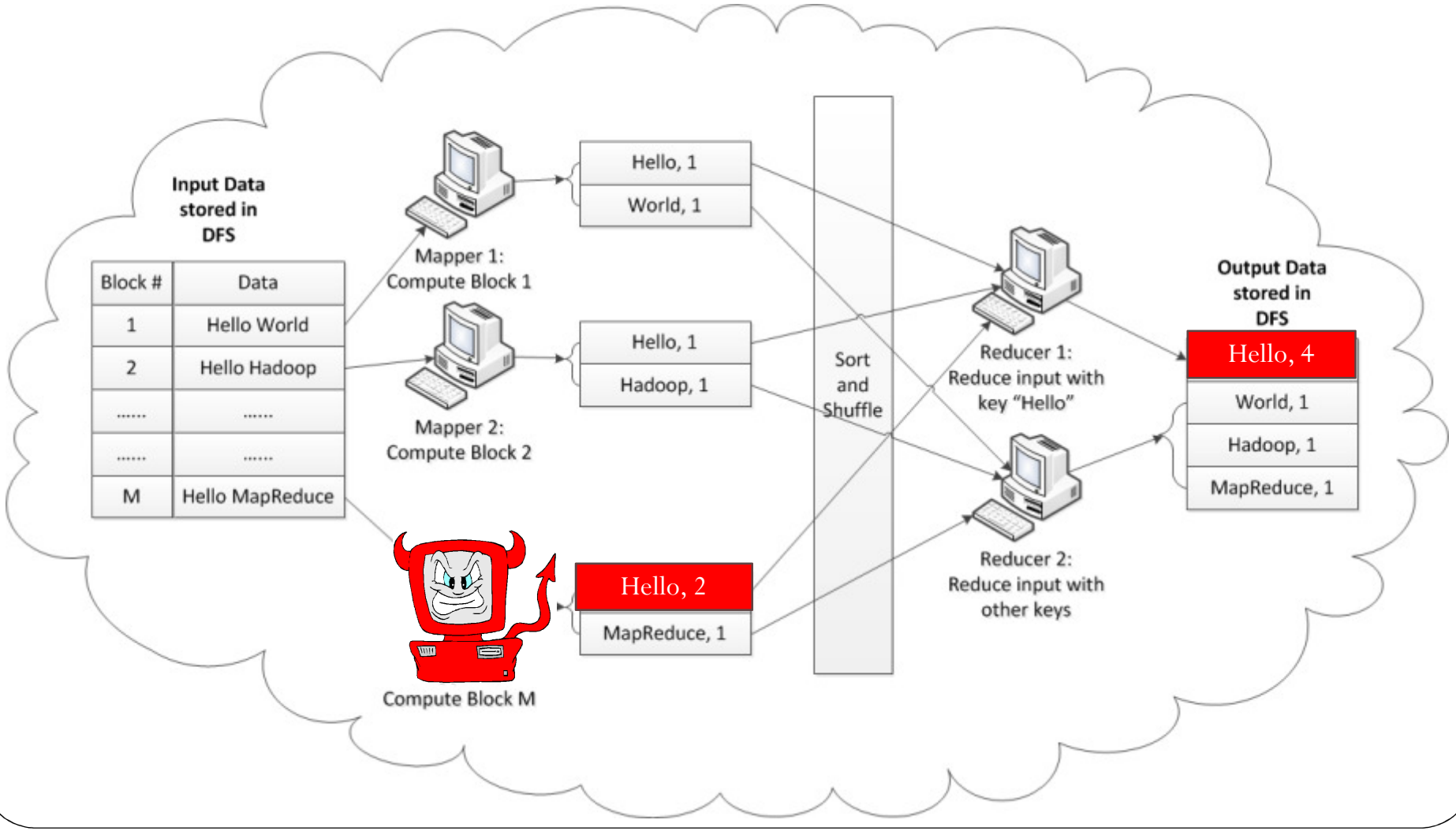
MapReduce

- A highly parallel computing model designed for Big Data computation.
- Computation is performed on a cluster consists of a master and many *slave workers*.
- Data are stored and processed in <*key, value*> tuples.
- One MapReduce *job* can be divided into *map phase* and *reduce phase*.

Word Count, a MapReduce Example



Problem

- How to provide high integrity MapReduce computing service on an untrusted public cloud.

Our Solution: Cross Cloud MapReduce (CCMR)

Trusted private cloud + Untrusted public cloud

Assumptions and Attacker model

- Assumptions
  - The private cloud is trusted.
  - The MapReduce storage (DFS) is trusted [5][6].
  - The tasks in MapReduce jobs are deterministic
- Attacker Model
  - Certain portion (m) of workers are malicious ($0 \leq m \leq 1$).
  - The malicious workers are controlled by an adversary.
  - The adversary directs malicious workers to collaborate with each other to inject as many errors as possible without being detected.

[5]Bowers, Kevin, et al. "HAIL: a high-availability and integrity layer for cloud storage." CCS '09.
[6] Popa, Raluca Ada, et al. "Enabling security in cloud storage SLAs with Cloud Proof." USENIX ATC '11.

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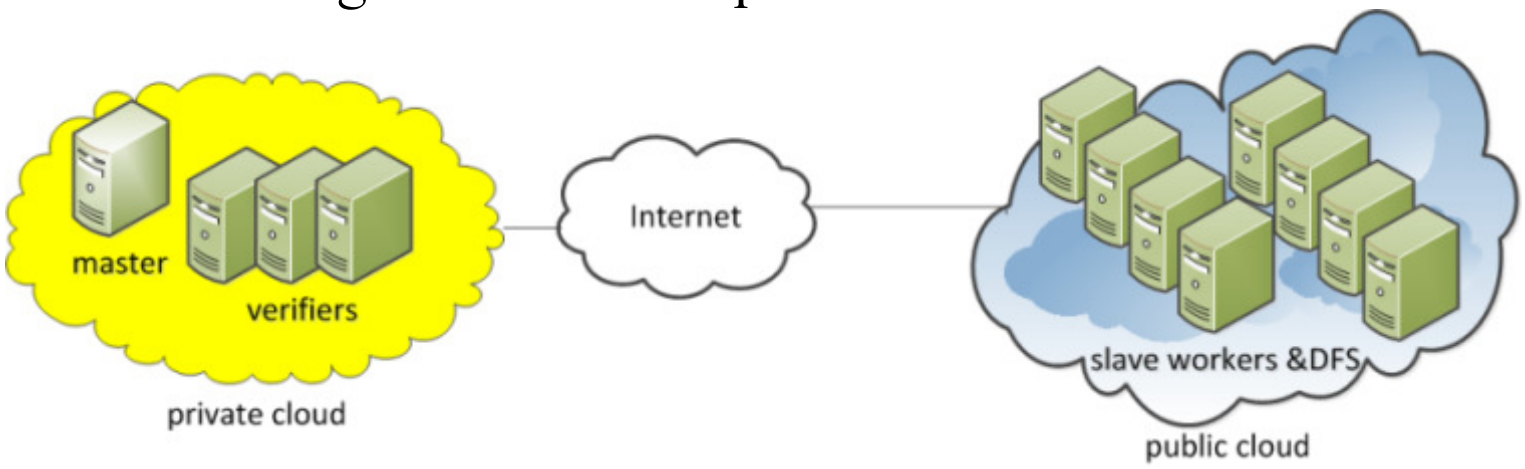
System Design

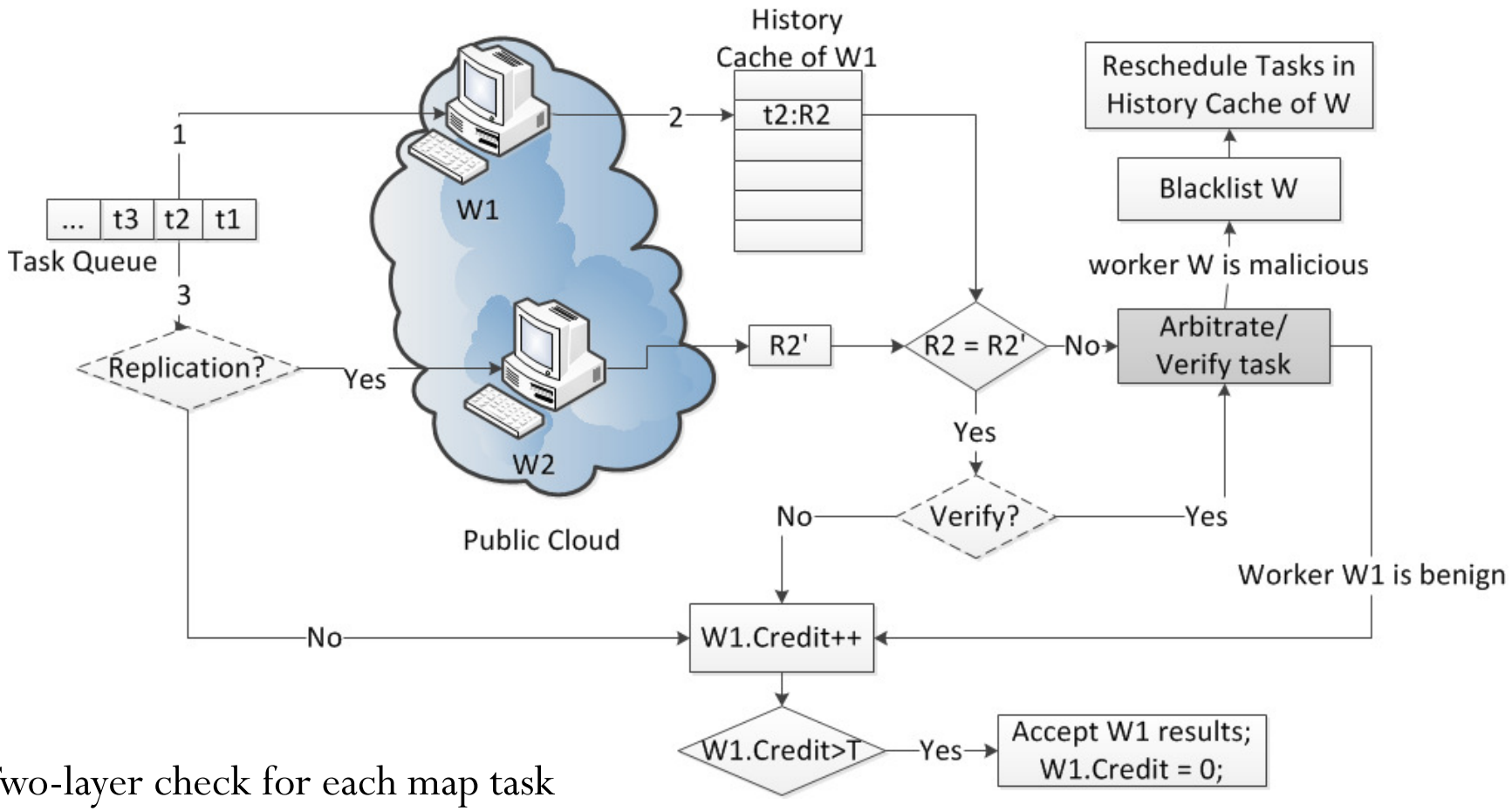
- Hybrid cloud architecture
  - Trusted private cloud with verifiers
  - Untrusted public cloud
- Core Techniques
  - Two-layer check
  - Credit based trust management
- Different design for different phases.



Map Phase Integrity Check

- Two-layer check for each map task
  - Replication with *replication probability r*.
  - For task passed first-layer check, verification with *verification probability v*.
- Credit accumulation for each mapper
  - Increment credit of the worker.
  - Buffer the task result on the worker.
  - Accept results in batch only when worker achieves *credit threshold T*.

Map Phase Integrity Check



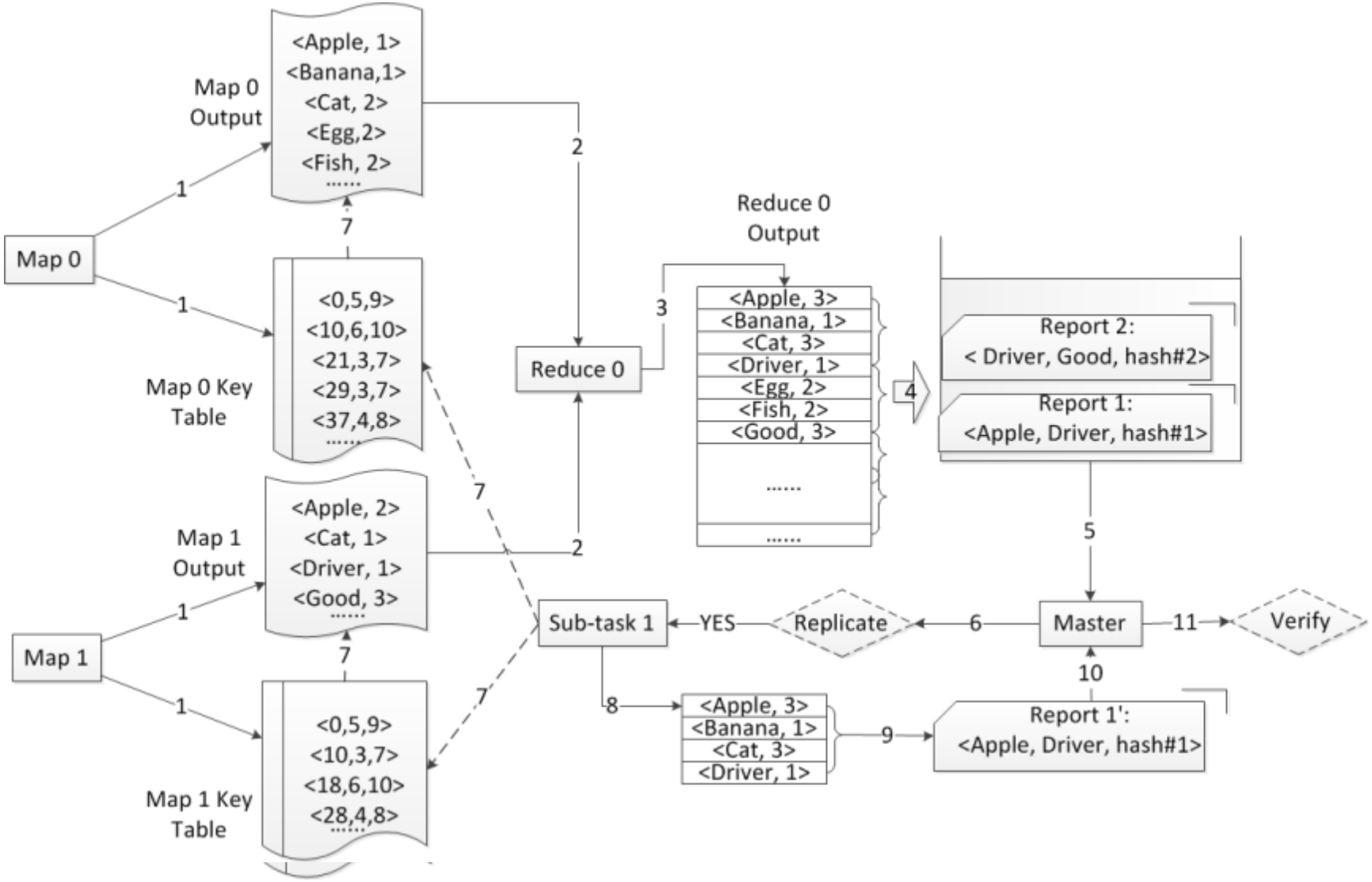
Two-layer check for each map task

Credit accumulation for each mapper

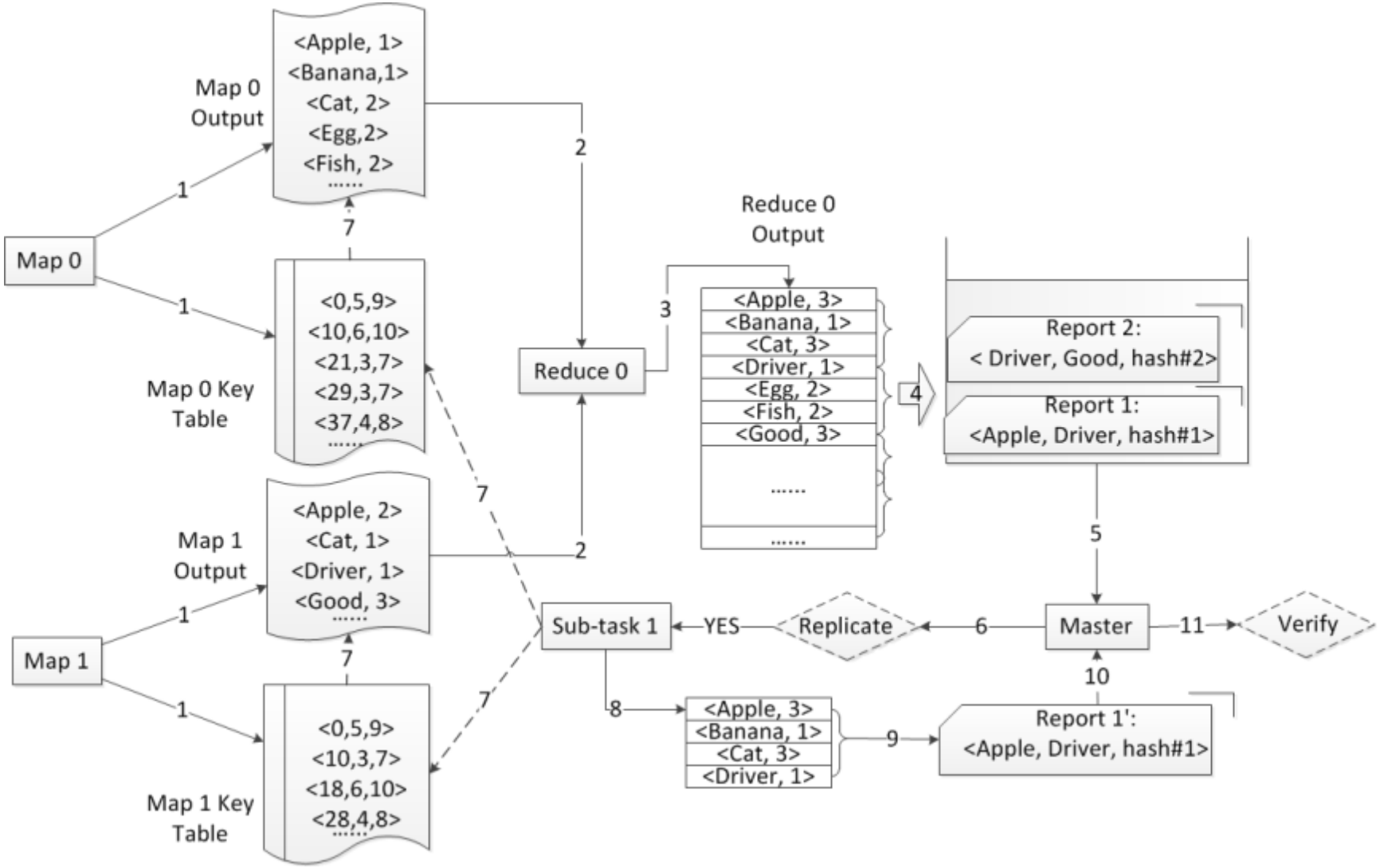
Reduce Phase Integrity Check

- Straightforwardly applying aforementioned techniques to Reduce phase may encounter difficulties
  - In some job, reduce task number is smaller while the processed records in one task is huge. (e.g., word count: 1 reduce task, 2.7 M of records to be processed, 262 seconds to finish).
- We wish
  - To divide such reduce task into many ***sub-tasks***.
  - To apply two-layer check and credit based trust management to each reduce *sub-task*.

Reduce Phase Integrity Check



Reduce Phase Integrity Check



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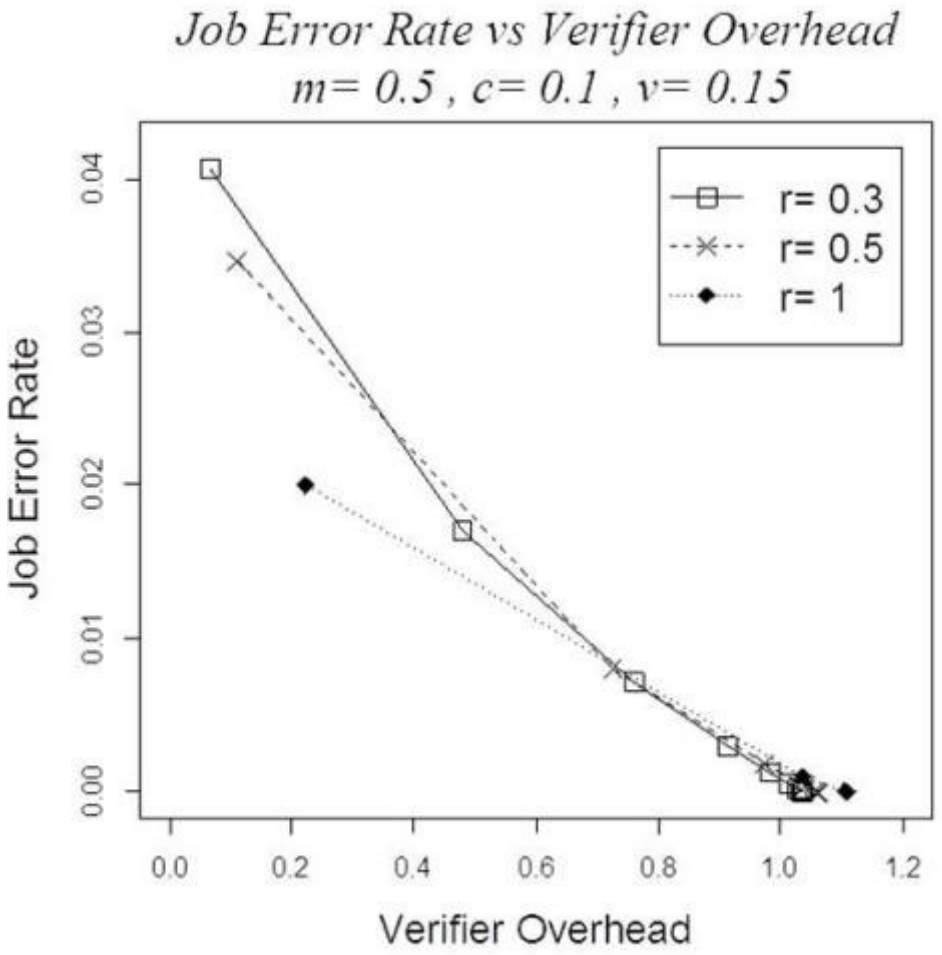
Model the System

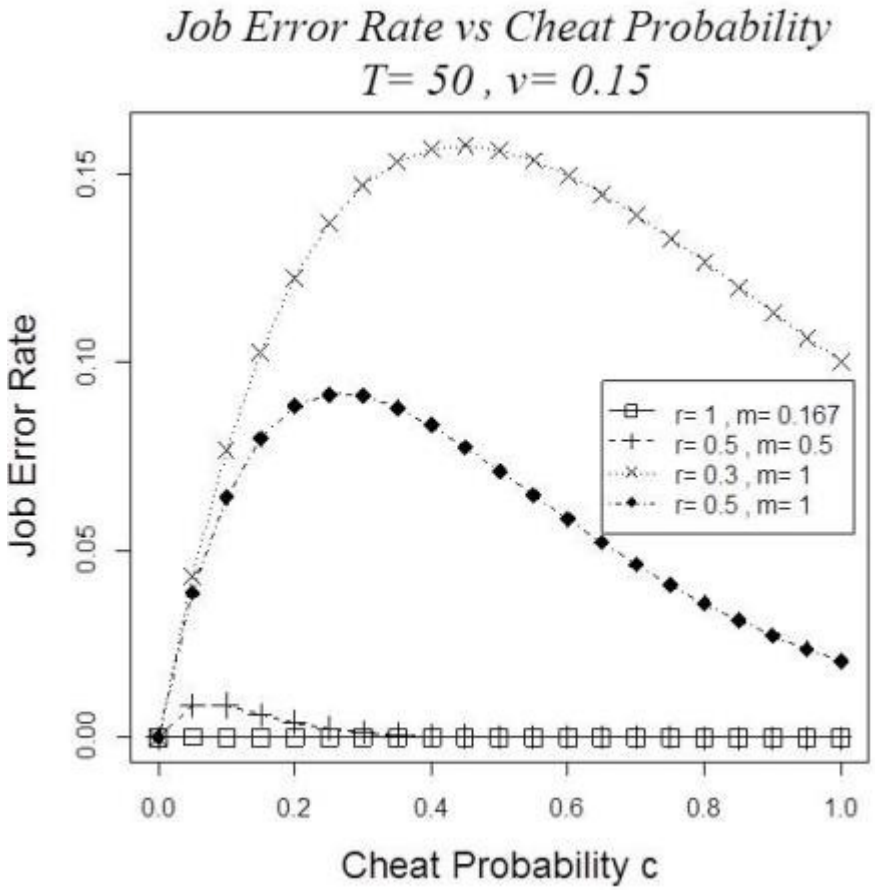
- Model map and reduce phase with same set of parameters
- Model the CCMR
  - T: Credit Threshold
  - r: Replication probability
  - v: Verification probability
- Model the Attacker
  - m: Malicious worker fraction
  - c: Cheat probability
- Measurement Metrics
  - Accuracy: Job Error Rate
    - Fraction of incorrect task/sub-task accepted by the master in one job.
  - Performance: Overhead & Verifier Overhead
    - For each task/sub-task, the expected number of extra executions performed on public/private cloud.
- Theoretical analysis conclusion is presented in **Theorem 1**.

Accuracy and Performance Trade Off



- To decrease Job Error Rate
  - Increase T
  - A higher overhead
  - A higher verifier overhead

Job Error Rate vs. Cheat Probability



- What's the upper bound of job error rate.
- When m is 0.5, r is 0.5, job error rate upper bound is less than 1%.
- When m is 1.0,r is 0.5, job error rate upper bound is 9%.

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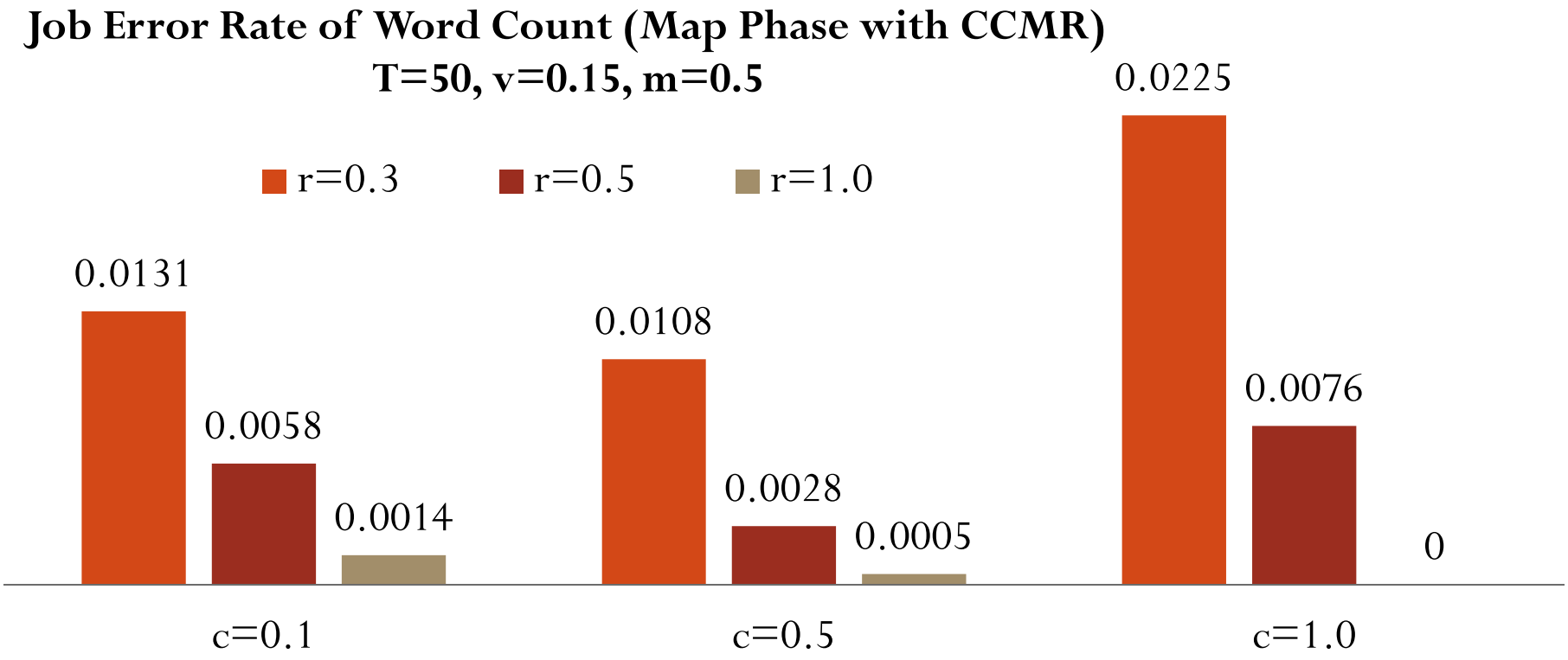
Environment Setup

- CCMR
  - Private Cloud:
    - 1 Linux server (2.93 GHz, 8-core Intel Xeon CPU and16 GB of RAM)
    - Running as a master and the verifier
  - Public Cloud
    - 12 Amazon EC2 micro instances (Amazon Linux AMI 32-bit, 613 MB memory, Shared ECU, Low I/O performance)
    - Running as 12 slave workers.
- Baseline (Original MapReduce)
  - 13 Amazon EC2 micro instances (Amazon Linux AMI 32-bit, 613 MB memory, Shared ECU, Low I/O performance)
  - Running as 1 master and 12 slave workers.

Experiment Applications

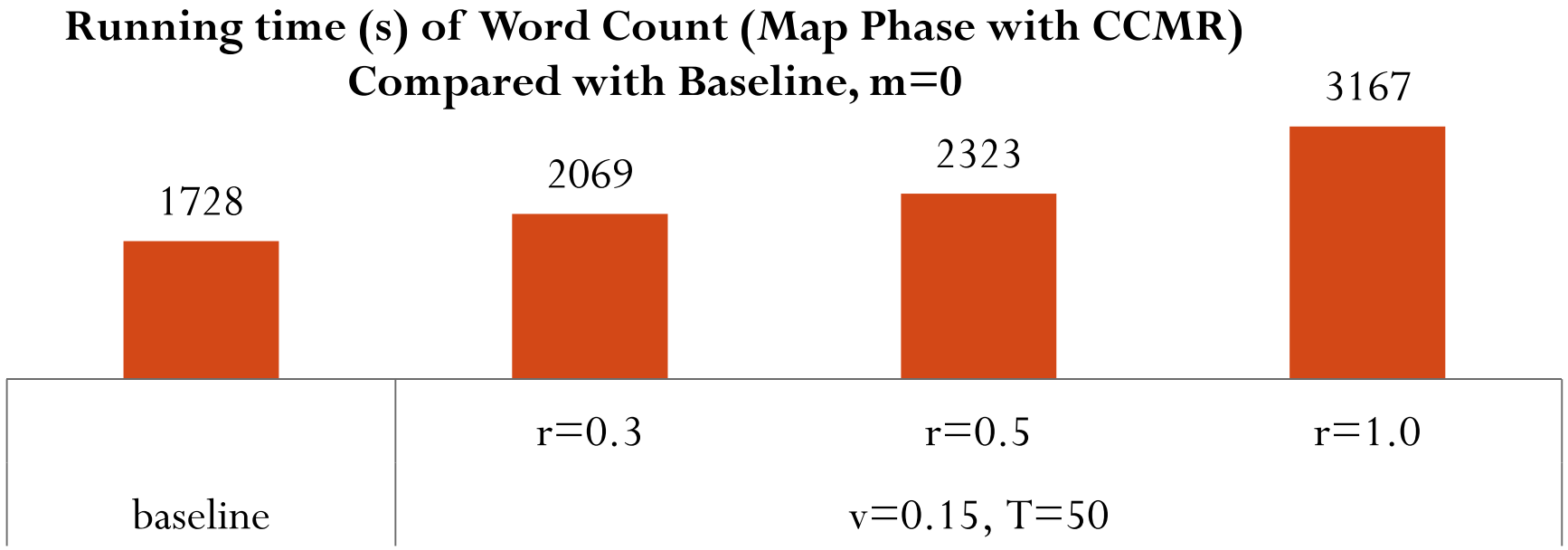
- Word Count:
  - Compute the frequency of each word in a batch of text files.
  - 800 text files as input, total input size as 653M.
  - 800 map task, 1 reduce task.
- Mahout 20 news group classification:
  - MapReduce implementation of Naïve Bayes classification
  - Classify news text files into 20 different categories.
  - 5 jobs in one application.

Map Phase (Accuracy)



When r is 0.3, job error rate ranges from 1.08% to 2.25%.
When r is 1.0, job error rate ranges from 0.14% to 0%.

Map Phase (Performance)

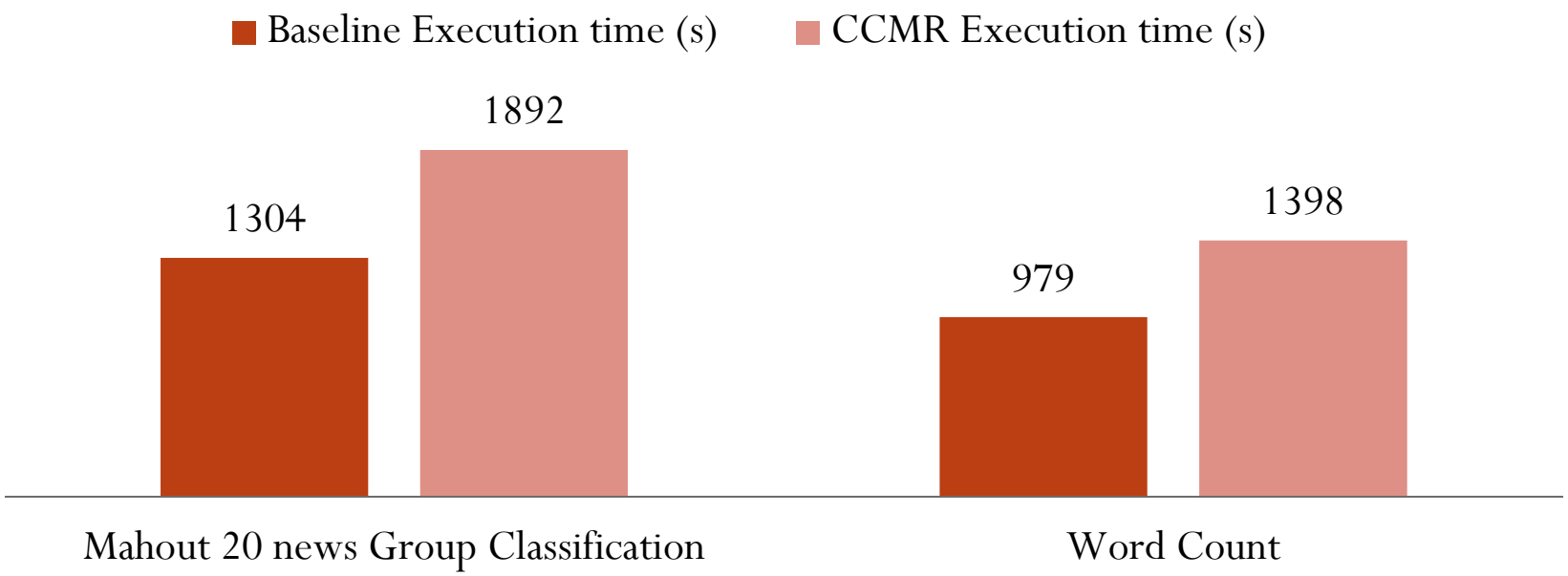


Extra execution times are 19%, 34% and 83%, when r increases from 0.3 to 1.0

The extra execution times are proportional to the replication probability r.

Reduce Phase(Performance)

Running time (s) of Mahout 20 Class. & Word Count (Reduce phase with CCMR) compared with baseline m = 0, r = 0.167, v = 0.07, T = 600



Extra execution time are 45% in Mahout classification, 43% in word count application.

The extra execution time are attributed to the vast number of sub-tasks for replication and verification.

E.g., Word Count application consists of 88 replication sub-tasks and 6 verification sub-tasks

Conclusion and Future Work

- Cross Cloud MapReduce(CCMR), a hybrid cloud MapReduce framework is proposed.
- By utilizing the trusting base gained from private cloud, a high integrity assurance MapReduce service can be achieved with majority of computation performed on public cloud.
- Reduce performance overhead and reasoning the optimal system parameter would be the next step work.


Thank you!
Q&A