Percolator

Large-Scale Incremental Processing using Distributed Transactions and Notifications

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Motivation

- Built to maintain the Google web search index
- Need to maintain a large repository, but cost of updates should be independent of size
- Must be able to maintain data invariants
- Must scale horizontally (number of machines)
- Must be easy for a programmer to reason about concurrency

Non-Goals

- Not required to be real-time (latency doesn’t matter)
- Availability secondary to scalability

EXISTING METHODS

MapReduce?

- Hides concurrency from the programmer
- Scales and performs very well

But…

- No incremental updates – all output is thrown away when the repository is updated
- Cost of update is proportional to size of the repository

Traditional DBMS?

- Provides incremental updates
- Concurrency is a non-issue for programmer
- Provides transactions and data constraints

But…

- Scalability (CPU, storage) usually limited to a few hosts
- Cannot handle larger data sets (tens of petabytes)

BigTable

- Distributed DBMS
- Very scalable in terms of throughput and storage using many machines
- Provides incremental updates

But…

- No transactions across rows – hard to maintain data invariants
- Provides few abstractions – essentially just structured storage

BigTable

- Dataset split into blocks
- Each block mapped to a BigTable ‘tablet’
- BigTable uses GFS for storage (high availability)
- Provides simple transactions and consistency guarantees for single rows
- Keeps revision history of individual cells

PERCOLATOR

What is Percolator?

- Large-Scale system for incremental processing
- Built on top of a BigTable distributed database
- Each machine in cluster runs:
  - GFS Chunkserver
  - BigTable tablet server
  - Percolator worker
- Provides useful abstractions to the programmer:
  - ‘Observers’
  - Multi-row transactions

Overview

- Data is written to BigTable by external process
- Programmer chooses columns for Percolator to watch
- Changes to watched columns trigger small user programs – ‘observers’
- These observers can then update other parts of the dataset, triggering further observers
- Each observer can atomically update multiple fields (all or nothing)

Observers

- Piece of user code with conditions for when to run it
- A column is added for every watched column in a table, which is set when the a cell is updated
- Each Percolator worker continuously scans random subsets of the repository for changes
- Runs observer if flag is set, then resets flag

Transactions

- A single observer is likely to modify values across several rows/tables, how to guarantee consistency?
- Want to provide ‘Snapshot Isolation Semantics’ – easy to reason about
- Need a high-performance locking service
  - BigTable fits
- Transactions ensure that if two observers touch the same rows, only one can commit

Two-Phase Commit

- Mechanism for coordinating writes
- Do all writes in two stages – lock and commit
- Try to acquire lock on every row
- Iff all locks succeed, then commit changes
- Lock and write are implemented in one operation using BigTable *time dimension*
- Commit updates current data pointer

Two-Phase Commit (cont'd)

Key	T	bal:data	bal:lock	bal:write
Bob				
	6			data @ 5
	5	£10		
Joe				
	6			data @ 5
	5	£2		

Two-Phase Commit (cont'd)

Key	T	bal:data	bal:lock	bal:write
Bob				
	7	£3	LOCK	
	6			data @ 5
	5	£10		
Joe				
	6			data @ 5
	5	£2		

Two-Phase Commit (cont'd)

Key	T	bal:data	bal:lock	bal:write
Bob				
	7	£3	LOCK	
	6			data @ 5
	5	£10		
Joe				
	7	£9	LOCK @ Bob.bal	
	6			data @ 5
	5	£2		

Two-Phase Commit (cont'd)

Key	T	bal:data	bal:lock	bal:write
Bob	8			data @ 7
	7	£3		
	6			data @ 5
	5	£10		
Joe				
	7	£9	LOCK @ Bob.bal	
	6			data @ 5
	5	£2		

Two-Phase Commit (cont'd)

Key	T	bal:data	bal:lock	bal:write
Bob	8			data @ 7
	7	£3		
	6			data @ 5
	5	£10		
Joe	8			data @ 7
	7	£9		
	6			data @ 5
	5	£2		

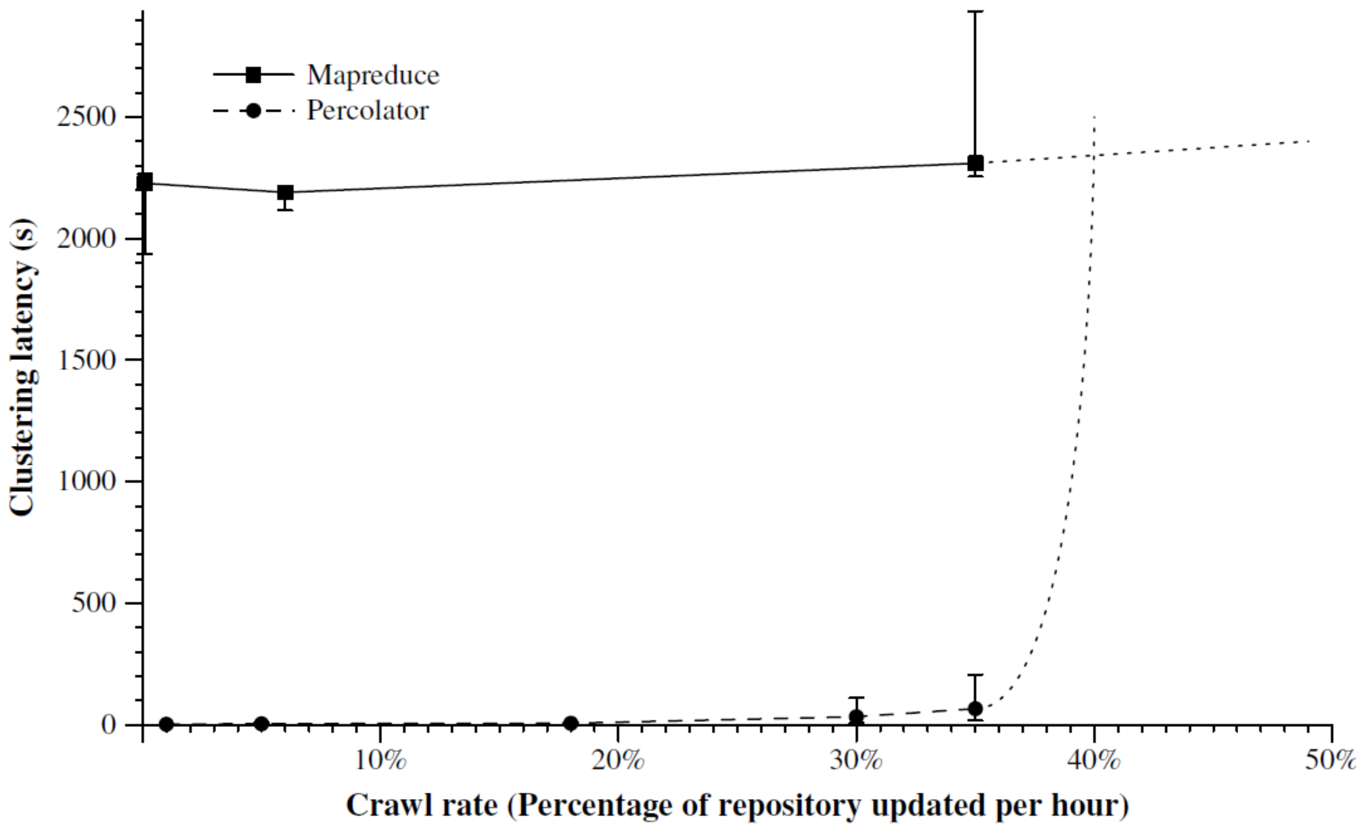
Transactions (cont'd)

- Each transaction has a start and commit timestamp requested from an oracle
- For writes:
  - if transaction sees another write after its start timestamp it aborts
  - if transaction sees another lock at any timestamp it aborts
  - otherwise, initiate Two-Phase commit
- For reads:
  - if locks prior to start timestamp, block
  - otherwise read the data value corresponding to the latest write record
- Synchronising on primary allows any client to clean any lock

EVALUATION

Evaluation Method

- Compared to MapReduce for web index
- Overhead of Percolator relative to BigTable
- Synthetic benchmarks (TPC-E)
- Resilience to failure



Percolator vs MapReduce

Remove duplicates from a billion document repository by clustering. Clustering is from a random value. Average cluster has 3.3 documents.

Percolator processes fewer documents per unit time, but only processes updated documents.

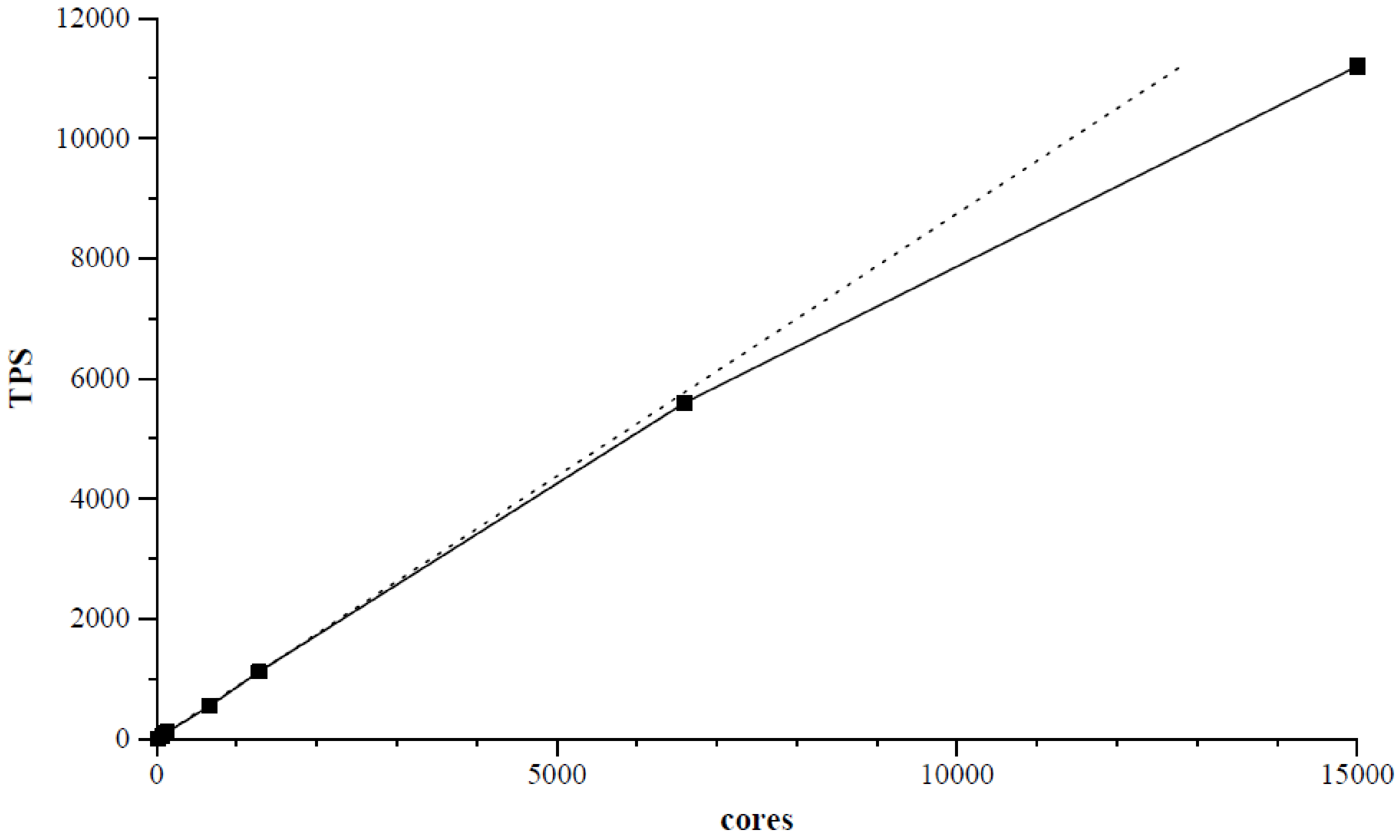
	BigTable	Percolator	Relative
Read/s	15513	14590	0.94
Write/s	31003	7232	0.23

Percolator vs BigTable

Worst case for Percolator - constant number of operations for commit.

Write incurs 3 RPC operations for lock handling.

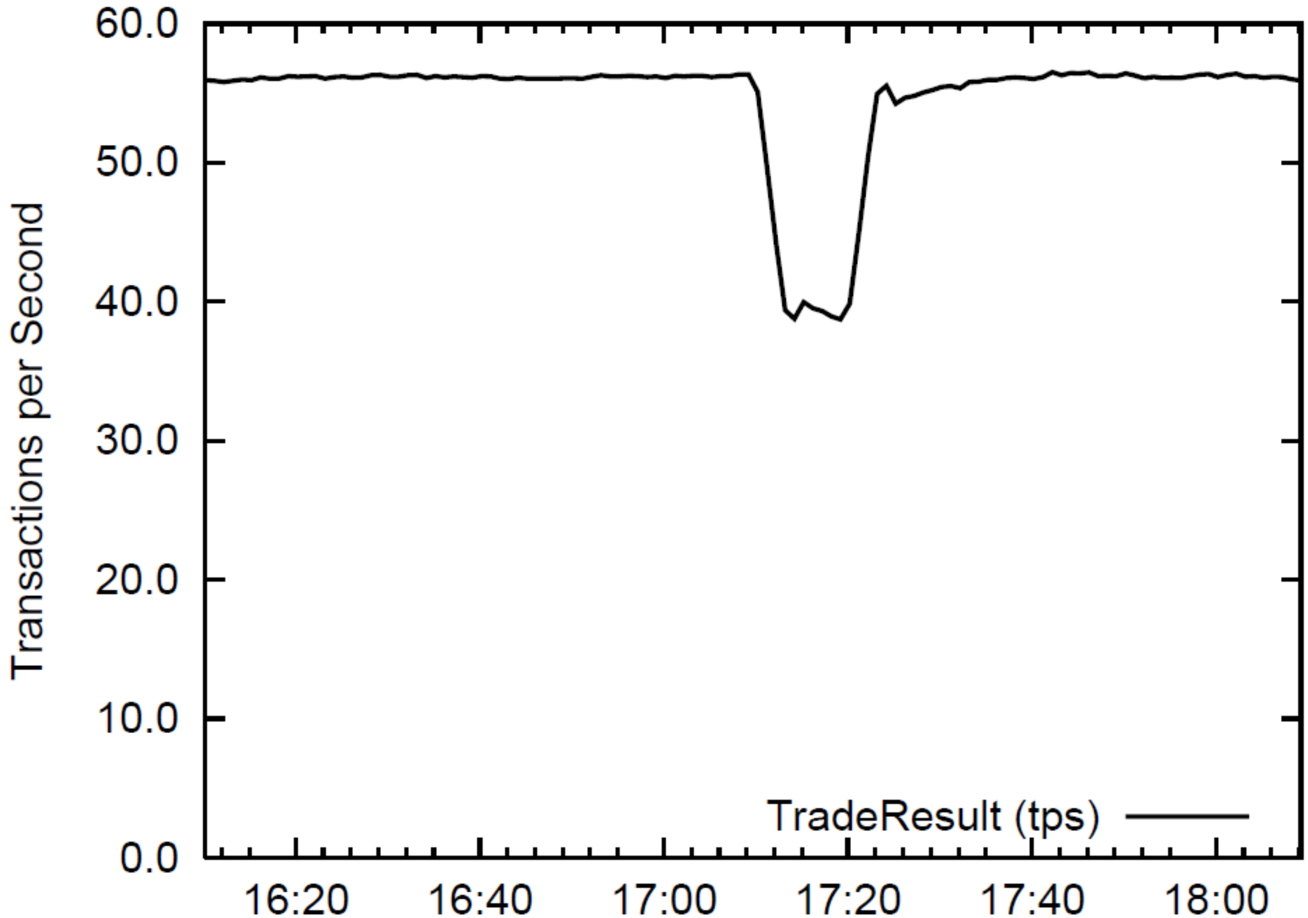
Additional overhead comes from extra metadata.



Percolator vs DBMS

TPC-E is a widely recognized DBMS benchmark which simulates a brokerage firm with customers who perform trades, market search and account enquiries.

Current single-host record is 3183 TPS, Percolator is less efficient per host, but scales better.



Percolator vs Failures

Kill a third of the 15 BigTable tablet servers and allow them to restart.

Performance drops by approximately 1/3.

Tradeoffs

- Blocking API calls
  - Makes programming easier
  - Individually, worker processes are limited to a single task
  - Achieve parallelism by running <u>many</u> workers
- Sacrifice performance for near-linear scalability
- Programmer must handle transactions
- Sacrifices availability for stronger consistency

Future Work

- Percolator overhead is 30x that of DBMS for a single host
  - What overhead is fundamental to distributed storage systems?
  - What is due to inefficiencies in the design?
- Percolator sacrifices availability (e.g. cross-datacentre replication) for consistency
  - Is this necessary?

FIN

Questions?