Percolator

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Outline

1. Motivation
    - Google's Search Algorithm
    - Requirements
2. Design
    - Structure
    - Algorithm
    - Details and Optimizations
3. Evaluation

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1 Motivation
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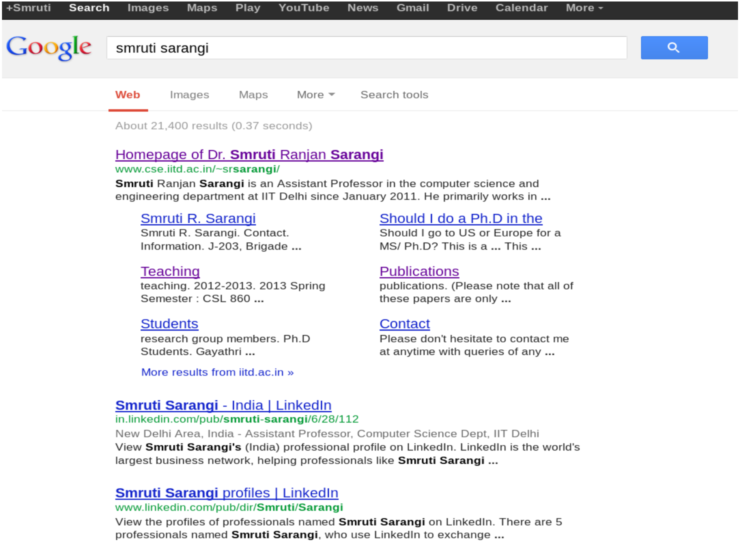
3 Evaluation

- Updating Google's web index continuously is a major challenge.
  - Tens of petabytes of data
  - Billions of updates per day
  - Thousands of machines.
  - Cascading updates.

Google's Search Algorithm

- Every page has a "page rank".
- The page rank of a popular page is supposed to be high.
- The page rank of a page is determined by the page rank of all the pages that link to it.
- For example:
    - If the New York Times website points to some link, then it has a high page rank. ☺
    - If my website points to some website, it will have a very low page rank. ☹

Example of a Google Search Query



About 21,400 results (0.37 seconds)

Homepage of Dr. **Smruti** Ranjan **Sarangi**
www.cse.iitd.ac.in/~sr**sarangi**/
Smruti Ranjan **Sarangi** is an Assistant Professor in the computer science and engineering department at IIT Delhi since January 2011. He primarily works in ...

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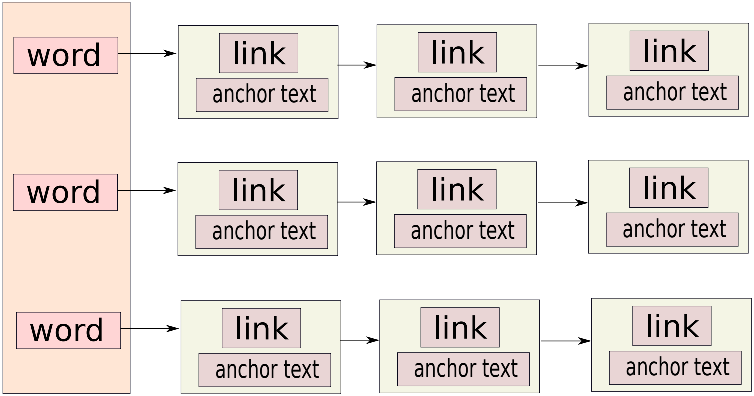
Structure of a Web Index



The Problem of Updates

- The links in the inverted list are arranged according to their page rank.
- If the page rank of a website changes then:
  - We need to update the inverted list to reflect the change.
  - The page rank of sites that it points to need to change.
  - This problem is known as cascading update .

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Requirements of a Solution

- Should provide ACID transaction semantics (do not want to corrupt database).
- Should have high throughput, and acceptable latency.
- Should be able to handle petabytes of data.
- Traditional DBMS systems are too slow → Need new technology
- Random access to data such that changes can percolate
- Consistency Model: Snapshot Isolation

Snapshot Isolation

- Assume two concurrent updates to a linked list.
    - If they do not access the same node or its parent, then they are disjoint.
    - Disjoint accesses can continue in parallel.
    - This is different from regular transaction semantics such as serializability.
- Definition :
    - When a transaction starts, it takes(appears to) a consistent snapshot of the entire database.
    - It then proceeds to update its private copy of the database.
    - The values are committed if they have not been changed by another transaction since the snapshot.

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Design of Percolator

- Built on top of Bigtable – Google's distributed storage engine
- Bigtable is a multidimensional database
  - Distributed key-value store
  - We save – row, column, timestamp
  - Atomic read-modify-write operations for each row
  - Meta data is stored in separate columns
- Observer framework
  - Any row has a set of observers.
  - They run specialized functions when data in the row changes.

Model of Transactions

- Provides support for ACID transactions
  - Hard to do in such a large database
  - Required : Do not want to have Google's database in an inconsistent state
  - Uses a timestamp for each data item
  - The set of timestamps at the beginning of a transaction is its snapshot.
- Transactions can include multiple rows across multiple BigTable tables
- Percolator implements its own lock service
- Percolator adds a special column to save locks.

Columns in BigTable

Column	Use
lock	contains a pointer to the lock
write	timestamp of committed data
data	data value
notify	list of observers
ack_O	last timestamp at which observer *O* ran

Example

A transfers B 7₹

key	data	lock	write
A	6: 5:10₹	6: 5:	6:data@5 5:
B	6: 5:2₹	6: 5:	6:data@5 5:

key	data	lock	write
A	7:**3₹** 6: 5:10₹	7:**primary** 6: 5:	7: 6:data@5 5:
B	6: 5:2₹	6: 5:	6:data@5 5:

Example - II

key	data	lock	write
A	7:3₹ 6: 5:10₹	7: primary 6: 5:	7: 6:data@5 5:
B	7:**9**₹ 6: 5:2₹	7: **primary@A** 6: 5:	7: 6:data@5 5:

key	data	lock	write
A	8: 7:3₹ 6: 5:10₹	8: 7: 6: 5:	8: **data @ 7** 7: 6:data@5 5:
B	7:9₹ 6: 5:2₹	7: primary@A 6: 5:	7: 6:data@5 5:

Example - III

key	data	lock	write
A	8:	8:	8: **data @ 7**
	7:3₹	7:	7:
	6:	6:	6:data@5
	5:10₹	5:	5:
B	8:	8:	8: **data @ 7**
	7:9₹	7:	7:
	6:	6:	6:data@5
	5:2₹	5:	5:

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Algorithm: Begin Transaction

```
Algorithm 1: Begin Transaction
$startTs \leftarrow$ oracle.getTimeStamp()

Set(W):
    writes.push(W)
```

Get Method

```
Get(row, column):
while True do
    $T \leftarrow$ startTrans(row)
    if T.hasLock(0,startTs) then
        backOffAndMaybeRemoveLock(row,col)
        continue
    end
    latestWrite $\leftarrow$ T.read(row, [0,startTs])
    if !latestWrite then
        return $\phi$
    end
    dataTs $\leftarrow$ latestWrite.timeStamp
    return (T.read(row, "data", dataTs)
end
```

PreWrite

```
PreWrite(Write $w$, Write $primary$)
Column $col \leftarrow w.col$
$T \leftarrow$startTransaction($w.row$)

if $T.read(w.row, "write", [startTs, \infty])$ then
    return false
end
if $T.read(w.row, "lock", [0, \infty])$ then
    return false
end

T.write ($w.row$, "data", $startTs$, $w.value$)
T.write ($w.row$, "lock", $startTs$, {$primary.row$, $primary.col$})
return $T.commit()$
```

Commit - I

```
Commit()
    /* Prewrite all the entries                                   */
$(primary, secondaries) \leftarrow (writes[0], writes[1 \ldots n])$
if !PreWrite(primary,primary) then
    return false
end
for Write w: secondaries do
    if !PreWrite(w,primary) then
        return false
    end
end
$commitTs \leftarrow oracle.getTimeStamp()$
```

Commit - II

```
/* Commit the primary                                        */
$T \leftarrow$ startTransaction(primary.row)

/* Test to see if aborted by somebody else                   */
if !T.read(primary.row, "lock", startTs) then
    return false
end
/* Write the primary and erase the lock                      */
T.write(primary.row, "write", commitTs, "data@"+startTs)
T.erase (primary.row, "lock", commitTs)

/* Point of commit                                           */
if !T.Commit() then
    return false
end
```

Commit - III

```
for Write w: secondaries do
    write(w.row, "write", commitTs, "data@"+startTs)
    erase (w.row, "lock", commitTs)
end
return true
```

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Timestamps

- The timestamp oracle needs to be able to sustain a very high throughput.
- Possible to batch several RPC calls to the oracle to reduce network load.
- Needs to give out timestamps in increasing order.
- If it fails, then it needs to recover and issue timestamps that are greater than the ones it issued earlier.

Observers

- Each observer registers a set of columns, and a function.
- The function gets invoked, if any of the columns are updated.
- Possible to do message collapsing
- At most one observer's transaction will commit per column.
- Steps in running an observer
  - After an update to a column, Percolator sets the notify column.
  - A worker thread, ultimately picks up this information, and runs an observer.
  - If the latest timestamp of an observer run (**ack_O**) is less than the commit timestamp of the update, then run the observer.
  - Worker threads avoid clumping by scanning random parts of the database.

Performance Improvements

- Support for read-modify-write RPCs in BigTable.
- Create batches of RPC calls.
- Employ pre-fetching to reduce reads.
- Use blocking API calls, and a large number of threads to simplify the programming model.

Setup

- Existing Setup:
    - Crawl billions of documents
    - Series of 100 map-reduces
    - A document takes 2-3 days for getting indexed
- Percolator based indexing system – Caffeine
    - 100x faster
    - Average age of documents gets reduced by 50%

Performance vs Crawl Rate

- Crawl rate → Percentage of repository that is updated per hour.
- Let us plot the clustering latency (y axis) vs the crawl rate (x axis)
- For Map-reduce it starts at 2200s and rises to infinity when the crawl rate exceeds 33%.
- For Percolator it remains below 200s till about 37%. Then it continues to rise.

Scalability for TPC/E benchmarks

- The transactions per second (TPS) varies linearly as we scale the number of cores.
- 4000 TPS is achieved with 5,000 cores.
- It increases to 12,000 TPS for 15,000 cores.

Close to Linear Scaling

Large-scale Incremental Processing Using Distributed Transactions and Notifications by Daniel Peng and Frank Dabek, OSDI, 2010