Bigtable

15799 - Advanced Topics in DB

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October 2, 2013

stolen slides from Jeff Dean (a lot) and Edward Yoon (one)

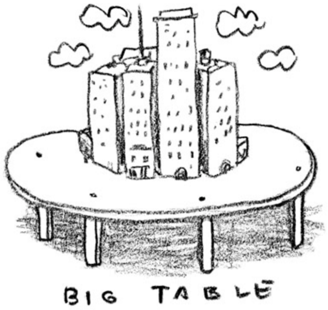
Typical New Engineer

- Never seen a petabyte of data
- Never used a thousand machines
- Never **really** experienced machine failure

Our software has to make them successful.

Google

Data Storage: BigTable



What is it, really?

- 10-ft view: Row & column abstraction for storing data
- Reality: Distributed, persistent, multi-level sorted map

Comparing with Dynamo

- Data Model: Table vs. Key-Value
- Consistency: Atomic row mutation vs. record-at-a-time and eventual consistency
- How to run: Centralized management vs. each application run its own instance
- Access control vs. No
- Focus: Easy to use vs. availability

Outline

Topics will be covered today:

- Data Model and API
- System Overviews
- Implementation of Tablet Servers
- Current State of Bigtable

Things are ignored

- Refinement to improved the performance
- Experiments

BigTable Data Model

- Multi-dimensional sparse sorted map

  (row, column, timestamp) => value

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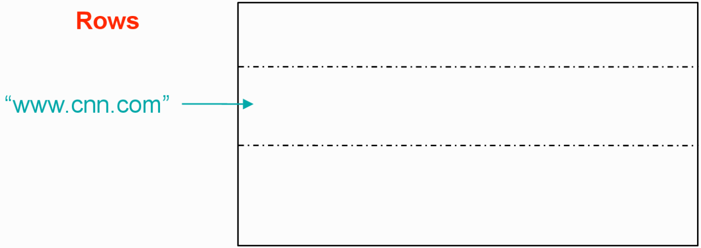

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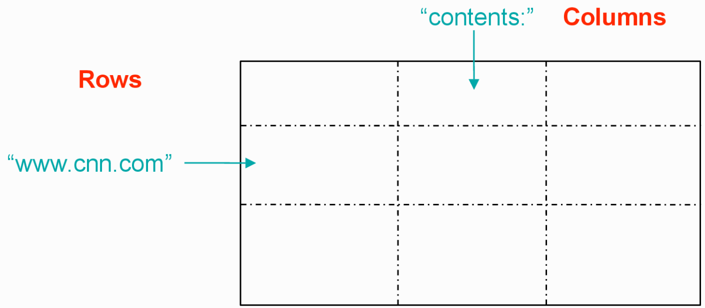

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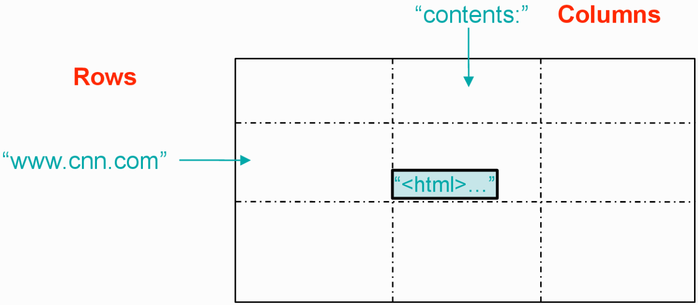

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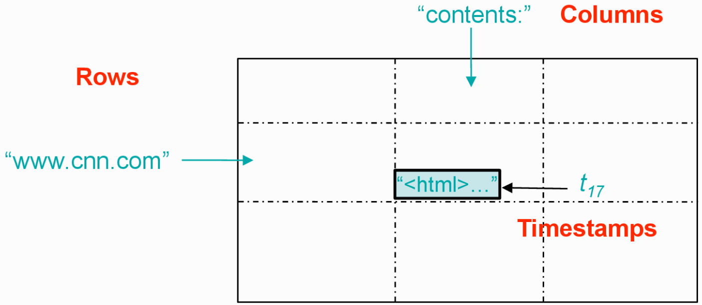

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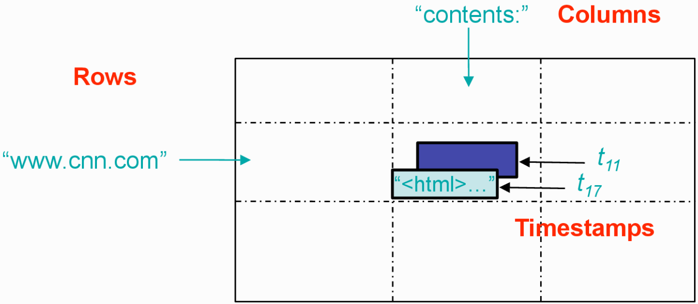

Google

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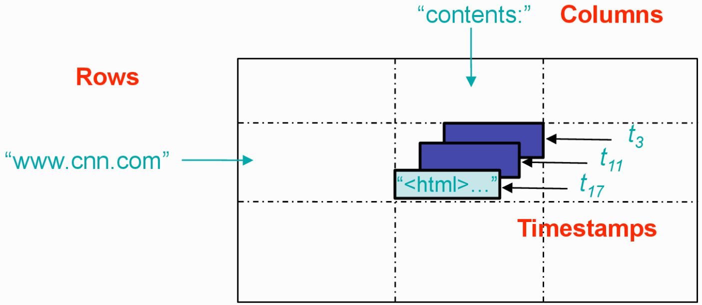

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API

- Atomic single row mutation

```
RowMutation r1(T, "com.cnn.www");
r1.Set("anchor:www.c-span.org", "CNN");
r1.Delete("anchor:www.abc.com");
Operation op;
Apply(&op, &r1);
```

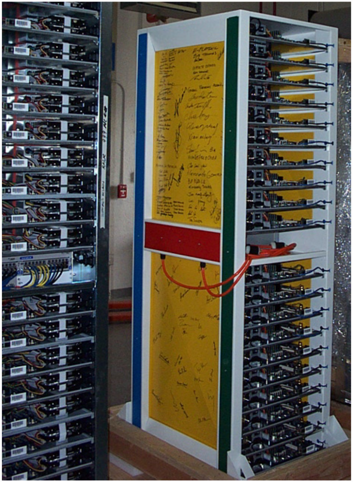
- scanning cells by rows, column, and timestamp

```
Scanner scanner(T);
ScanStream *stream;
stream = scanner.FetchColumnFamily("anchor");
stream->SetReturnAllVersions();
scanner.Lookup("com.cnn.www");
for (; !stream->Done(); stream->Next()) {}
```

- server-side scripts: Sawzall
- integration with other products: Mapreduce, Pregel, Parameter Server, ...

Current Design

- In-house rack design
- PC-class motherboards
- Low-end storage and networking hardware
- Linux
- + in-house software



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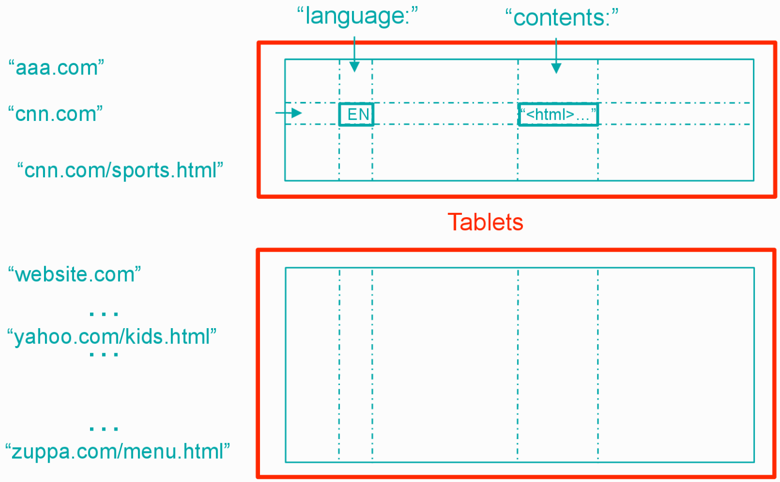
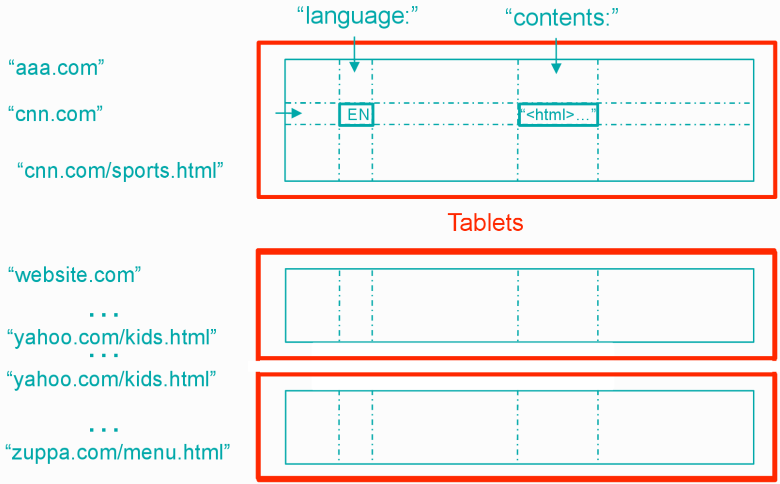
Tablets (cont.)



Tablets (cont.)



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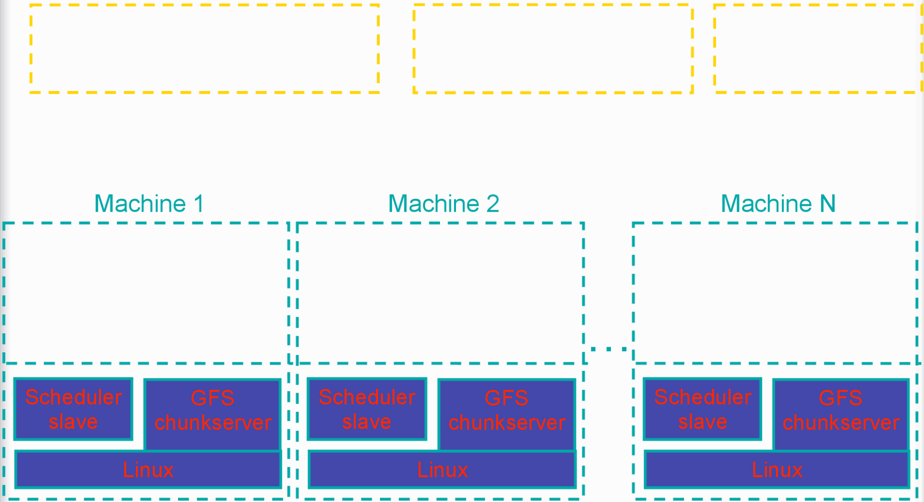
Typical Cluster



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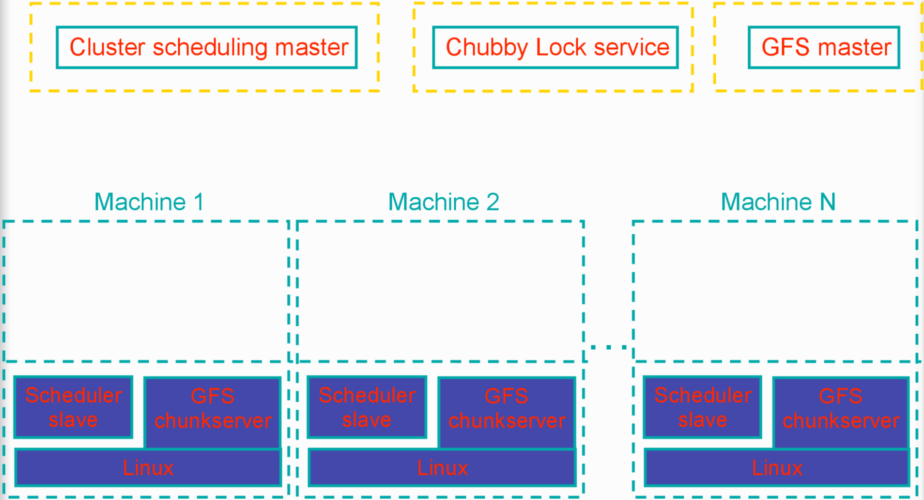

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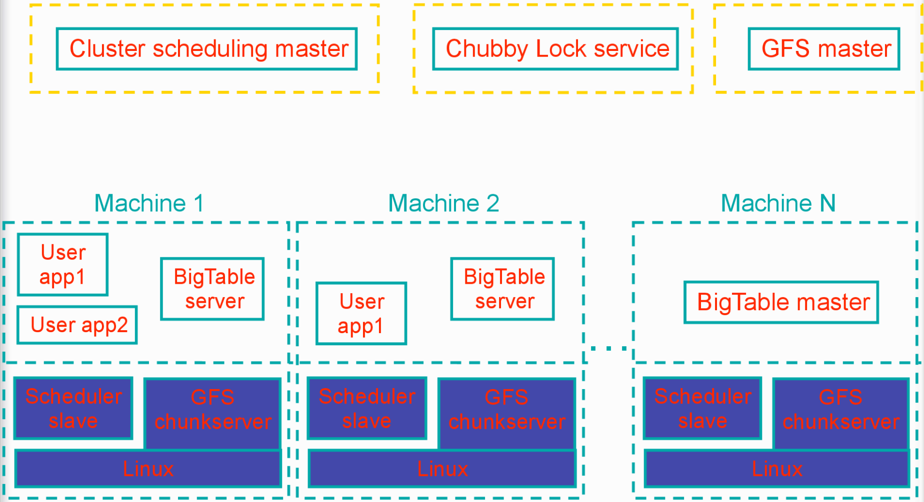

Bigtable System Structure

Bigtable Cell

Bigtable master

Bigtable tablet server | Bigtable tablet server | … | Bigtable tablet server

Bigtable System Structure

Bigtable Cell

Bigtable master

performs metadata ops +
load balancing

Bigtable tablet server

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...

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Cluster scheduling system

GFS

Lock service

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handles failover, monitoring

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holds tablet data, logs

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holds metadata, handles master-election

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Bigtable client

Bigtable client library

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performs metadata ops + load balancing

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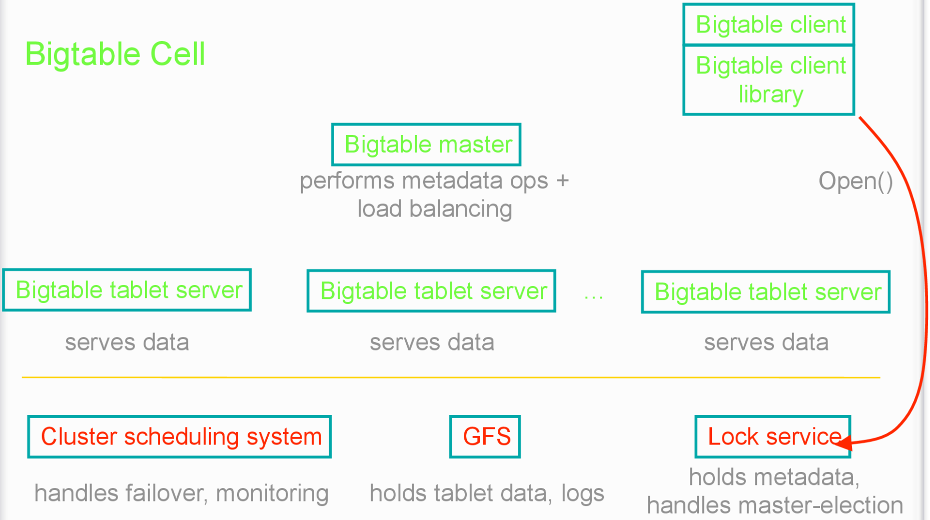

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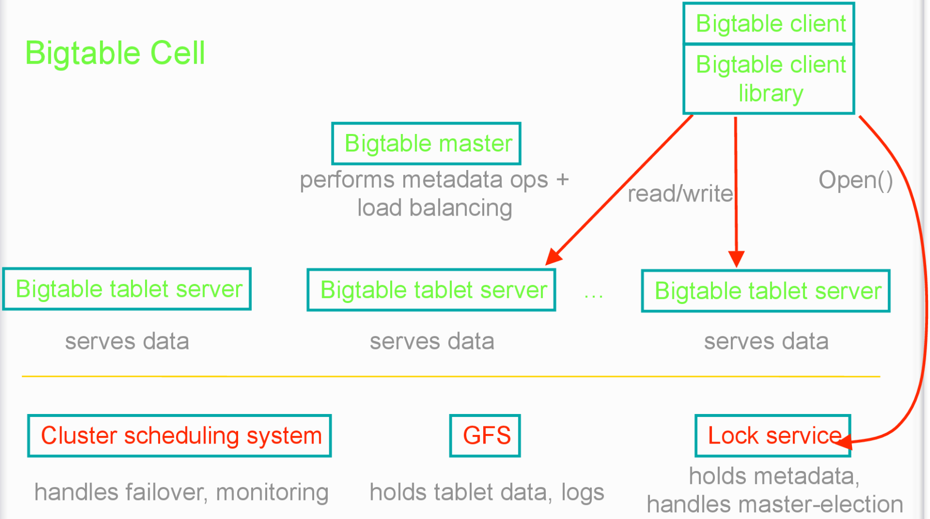

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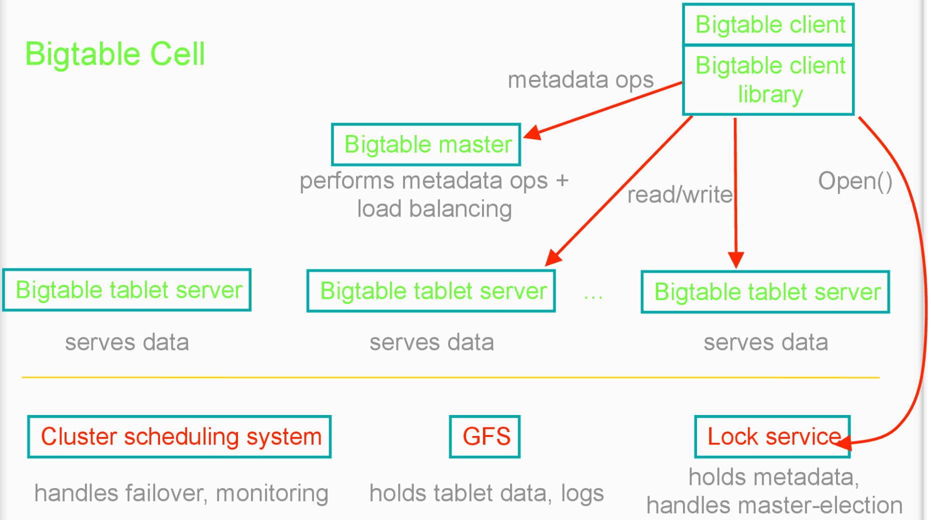

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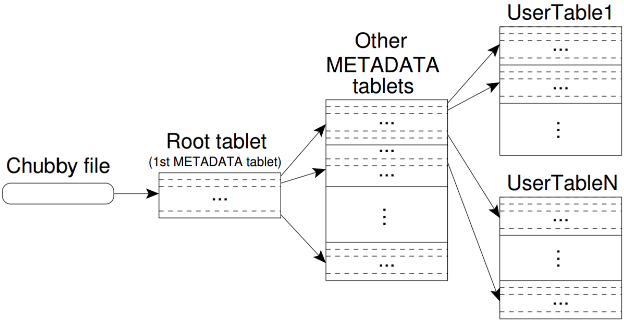
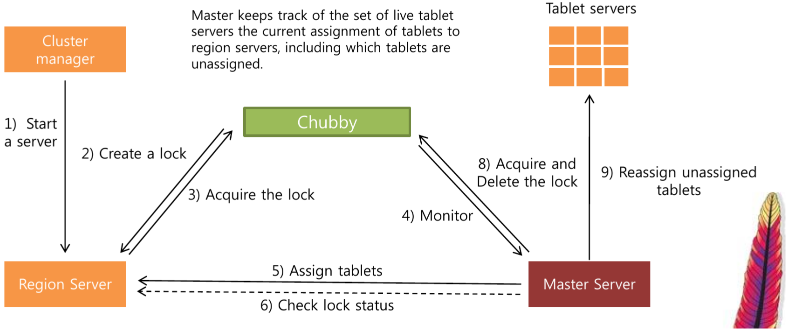
Find Tablet Location

- Three-level hierarchy analogous to a B+ tree
  - 1st level: bootstrapped from chubby
  - 2nd level: use META0 tablet to find the owner of appropriate META 1 tablets
  - 3rd level: META1 table holds locations of all other tablets



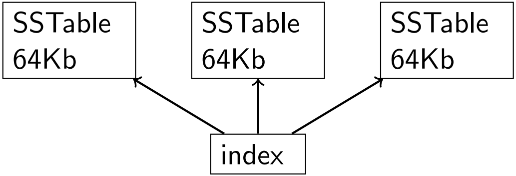
Tablet Assignment

- Master assigns tablets to tablet servers



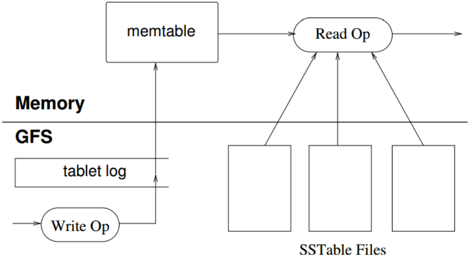
Store a tablet

- A tablet is maintained by one tablet server.
- A tablet consists of serveral SSTable blocks with an index to store the first and last key of the block, and stored in GFS



Tablet Serving

- Updates are stored in tablet log and
  - new ones in memtable (in memory)
  - old ones in SSTables
- For read, first check memtable, then SSTables



Compaction

minor compaction

- convert memtable into an new SSTable and write into disk
- save memory

merging(major) compaction

- read several SSTable and memtable and merging into a few (exact one) SSTable
- save disk due to high compression rate, remove deleted entries

BigTable Status

- Production use for 100+ projects:
  - Crawling/indexing pipeline
  - Google Maps/Google Earth
  - My Search History
  - Google Print
  - Orkut
  - Blogger
  - …
- Currently ~500 BigTable clusters
- Largest cluster:
  - 70+ PB data; sustained: 10M ops/sec; 30+ GB/s I/O

BigTable: What's New Since OSDI'06?

- Lots of work on scaling
- Service clusters, managed by dedicated team
- Improved performance isolation
  - fair-share scheduler within each server, better accounting of memory used per user (caches, etc.)
  - can partition servers within a cluster for different users or tables
- Improved protection against corruption
  - many small changes
  - e.g. immediately read results of every compaction, compare with CRC.
    - Catches ~1 corruption/5.4 PB of data compacted

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BigTable Replication (New Since OSDI'06)

- Configured on a per-table basis
- Typically used to replicate data to multiple bigtable clusters in different data centers
- *Eventual consistency model*: writes to table in one cluster eventually appear in all configured replicas
- Nearly all user-facing production uses of BigTable use replication

Google

BigTable Coprocessors (New Since OSDI'06)

- Arbitrary code that runs run next to each tablet in table
  - as tablets split and move, coprocessor code automatically splits/moves too
- High-level call interface for clients
  - Unlike RPC, calls addressed to rows or ranges of rows
    - coprocessor client library resolves to actual locations
  - Calls across multiple rows automatically split into multiple parallelized RPCs
- Very flexible model for building distributed services
  - automatic scaling, load balancing, request routing for apps

Example Coprocessor Uses

- Scalable filesystem metadata management for Colossus (next gen GFS-like file system)

- Distributed language model serving for machine translation system

- Distributed query processing for full-text indexing support

- Regular expression search support for code repository

- ...