Big Data Project Report

Shenwei Liao, Anthony Ou, Jacqueline Terlaan
CMPUT 391
Winter 2014

April 23, 2014

1 Goals and Objectives

- To successfully implement a distributed database system which will quickly and reliably store several terabytes of random data into large tables with many columns (attributes).
- To distribute the data in the above tables across 8 "nodes" (servers), which form our "cluster".
- To generate additional tables distributed throughout the cluster to be optimally configured for the queries to meet their own requirements (see below).
- To query the above tables such that all of the following requirements are met by five queries.
    1. Four of five queries must retrieve data across from all of the distributed nodes.
    2. At least one of the queries must contain at least ten atomic conditions (formulas) in the WHERE clause.
    3. At least two of the queries must utilize both the GROUP BY and ORDER BY clauses. Since Cassandra does not yet support GROUP BY aggregation, the same functionality must be achieved in another way.
    4. At least three of the five queries must be range queries which specify an upper and lower bound on some ordered attribute that is used for the purposes of querying.
    5. None of the five queries can be trivial. That is, there can be no simple key searches or anything that is of little practical interest for measuring how a database system can deal with computationally expensive requests.
- To record the execution time of each query.

2 Methodology, Tools and Equipment Used

8 server instances were used, each with 32GB virtual memory and 1TB secondary storage

3 Implementation

4 Shell Script

A shell script was written to wrap all functionality of the OLAP project, including server setup for all nodes, table creation and population and executing the queries. To run it, cd into the directory containing group3.sh, and call sh group3.sh, and follow the prompts interactively.

4.1 Configuration Changes

Many different aspects of Cassandra cluster and the table were tuned so that we can achieve a high write availability and high performance for generating a randomly generated dataset. Here are some of the more notable configuration changes that we applied:

- Cluster-wide changes (in cassandra.yaml):
    1. Use of RoundRobinScheduler over NoScheduler. Having a request scheduler allowed for requests to be assigned to nodes faster by the coordinating node, speeding up concurrent reads and writes.
    2. Reducing commit log sync frequency. Writing to the commit log must happen for every transaction, as is necessary for write durability. For the purposes of this project, we can sacrifice some durability to go faster.
    3. Concurrent writes increased.
    4. Memtable flush writers increased. Memtable is the in-memory data structure cassandra uses to hold batched writes.
    5. Disabling automatic backups and snapshots of the keyspace.
    6. Removed the throttling on compaction throughput.
- Table-specific changes:
    1. Replication factor set to 3.
    2. Durable writes are disabled. The commit log doesn't need to be written to just for table generation. This and the next setting are only off because we are randomly generating data and there isn't such a thing as a wrong random value.
    3. Consistency level for inserts was set to 0 for maximum write availability.
    4. Compression is disabled to keep CPU utilization low.

4.2 Table Schemas

The cdr table follows the assignment specification's schema, with 470 columns. It and 16 column keys, indexed on MONTH_DAY and MOBILE_ID_TYPE. The role of the last two tables is to make the substitute aggregate queries both possible. These tables are not generated in a sparse manner, every column will have an entry of the appropriate type.

1. "CDR" The large 470 column family with 16 column keys and a UUID as the partition key.
2. "CDR_ALT" Contains the same 470 columns as cdr, but the last 6 column keys are no longer column keys. These 6 columns delete were never queried upon but here for testing.
3. "SMALLCDR" This table has the last 235 columns removed but has the same 10 column keys as CDR_ALT.
4. "GROUP_BY_MONTH"
   - Keys are between 1 and 31.
   - UUID of the partition key in CDR is kept as a column key
   - Reduces data to facilitate completion of a query equivalent to one in SQL containing 'GROUP BY MONTH_DAY'.
   - Ordering is implicitly done by Cassandra
5. "GROUP_BY_MOBILE_ID_TYPE"
   - Keys are between 0 and 7.
   - Again the UUID of the partition key in CDR is kept as a column key
   - Similar to "GROUP_BY_MONTH", but instead the assignment of the rows' locations is based on its insertion number modulo 8. This helps us identify if insertions are consistent since this number should not variate much.
   - Ordering is implicitly done by Cassandra

4.3 Programs

We wrote two main Python 2.7 scripts: generate.py and query.py. generate.py creates the tables and inserts them into cassandra. It takes lots of shortcuts as described above, and writes have no guarantees to succeed. Query.py runs the queries.

4.4 CQL Queries

1. Query 1

```
SELECT count (*) as ten_atomic
FROM ONE OF [CDR,CDR_ALT,SMALLCDR]
WHERE
 (MSC_CODE ,CITY_ID ,SERVICE_NODE_ID
 ,RUM_DATA_NUM ,DUP_SEQ_NUM ,SEIZ_CELL_NUM ,
     FLOW_DATA_INC ,SUB_HOME_INT_PRI ,CON_OHM_NUM,
SESS_SFC)
> (10000,10000,10000,3,10000,1
            ,10000,10000,10000,10000)
AND (MSC_CODE ,CITY_ID ,SERVICE_NODE_ID
 ,RUM_DATA_NUM ,DUP_SEQ_NUM ,SEIZ_CELL_NUM ,
     FLOW_DATA_INC ,SUB_HOME_INT_PRI ,CON_OHM_NUM,
SESS_SFC)
< (150000,150000,150000,30,150000,6
            ,150000,150000,150000,150000)
LIMIT 4000
ALLOW FILTERING ;
```

Cluster-wide range query with 10 atomic formulas. Searches on every column key of the CDR table, as this is the only conceivable way to properly execute a range query. Returns results from each node, satisfies the range query requirement and has 10 atomic formulas.

Potential uses: many 'outliers' are eliminated from the selection because they are above and below the minimum and maximum values of all the columns respectively, by approximately 10%. In other words, any 'extreme' data points in the CDR table can be ignored for statistical analysis.

Query 1 ('Alternate')

Performs the same cluster-wide query as Query 1, but over the table cdr_alt.

Query 1 ('Small')

This query is intended to take less time than the previous query, because fewer columns have to be read into memory in order for the atomic conditions to be evaluated.

2. Query 2

```
SELECT count (*) as range_city_id
FROM cdr
WHERE
MSC_CODE > 5000 AND MSC_CODE < 90000
LIMIT 4000
ALLOW FILTERING;
```

Satisfies two requirements: cluster-wide and range query. Retrieves the number of cdr entries for cities with IDs strictly greater than 5000 and strictly less than 90000.

Potential uses: In some cases companies may wish to know how many calls were made in a given range of cities, based on certain CITY_IDs. While those cities may not have any major features in common, this query can be used in cases where only a small sample of all cities is required.

3. Query 3

```
SELECT count(*) as range_DUP_SEQ_NUM
FROM cdr
WHERE
(MSC_CODE ,CITY_ID,SERVICE_NODE_ID,RUM_DATA_NUM ,
    DUP_SEQ_NUM )
>(0,0,0,0,10000) AND
(MSC_CODE ,CITY_ID,SERVICE_NODE_ID ,RUM_DATA_NUM ,
    DUP_SEQ_NUM)
<(9900,9900,9900,9900,30000)
LIMIT 4000
ALLOW FILTERING;
```

Satsifies two requirements: cluster-wide and range query. Counts the number of cdr entries such that DUP_SEQ_NUM is strictly greater than 30000 and strictly less than 300000. All other atomic conditions in the range query are used to ensure that all of the results fall within a valid range and have no null-valued entries for CITY_ID, SERVICE_NODE_ID, and so on.

Potential uses: Suppose that statistical data is to be generated for rows in the CDR table for which there are no null-valued entries in the columns CITY_ID, SERVICE_NODE_ID, RUM_DATA_NUM, MONTH_DAY and DUP_SEQ_NUM, and that DUP_SEQ_NUM falls within a more specific range, that is 30000-300000. The records could then be analyzed and compared to data for which not all of the attributes above are null, to compare behaviors of callers with different amounts of privacy. This could address questions such as "do people with more privacy make certain types of calls compared to people who do not?".

4. Query 4

```
prep = session.prepare("select count(*) from
    group_by_MOBILE_ID_TYPE where MOBILE_ID_TYPE = ?"
    )
prep.consistency_level = Consist_Level

for i in range (8):
    print str(i) + " : " , session.execute(prep.bind
        ([i]),timeout=None)
```

Satisfies two requirements: group-by and order-by clause, and cluster-wide query.

A table of UUIDs aggregates the keys of the MOBILE_ID_TYPE columns. This query has to be in a python loop to execute a query on each group.

This is an idempotent transaction, this can be done multiple times and it will not cause inconsistencies.

Inserting into counter columns is done in the following way:

```
insert into group_by_MOBILE_ID_TYPE
(MOBILE_ID_TYPE, id) values (?,?)
```

Potential uses: Most likely for the generation of histograms, but other basic kinds of statistical analysis can be performed on these small MOBILE_ID_TYPE 'buckets' as well, such as calculating arithmetic averages, etc.

5. Query 5

```
prep = session.prepare("select count(*) from
    group_by_month where month_day = ?")
prep.consistency_level = Consist_Level
for i in range (1,32):
    print str(i) + " : " , session.execute(prep.bind
        ([i]), timeout=None)
```

Satisfies the group-by and order-by clause requirements. 'CLUSTERING ORDER BY (MONTH_DAY)' ensures that the GROUP_BY_MONTHs entries are ordered by MONTH_DAY, and GROUP BY functionality is achieved via aggregating UUIDs of each row in CDR.

Potential uses: finding out which day(s) of each month of the year have the highest frequency of entries added to the CDR table can be of use for marketing to customers, optimizing billing rates, and so on. Similar queries can be written for different times of the day, months or weeks of the year, by aggregating CDR row counts into hourly, monthly or weekly groupings for more specific results which could be of use in billing plans with calls at different times incurring different costs.

5 Experimental Results

5.1 Table Population

The biggest table to generate took two and a half days, generating an average of 380GB per node for a total of just over 3TB of data, out of the 8TB that was available on the cluster, with roughly 8.8 million columns. The average speed of insertions to the big table was roughly 15MB/s.

A separate keyspace was used for some postliminary tests. With the additional smallcdr table to mimic a sparse table or a partitioned table, insertion of about 700000 entries — resulting about 40GB of data per node — took 0.5 days. This keyspace was tested at 4GB, with consistent reads, and at 40GB, with inconsistent reads.

5.2 Query Results

Our queries ran pretty quickly as expected when queries were done at consistently levels matching replication factor. The 400gb cluster was only ever read at consistent level, however query 2 and 3 ran slower than query 1, despite these queries doing a ranged search on fewer column keys.

The GROUP BY queries predictably executed the fastest, as the work was already done at insertion time. Both these tables look ups took the same amount of time to read since they both contained the same amount of entries, so the amount of I/Os was the same.

	400GB CsistLvl=3	4GB CsistLvl=3	40GB CsistLvl=1
Query 1	3.032994934	2.549625035	1.394323281
Query 1 Alt	6.137618132	2.039274001	4.377174052
Query 1 Small	N/A	0.9893522183	2.025322433
Query 2	4.171009902	1.673517132	1.726343501
Query 3	9.964161499	0.2884306033	0.5942962646
Query 4	0.9116296172	0.02507929802	0.134401083
Query 5	0.8965	0.03015551964	0.1395610134

A table of each query on keyspaces of replication factor 3 with units in minutes. Queries 1-3 return 4000 results.

6 Discussion

The 400GB queries were consistent reads at level 3 consistency. The normal CDR table performed faster mainly because it was sorted in ascending order, despite the fact it had 6 more column keys. This was a mistake in the configuration of the column, since this was suppose to be the faster table with fewer column keys, there is well documented performance loss when sorting descendingly in Cassandra.

7 Conclusions

The most important changes that affected insert speed was using the round robin scheduler to have more nodes handle requests in parallel, and to disable the commit log/durable writes in order to get more disk IO.

The queries on the other hand were pretty straightforward, except for the fact that GROUP BYs have to be done a priori, as Cassandra has no facility to do them on the fly.

8 Notes on Possible Improvements

Some tests were run on query 1 to assess the performance increase of data partitioning. We weren't able to re-generate the large table to see the effects on that, but trials on a smaller table reduced the runtime of query 1 from 2.6 minutes down to 1.0 minute. We haven't tested it on a larger scale, but would say that it has lots of potential to speed up querying, without much hit to our table populating speed.

9 References Used

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