Chapter 38.

February 2020

Welcome to the February 2020 edition of DataStax Developer's Notebook (DDN). This month we answer the following question(s);

> I've read all of the articles and documentation related to DataStax Enterprise (DSE) Graph, but am still not certain how these graph queries (traversals) actually execute. To me, this looks much like a SQL query processing engine, and I don't know how or if to index or model this. Can you help ?
>
> *Excellent question ! In this document we'll give a brief treatment to graph query processing; how graph traversals are actually (executed). For fun, we'll actually talk a little bit about a close (graph) neighbor, Neo4J.*

Software versions

The primary DataStax software component used in this edition of DDN is DataStax Enterprise (DSE), currently release 6.8 EAP (Early Access Program). All of the steps outlined below can be run on one laptop with 16 GB of RAM, or if you prefer, run these steps on Amazon Web Services (AWS), Microsoft Azure, or similar, to allow yourself a bit more resource.

For isolation and (simplicity), we develop and test all systems inside virtual machines using a hypervisor (Oracle Virtual Box, VMWare Fusion version 8.5, or similar). The guest operating system we use is Ubuntu Desktop version 18.04, 64 bit.

38.1 Terms and core concepts

As stated above, ultimately the end goal is to detail graph query processing, which also leads a bit into an indexing discussion. Figure 38-1 displays the four primary functional areas to DataStax Enterprise (DSE). A code review follows.

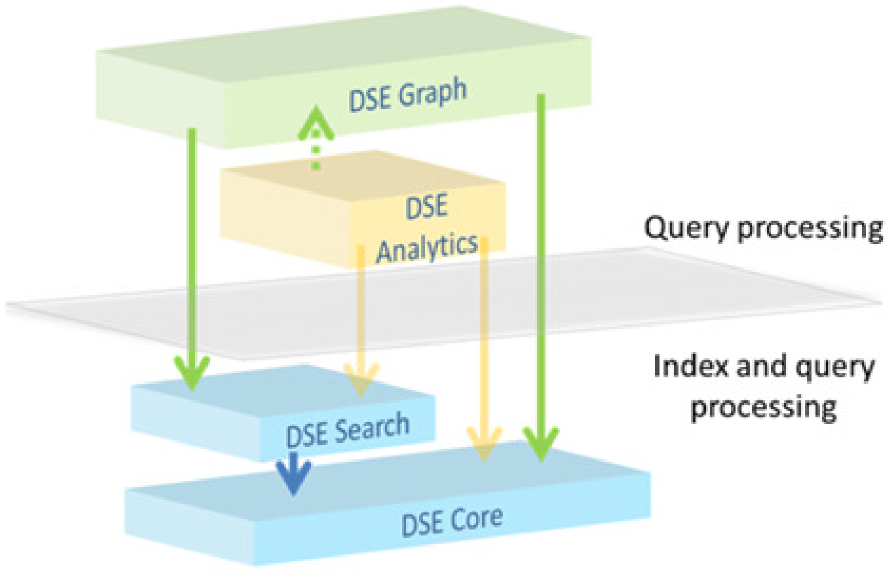


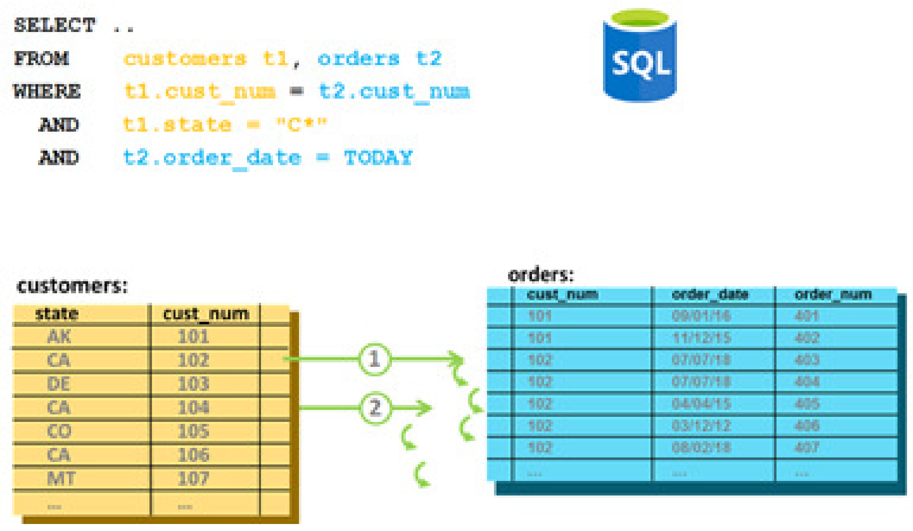
Figure 38-1 Four primary functional areas to DSE

Relative to Figure 38-1, the following is offered:

- The four primary functional components to DataStax Enterprise (DSE) include;
  - DataStax Core, largely Apache Cassandra
  - DataStax Search, largely Apache Solr/Lucene
  - DataStax Analytics, largely Apache Spark
  - DataStax Graph, large Apache TinkerPop/Gremlin
- DSE Core is the only storage tier, serving the remaining 3 functional areas to DSE. DSE Core, has at its center, a hash index.
- DSE Search provides additional index technology and query predicates for text analytics, scalars, and spatial/geospatial lookup.
- DSE Graph stores its vertices and edges as standard DSE Core tables.

By example, SQL query processing

Figure 38-2 displays a classic/standard SQL 2 table SELECT statement. A code review follows.



```
SELECT ..
FROM     customers t1, orders t2
WHERE    t1.cust_num = t2.cust_num
  AND    t1.state = "C*"
  AND    t2.order_date = TODAY
```

state	cust_num
AK	101
CA	102
DE	103
CA	104
CO	105
CA	106
MT	107
...	...

cust_num	order_date	order_num
101	09/01/16	401
101	11/12/15	402
102	07/07/18	403
102	07/07/18	404
102	04/04/15	405
102	03/12/12	406
102	08/02/18	407
...	...	...

Figure 38-2 SQL 2 table query

Relative to Figure 38-2, the following is offered:

- We offer this section to use a common denominator; we assume most folks know SQL and SQL SELECTS.
- Above, a standard 2 table SQL SELECT is offered. The 2 tables relate through an equality in the WHERE clause. Also, both tables have a filter predicate.
- Query processing will begin on one of the 2 tables, applying the filter predicate. The filter predicate that should be selected is that which is most selective, returning the smaller number of rows, and supported via a usable index.
    - There are 50-52 states in the United States, but given enough history, there should be hundreds of unique dates.
    - Both query predicates are equalities and if both columns are indexed, the first predicate processed should be using order_date in the orders table.
    - order_date is also an integer (or date), and easier to resolve than a character string for customers.state.

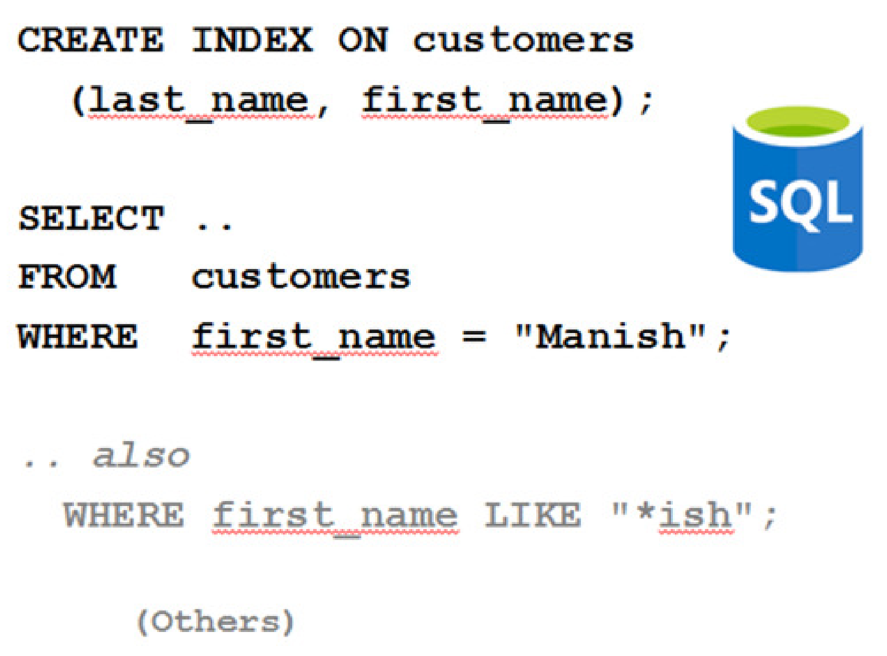
– If/when we drill into orders.order_date first, the join to customer should be processed and supported by an index on customer.cust_num.
– Given the above, there is no need to index customer.state, since we will have already retrieved the row when performing the join.

Note: What join method (algorithm) is used to join the two tables ?

The oldest, most common join method is nested-loop-join, that is;

– After finding the first row in the first table, use an index look up to find all matches in the second table. Second row in the first table, repeat, and so on. (A nested loop programming structure.)
– Since the second table is processed and (re-processed) an additional time for each matching row in the first table, nearly all databases will require an index exist on the join columns in the second table. This, lest each (re-processing) of the second table cause a sequential scan, over, and over.

Figure 38-3 displays our next sample query. A code review follows.



```
CREATE INDEX ON customers
   (last_name, first_name);

SELECT ..
FROM    customers
WHERE   first_name = "Manish";

.. also
   WHERE first_name LIKE "*ish";

      (Others)
```

Figure 38-3   Second sample SQL SELECT

Relative to Figure 38-3, the following is offered:

- This example is meant to introduce the topic of index-negation, that is; an index is available, waiting to be used, but can not be used. There are generally 3 reasons why an index will not be used.

    - Non-anchored composite key-

      From the example above, a composite index exists on last_name, then first_name. You can look up records by just last_name, or last_name and then first_name, but not just first_name alone.

      Imagine trying to find Dave Letterman in the phone book by just his first name, Dave. You would have to sequentially scan the phone book, since entries in the phone book are not sorted by first name.

    - Similar, and simpler to non-anchored composite key, is non-initial substring.

      Try find Dave Letterman in the phone book by just the last 3 letters of his last name; “man”. Again, the phone book is not sorted in this manner.

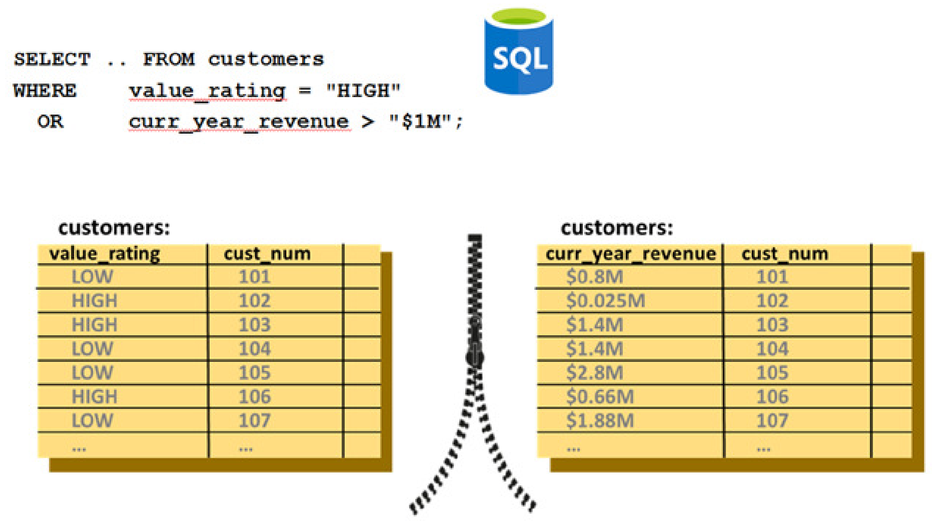
    - And then, negation of an index, poor selectivity of a filter.

      Instead of using an index on gender code, expectedly returning half or so of the entire contents of the table, it should be much more efficient to just sequentially scan the entire table, incurring must less physical I/O.

- How these conditions come into effect when performing graph traversals is column order in a composite key-

  Recalling the first_name, last_name effect detailed above, we normally need one index to support traversing from vertex to vertex in one direction, and a second index when traversing in the reverse direction.

Figure 38-4 displays our last SQL example. A code review follows.



```
SELECT .. FROM customers
WHERE     value_rating = "HIGH"
  OR      curr_year_revenue > "$1M";
```

customers:

value_rating	cust_num	
LOW	101	
HIGH	102	
HIGH	103	
LOW	104	
LOW	105	
HIGH	106	
LOW	107	
...	...	

customers:

curr_year_revenue	cust_num	
$0.8M	101	
$0.025M	102	
$1.4M	103	
$1.4M	104	
$2.8M	105	
$0.66M	106	
$1.88M	107	
...	...	

Figure 38-4   Last of 3 SQL examples.

Relative to Figure 38-4, the following is offered:

– This is a single table SELECT, with 2 filter predicates, topped by an OR clause. If this query had an AND clause, a single composite index would serve this query.

  From what we detailed above relative to non-anchored composite index negation, the OR condition causes us to need 2 indexes.

– But, if we use one index to serve the first filter predicate, and a second index to serve the second filter predicate, a row might qualify for both filter predicates, and SQL does not let us return the same row twice as the result from one SQL SELECT.

  So, we could use two indexes, but then would have to-

  • Sort both lists, merge, and remove duplicate rows. This activity is titled, a sort-merge join.

  • We use a sort-merge join when both filter predicates are served via indexes, and both predicates are highly selective.

Note: A long, long time ago, we (programmers) would manually rewrite this query using an "or union transform", example as shown;

```
    SELECT * FROM t1 WHERE value_rating = "HIGH"
    UNION
    SELECT * FROM t1 WHERE curr_year_revenue > "$1m";
```

With modern database servers, we expect the server software to perform this rewrite for us.

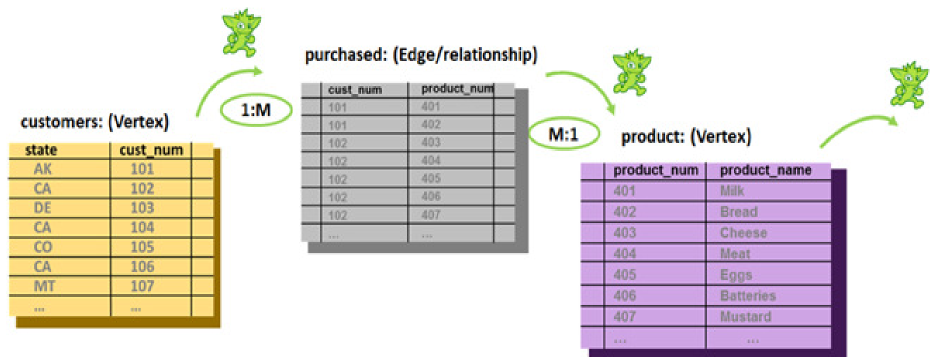
Extra note:

SQL UNION automatically calls to remove duplicates. A UNION ALL does not call to remove duplicates. If you are certain that both filter predicates produce unique data sets, consider using a UNION ALL.

How DSE processes graph traversals

DataStax Enterprise (DSE) processed queries through the DSE Core functional area, DSE Search (additional index types and query predicates), DSE Analytics (basically full/Hive SQL), and then DSE Graph traversals (queries).

In this section, we discuss graph traversals only. Figure 38-5 displays a graph traversal. A code review follows.



state	cust_num
AK	101
CA	102
DE	103
CA	104
CO	105
CA	106
MT	107
...	...

cust_num	product_num
101	401
101	402
102	403
102	404
102	405
102	406
102	407
...	...

product_num	product_name
401	Milk
402	Bread
403	Cheese
404	Meat
405	Eggs
406	Batteries
407	Mustard
...	...

Figure 38-5 Graph traversal

Relative to Figure 38-5, the following is offered:

– We don't see the Gremlin traversal syntax for this (query). If the traversal terminated on product, a sample Gremlin traversal to support this picture would be.

  g.V().hasLabel("customers").out("product")

– With no filter predicate on customers, all rows are returned. Each row in customers would start a new traverser; effectively a single SQL SELECT (from each row), with its own distinct result set; whatever that single row joins to in the edge table titled, purchased.

  Each row from purchased also starts its own traverser, with its own result set; whatever each single row joins to in the vertex titled, product.

– As such (above), we need no index on customers.

  If there was a filter predicate on customers, we would need the index to support that.

– As such (above), we need no additional index on purchased. The edge table itself will require a primary key, which will be the join pairs between customers and product.

– And product needs no additional index, since the join is on the primary key to product.

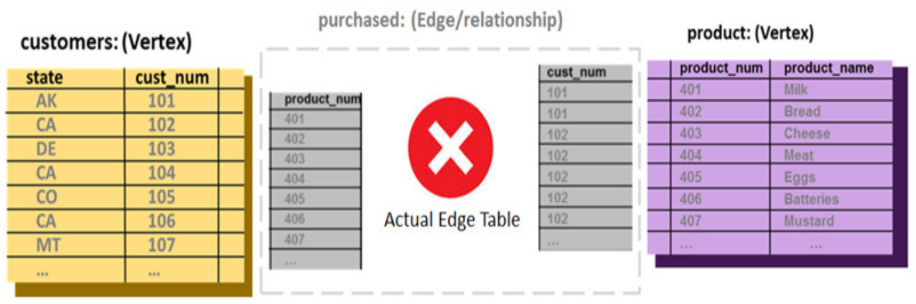
– The (join method) used to process DSE Graph queries, is nested loop join method.

A bit on Neo4J

From documentation located at,

```
https://neo4j.com/graphacademy/online-training/introduction-to-neo4j
/part-2/
```

Neo4J does something interesting, as displayed in Figure 38-6. A code review follows.



state	cust_num
AK	101
CA	102
DE	103
CA	104
CO	105
CA	106
MT	107
...	...

product_num
401
402
403
404
405
406
407
...

cust_num
101
101
102
102
102
102
102
...

product_num	product_name
401	Milk
402	Bread
403	Cheese
404	Meat
405	Eggs
406	Batteries
407	Mustard
...	...

Figure 38-6   Neo4J storage model

Relative to Figure 38-6, the following is offered:

- Super cool idea. Neo4J stores the address of the remote key entity instances (rows from the adjoining vertex), directly inside the neat side vertex. This has the promise to reduce physical I/O on reads.
- However, what about writes; every INSERT, UPDATE, DELETE becomes a scalability concern, with a higher than linear scaling need.

38.2 Complete the following

Optionally, and if you wish, reconstruct each of the queries and run time conditions discussed above, and run in the various and appropriate functional area inside DSE; DSE Core, DSE Analytics, or DSE Graph.

Work to create the index use or negations, as detailed above. Using profiling (graph, or DSE Core), produce query plan details as discussed above.

38.3 In this document, we reviewed or created:

This month and in this document we detailed the following:

- An introductory level discussion to query processing for SQL (DSE Analytics), DSE Core and DSE Graph.
- We discussed SQL query processing operative patterns for Filter/Join/Sort, and index negation.

Persons who help this month.

Kiyu Gabriel, Dave Bechberger, and Jim Hatcher.

Additional resources:

Free DataStax Enterprise training courses,

`https://academy.datastax.com/courses/`

Take any class, any time, for free. If you complete every class on DataStax Academy, you will actually have achieved a pretty good mastery of DataStax Enterprise, Apache Spark, Apache Solr, Apache TinkerPop, and even some programming.

This document is located here,

`https://github.com/farrell0/DataStax-Developers-Notebook`

`https://tinyurl.com/ddn3000`