Google Cloud

High-Throughput BigQuery and Bigtable Streaming Features

Agenda

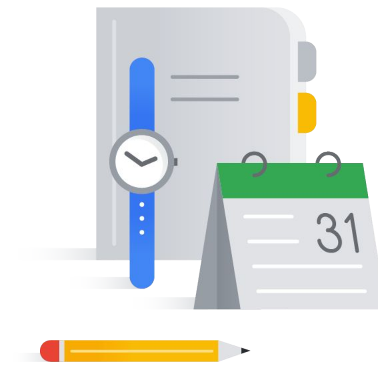
Streaming into BigQuery and Visualizing Results

Lab: Streaming Analytics and Dashboards

High-Throughput Streaming with Cloud Bigtable

Optimizing Cloud Bigtable Performance

Lab: Streaming Data Pipelines into Bigtable



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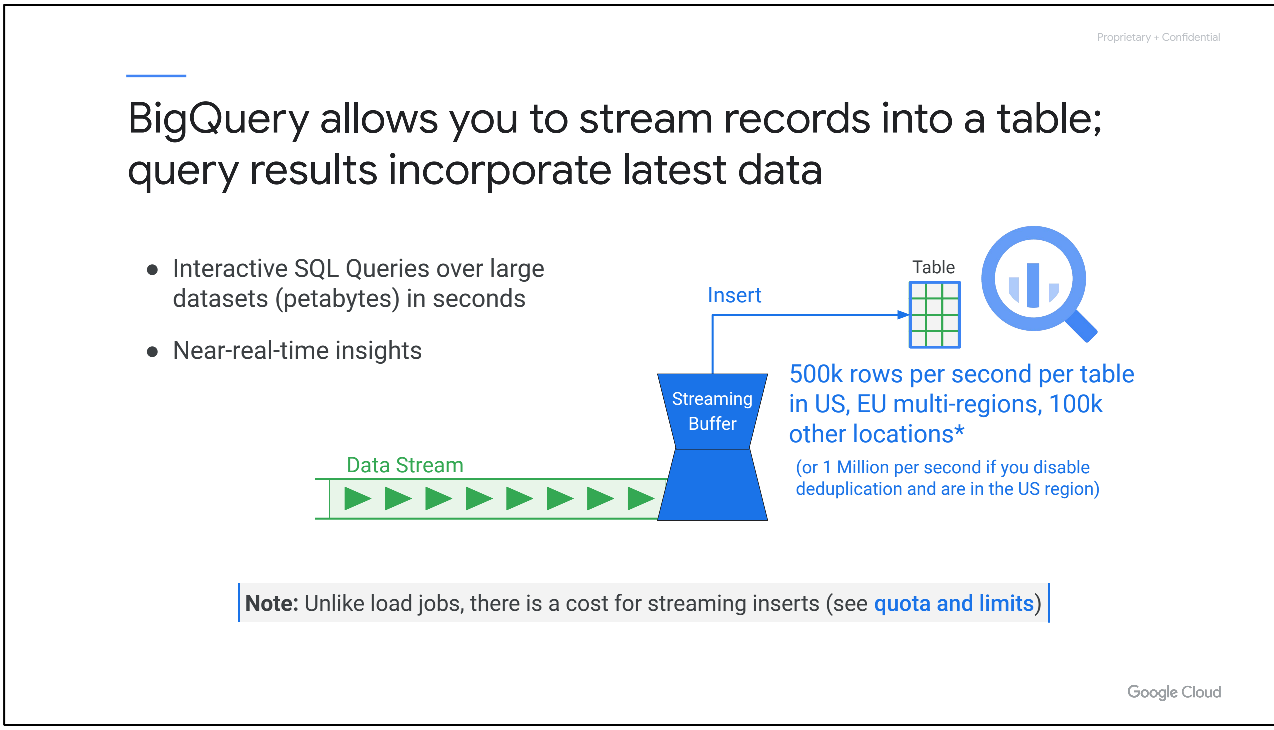
In this module, you will learn about Streaming Analysis and the throughput constraints associated. These analysis systems are majorly responsible for analyzing data in real time and help getting timely business decisions done. We're going to talk about BigQuery and Bigtable in this module which helps us in making timely decisions.



Streaming is not a load job. It is a separate BigQuery method called, "streaming inserts". It allows you to insert one item at a time into a table. New tables can be created from a template table that identifies the schema to be copied. Usually the data is available in seconds. The data enters a streaming buffer, where it is held briefly until it can be inserted into the table.

Data availability and consistency are considerations. Candidates for streaming are analysis or applications that are tolerant of late or missing data or data arriving out of order or duplicated. The stream can pass through other services introducing additional latency and the possibility of errors.

Since streaming data is unbounded, you need to consider the streaming quotas. There is both a daily limit and a concurrent rate limit. You can find more information about these in the online documentation (https://cloud.google.com/bigquery/streaming-data-into-bigquery).

You can disable best effort de-duplication by not populating the insertId field for each row inserted. When you do not populate insertId, you get much higher streaming ingest quotas for the US region. (1 Million per second vs 500,000 inserts per second)

See:
https://cloud.google.com/blog/products/data-analytics/whats-happening-bigquery-adding-speed-and-flexibility-10x-streaming-quota-cloud-sql-federation-and-more

Question:
When should you ingest a stream of data rather than use a batch approach to load data?

Answer:
When the immediate availability of the data is a solution requirement.

Reason:
In most cases loading batch data is not charged. Streaming is charged. So use batch loading or repeated batch loading rather than streaming unless that is a requirement of the application.

Insert streaming data into a BigQuery table

```
export GOOGLE_APPLICATION_CREDENTIALS="/home/user/Downloads/[FILE_NAME].json"
```

Credentials

The service must have Cloud IAM permissions set in the Web UI

```
pip install google-cloud-bigquery
```

Install API

Python

```
from google.cloud import bigquery
client = bigquery.Client(project='PROJECT_ID')

dataset_ref = bigquery_client.dataset('my_datasset_id')
table_ref = dataset_ref.table('my_table_id')
table = bigquery_client.get_table(table_ref)

# read data from Cloud Pub/Sub and place into row format
# static example customer orders in units:
rows_to_insert = [
    (u'customer 1', 5),
    (u'customer 2', 17),
    ]
errors = bigquery_client.insert_rows(table, rows_to_insert)
```

Get table access from API

Insert rows into table

Create a client

Access dataset and table

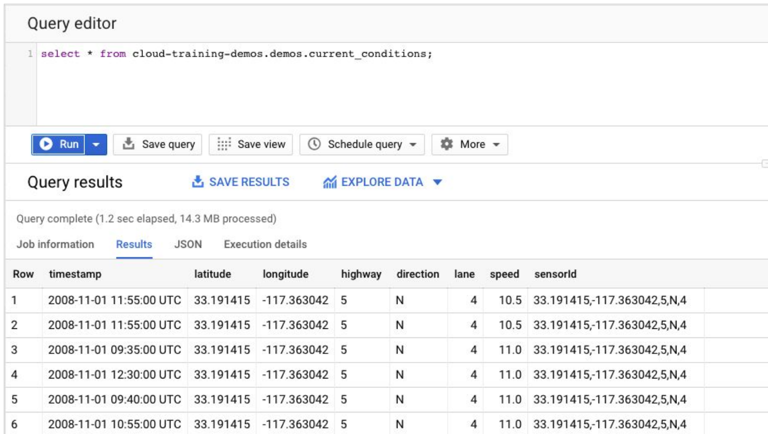
Perform insert

Here is an example of the code used to insert streaming data into a BigQuery table.

In this example, the message body has already been decoded. In a full example a step would be required to extract the appropriate message elements to be inserted.

Proprietary + Confidential

Review streaming data in BigQuery



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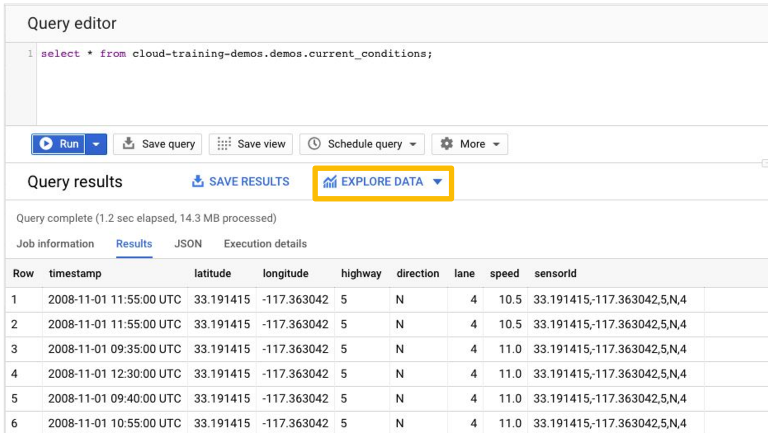
After streaming into a BigQuery table has been initiated, you can review the data in BigQuery by querying the table receiving the streaming data.

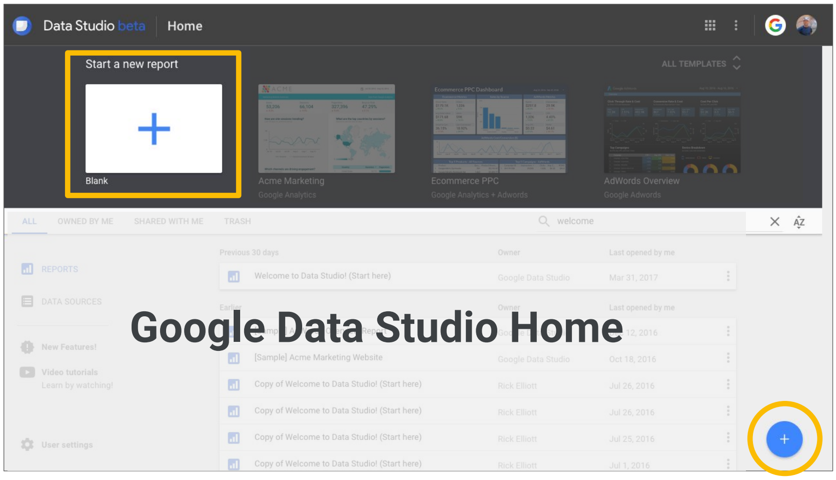
Want to visualize insights? Explore Google Data Studio insights right from within BigQuery



Row	timestamp	latitude	longitude	highway	direction	lane	speed	sensorId
1	2008-11-01 11:55:00 UTC	33.191415	-117.363042	5	N	4	10.5	33.191415,-117.363042,5,N,4
2	2008-11-01 11:55:00 UTC	33.191415	-117.363042	5	N	4	10.5	33.191415,-117.363042,5,N,4
3	2008-11-01 09:35:00 UTC	33.191415	-117.363042	5	N	4	11.0	33.191415,-117.363042,5,N,4
4	2008-11-01 12:30:00 UTC	33.191415	-117.363042	5	N	4	11.0	33.191415,-117.363042,5,N,4
5	2008-11-01 09:40:00 UTC	33.191415	-117.363042	5	N	4	11.0	33.191415,-117.363042,5,N,4
6	2008-11-01 10:55:00 UTC	33.191415	-117.363042	5	N	4	11.0	33.191415,-117.363042,5,N,4

When working with data in BigQuery, including streaming data, you can use Data Studio to explore the data further. After you execute a query, you can choose Data Studio from the Explore Data options to immediately start creating visualizations as part of a dashboard.

Create new reports in the Google Data Studio UI



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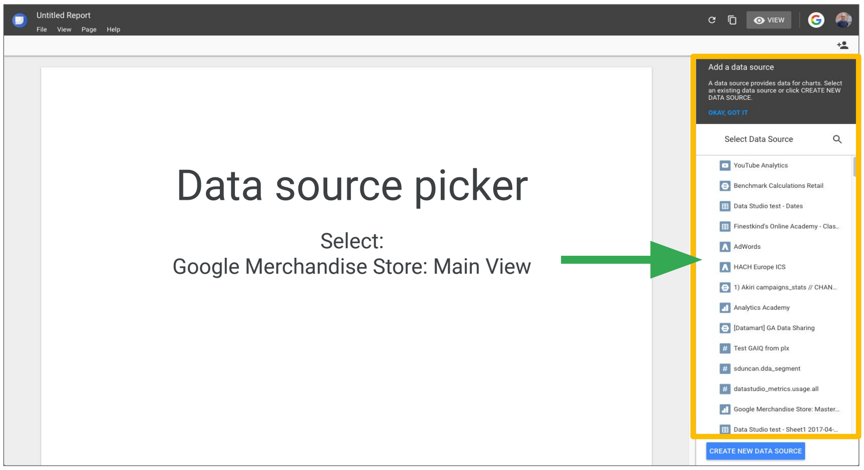
Here's a quick walkthrough of the Google Data Studio UI. Keep in mind the team is continually updating the product so refer to their documentation and examples for additional practice.

The home page shows the dashboards and data sources you have access to. It's an important distinction -- connected data sources can feed into dashboards but just because someone has access to your dashboard doesn't mean they have permission to view the data presented (because that could be controlled in BigQuery or your Google Cloud project).

Anyway, there two ways to create a new report from scratch: from the templates panel on top

Or from the button in the lower right.

Select data sources to build your visualizations



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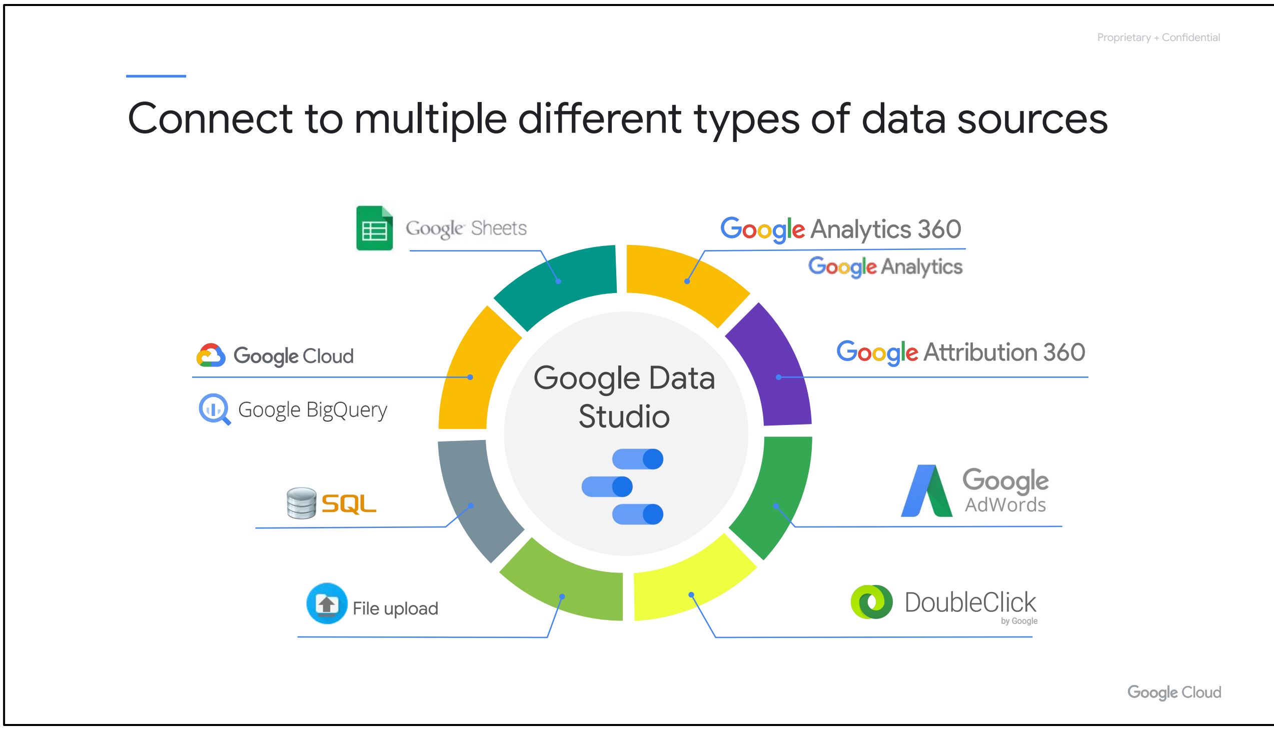
The first thing you need to do is tell Google Data Studio where your data is coming from. That is known as the "data source".

A Google Data Studio report can have any number of data sources, but we'll just start with one.

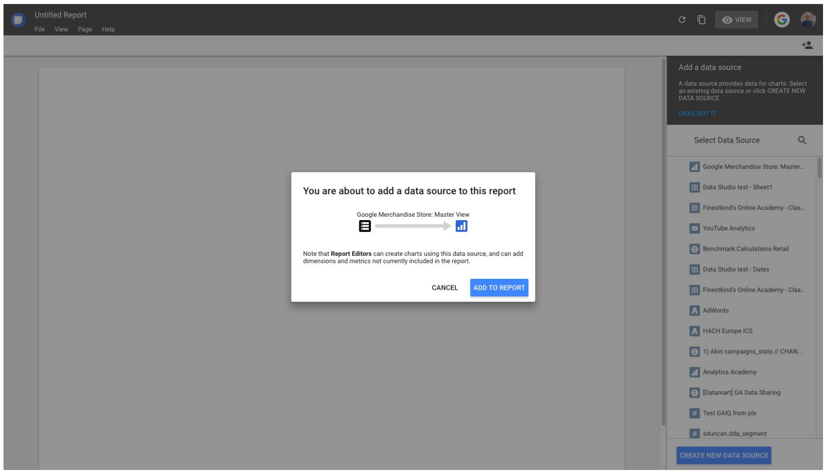
The data source picker shows all the data sources you have access to.



Note that you can have any or all of these data sources in a single Google Data Studio report.

Since Google Data Studio reports and datasets can be shared, you should be aware of the ramifications of adding a data source.

Add the data source to your report

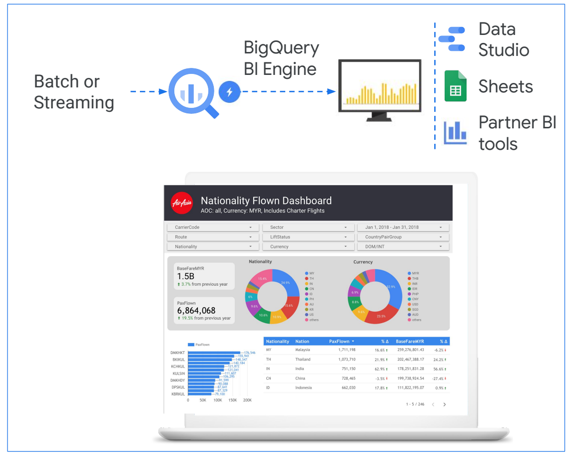


When you add a data source to a report, other people who can view the report can potentially see all the data in that data source if you share that source with them. And anyone who can edit the report can use all the fields from any added data sources to create new charts with them.

You can click ADD TO REPORT to connect the data source and then you are ready to start visualizing.

Add value: BI Engine for dashboard performance

- No need to manage OLAP cubes or separate BI servers for dashboard performance.
- Natively integrates with BigQuery streaming for real-time data refresh.
- Column oriented in-memory BI execution engine.



One of the Google Cloud products that helps manage the performance of dashboards is BigQuery BI Engine. [BI Engine] is a fast, in-memory analysis service that is built directly into BigQuery and available to speed up your business intelligence applications.

Historically, BI teams would have to build, manage, and optimize their own BI servers and OLAP cubes to support reporting applications. Now, with BI Engine, you can get sub-second query response time on your BigQuery datasets without having to create your own cubes. BI Engine is built on top of the same BigQuery storage and compute architecture and servers as a fast in-memory intelligent caching service that maintains state.

https://www.youtube.com/watch?v=TqlrlcmqPgo

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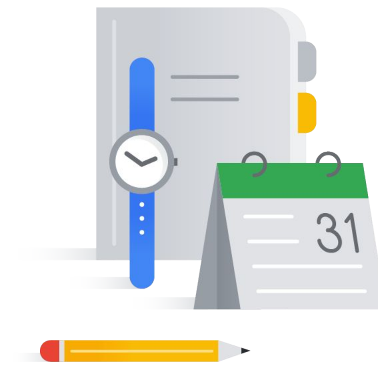
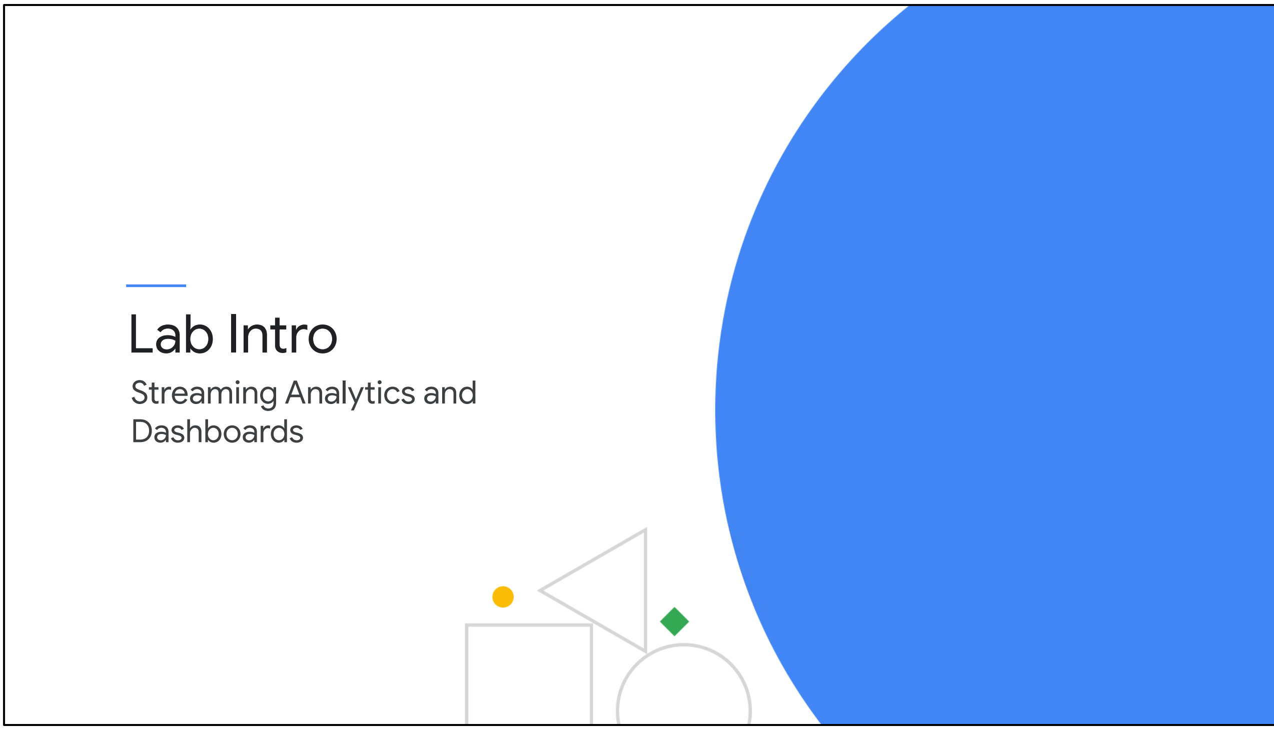
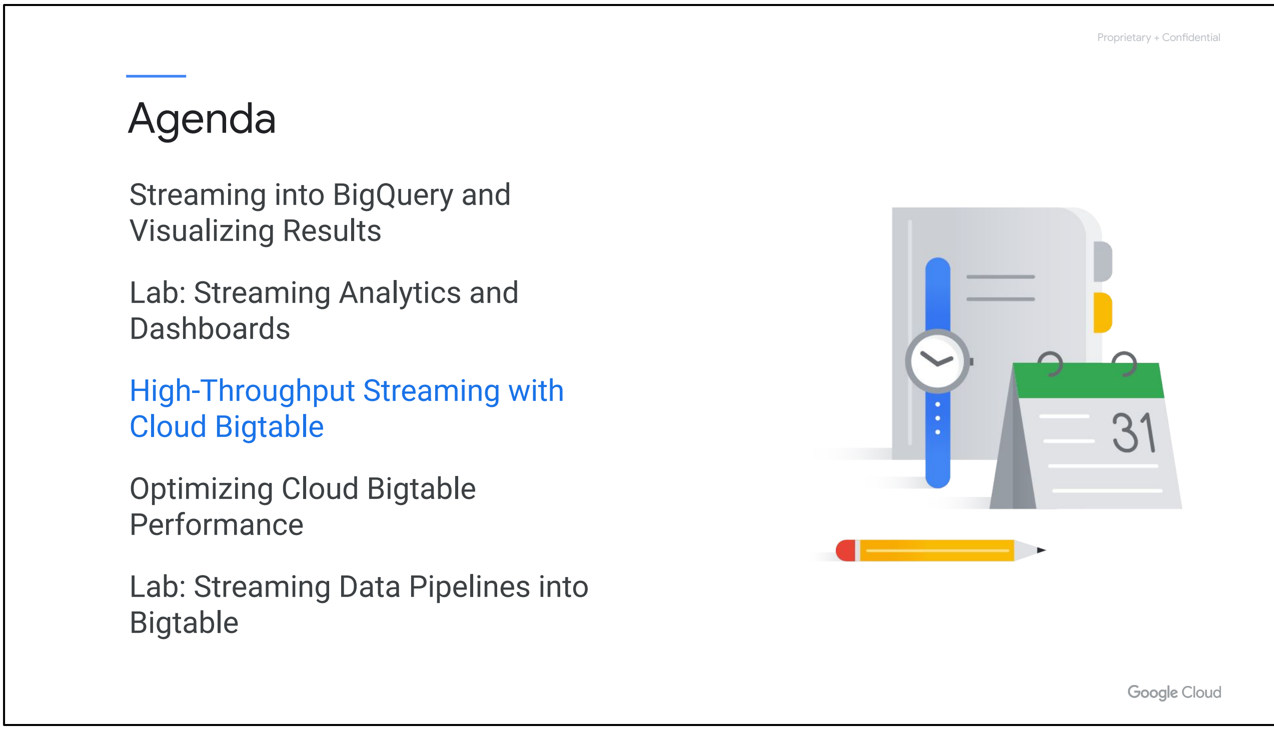




In this lab, we will connect to BigQuery data source from Google Data Studio and create reports and charts to visualize the BigQuery data.

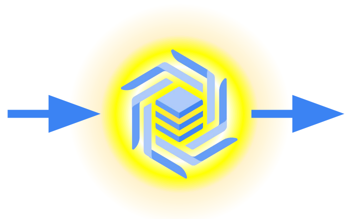


So far, we looked at how to do queries on data even if it's streaming in using BigQuery, and displaying the data using Data Studio. BigQuery is a very good general purpose solution, something that would work in most cases. But every once in a while, you will come across a situation where the latency of BigQuery is going to be problematic.

In BigQuery, the data that's streaming in is available in a matter of seconds, but sometimes you will want lower latency than that. You will want your information to be available in milliseconds or microseconds. You may also have run into issues where the throughput of BigQuery may not be enough and you may want to deal with a higher throughput.

So what we will be looking at next is how to handle such throughput or latency requirements when BigQuery is not enough. Where do you go? We will talk about Bigtable, which is suited to high-performance applications. We will look at how to design for Bigtable , specifically how to design schemas, how to design the row key from Bigtable. We will look at how to ingest data into Bigtable.

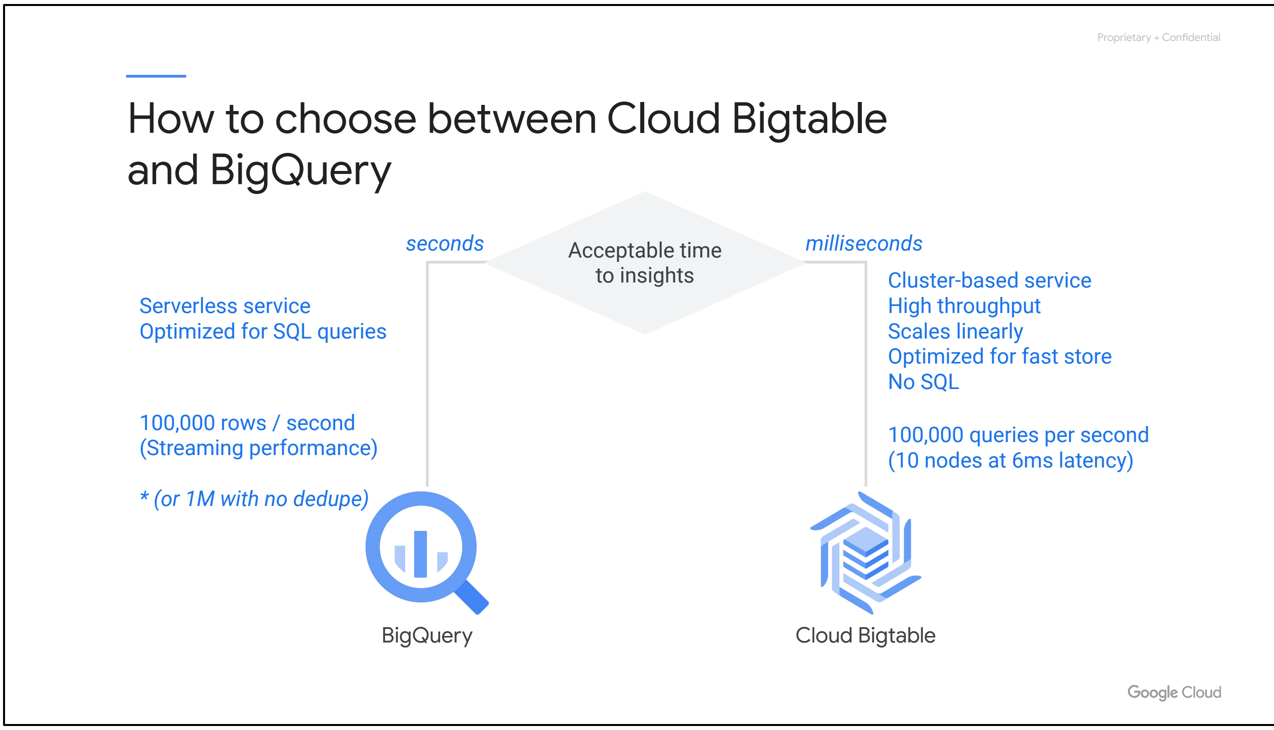
Cloud Bigtable



Qualities that Cloud Bigtable contributes to data engineering solutions:

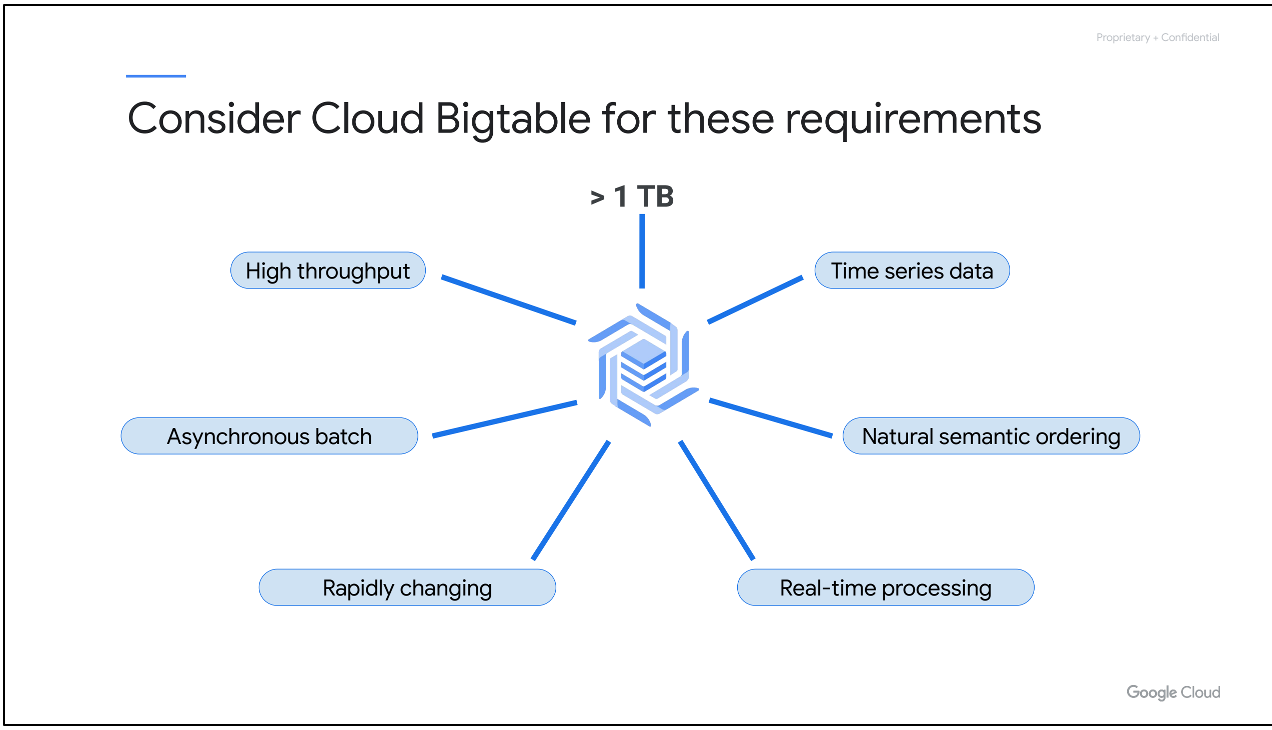
- NoSQL Queries over large datasets (petabytes) in milliseconds
- Very fast for specific cases

To use Cloud Bigtable effectively you have to know a lot about your data and how it will be queried up-front. A lot of the optimizations happen before you load data into Cloud Bigtable.



Cloud Bigtable is ideal for applications that need very high throughput and scalability for non-structured key/value data, where each value is typically no larger than 10 MB.

Not good for highly structured data, transactional data, small data (less than 1 TB), and anything requiring SQL Queries and SQL-like joins.



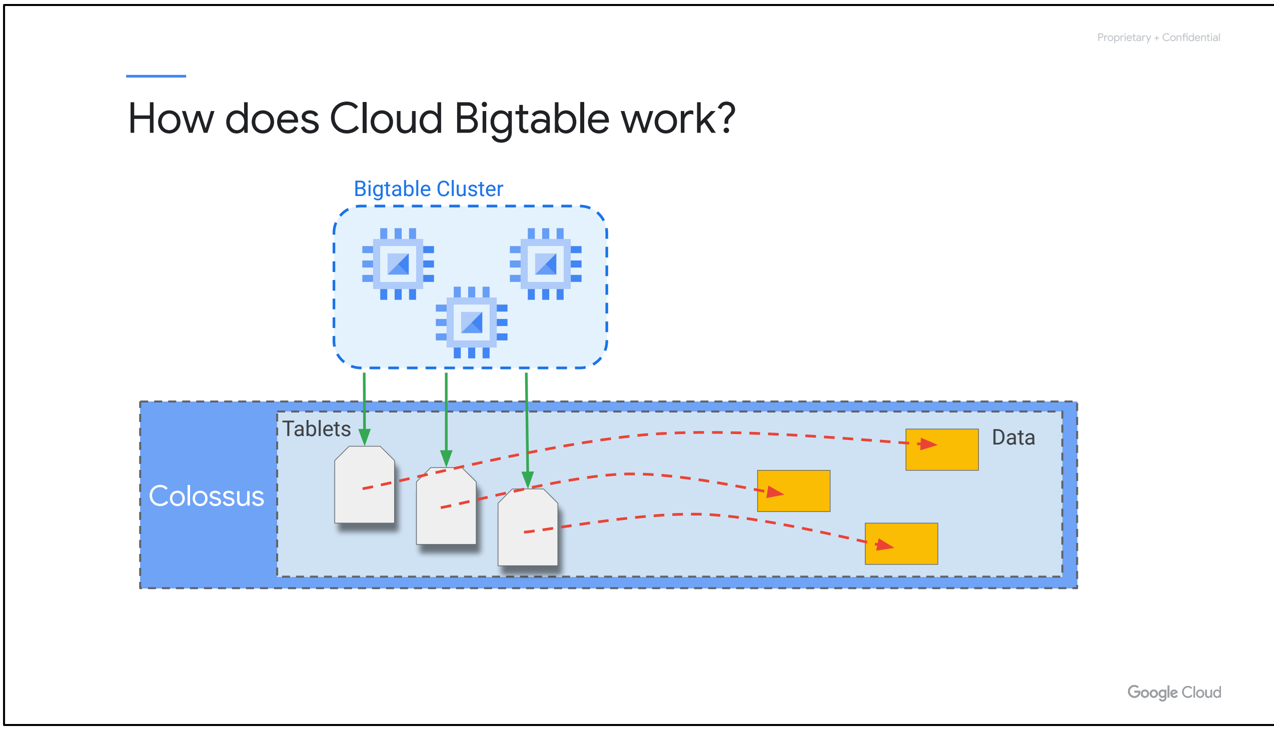
Here are a few examples of data engineering requirements that have been solved using Cloud Bigtable.

Machine learning algorithms frequently have many or all of these requirements. Application that use marketing data, such as purchase histories or customer preferences. Applications that use financial data such as transaction histories, stock prices, or currency exchange rates. Internet of Things, IoT data, such as usage reports from meters, sensors, or devices.

Time-series data, such as resource consumption like CPU and memory usage over time for multiple servers.

The most common use of Cloud Bigtable

Productionize a real-time lookup as part of an application, where speed and efficiency are desired beyond that of other databases.

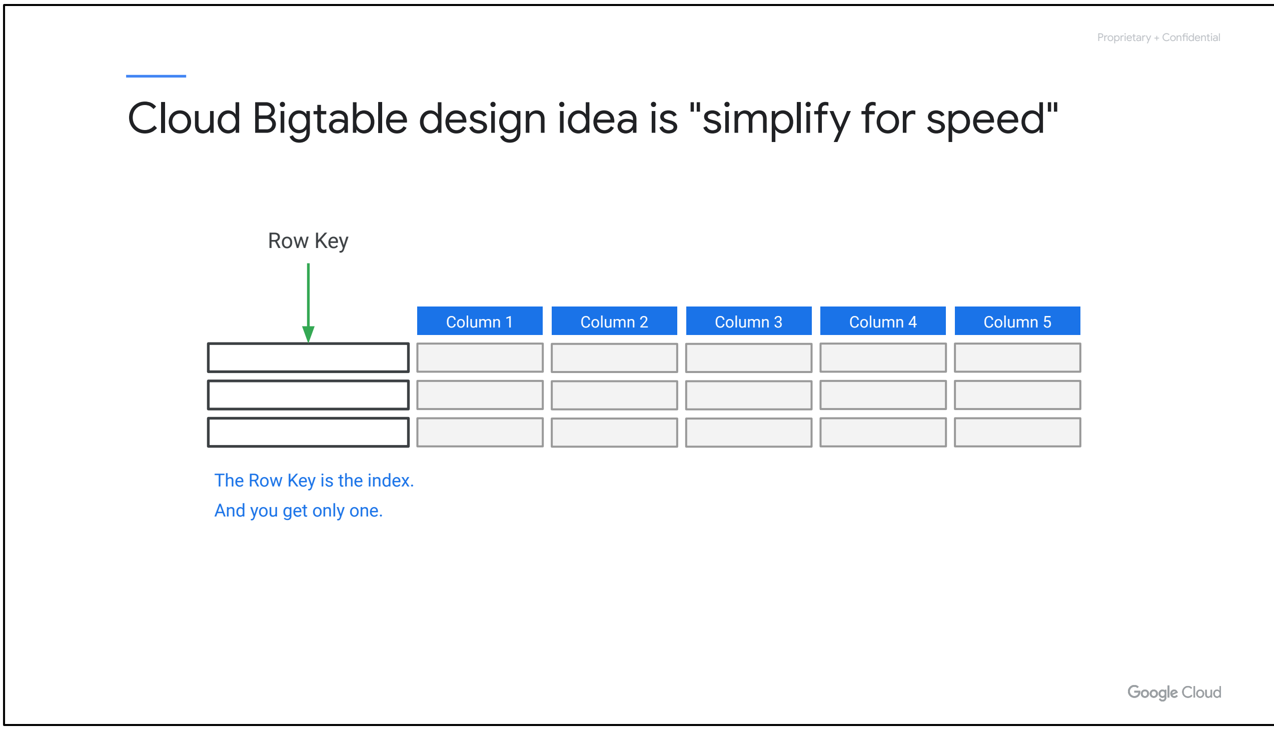


Cloud Bigtable stores data in a file system called Colossus. Colossus also contains data structures called Tablets that are used to identify and manage the data. And metadata about the Tablets is what is stored on the VMs in the Bigtable cluster itself.

This design provides amazing qualities to Cloud Bigtable. It has three levels of operation. It can manipulate the actual data. It can manipulate the Tablets that point to and describe the data. Or it can manipulate the metadata that points to the Tablets. Rebalancing tablets from one node to another is very fast, because only the pointers are updated.

Cloud Bigtable is a learning system. It detects "hot spots" where a lot of activity is going through a single Tablet and splits the Tablet in two. It can also rebalance the processing by moving the pointer to a Tablet to a different VM in the cluster. So its best use case is with big data -- above 300 GB -- and very fast access but constant use over a longer period of time. This gives Cloud Bigtable a chance to learn about the traffic pattern and rebalance the Tablets and the processing.

When a node is lost in the cluster, no data is lost. And recovery is fast because only the metadata needs to be copied to the replacement node.
Colossus provides better durability than the default 3 replicas provided by HDFS.

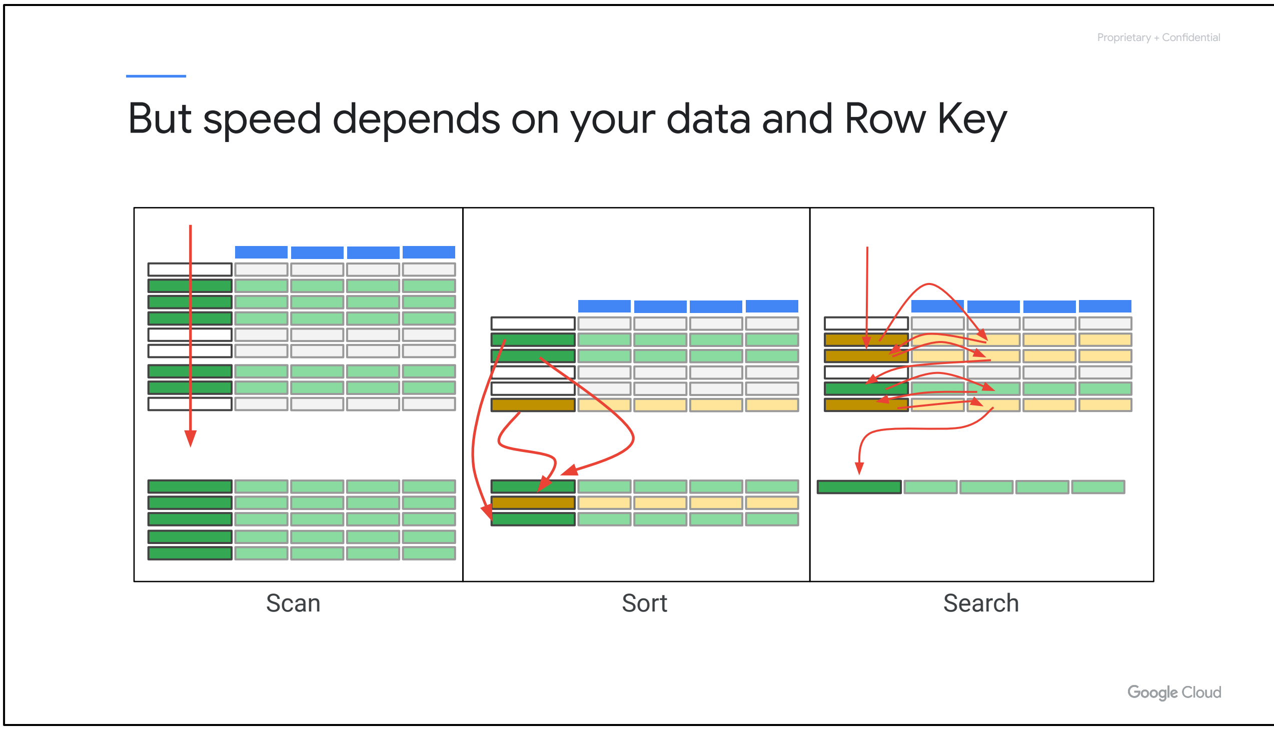


Cloud Bigtable stores data in tables. And to begin with, it is just a table with rows and columns. However, unlike other table-based data systems like spreadsheets and SQL databases, Cloud Bigtable has only one index.
That index is called the Row Key. There are no alternate indexes or secondary indexes. And when data is entered, it is organized lexicographically by the Row Key.

The design principle of Cloud Bigtable is speed through simplification. If you take a traditional table, and simplify the controls and operations you allow yourself to perform on it then you can optimize for those specific tasks.

It is the same idea behind RISC (Reduced Instruction Set Computing). Simplify the operations. And when you don't have to account for variations, you can make those that remain very fast.

In Cloud Bigtable, the first thing we must abandon in our design is SQL. This is a standard of all the operations a database can perform. And to speed things up we will drop most of them and build up from a minimal set of operations. That is why Cloud Bigtable is called a NoSQL database.



The green items are the results you want to produce from the query. In the best case you are going to scan the Row Key one time, from the top-down. And you will find all the data you want to retrieve in adjacent and contiguous rows. You might have to skip some rows. But the query takes a single scan through the index from top-down to collect the result set.

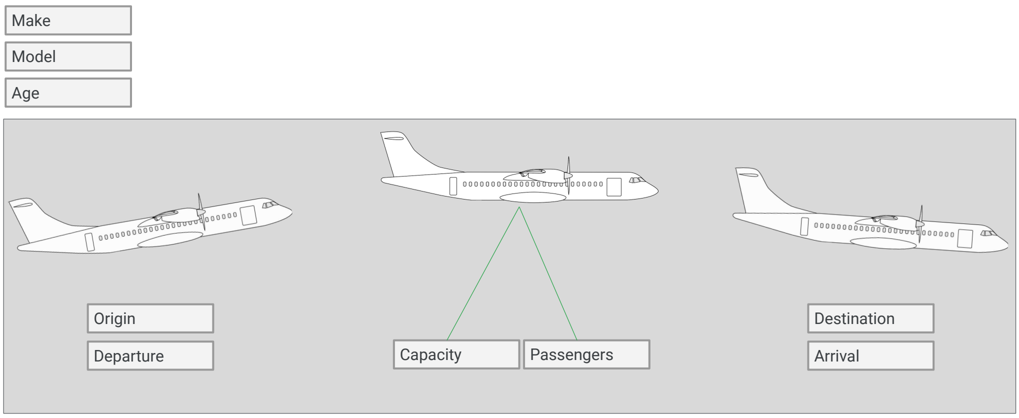
The second instance is sorting. You are still only looking at the Row Key. In this case the yellow line contains data that you want, but it is out of order. You can collect the data in a single scan, but the solution set will be disorderly. So you have to take the extra step of sorting the intermediate results to get the final results. Now think about this. What does the additional sorting operation do to timing? It introduces a couple of variables. If the solution set is only a few rows, then the sorting operation will be quick. But if the solution set is huge, the sorting will take more time. The size of the solution set becomes a factor in timing. The orderliness of the original data is another factor. If most of the rows are already in order, there will be less manipulation required than if there are many rows out of order. The orderliness of the original data becomes a factor in timing. So introducing sorting means that the time it takes to produce the result is much more variable than scanning.

The third instance is searching. In this case, one of the columns contains critical data. You can't tell whether a row is a member of the solution set or not without examining the data contained in the critical column. The Row Key is no longer sufficient. So now you are bouncing back and forth between Row Key and column contents. There are many approaches to searching. You could divide it up into multiple steps, one scan through the Row Keys and subsequent scans through the columns, and then perhaps a final sort to get the data in the order you want. And it gets much more complicated if there are multiple columns containing critical information. And it gets more complicated if the conditions of solution set membership involve logic such as a value in one column AND a value in another column, or a value in one column OR a value in another column. However, any algorithm or strategy you use to produce the result is going to be slower and more variable than scanning or sorting.

What is the lesson from this exploration? That to get the best performance with the design of the Cloud Bigtable service, you need to get your data in order first, if possible, and you need to select or construct a Row Key that minimizes sorting and searching and turns your most common queries into scans.

Not all data and not all queries are good use cases for the efficiency that the Cloud Bigtable service offers. But when it is a good match, Cloud Bigtable is so consistently fast that it is magical.

Flights of the world: Reviewing the data

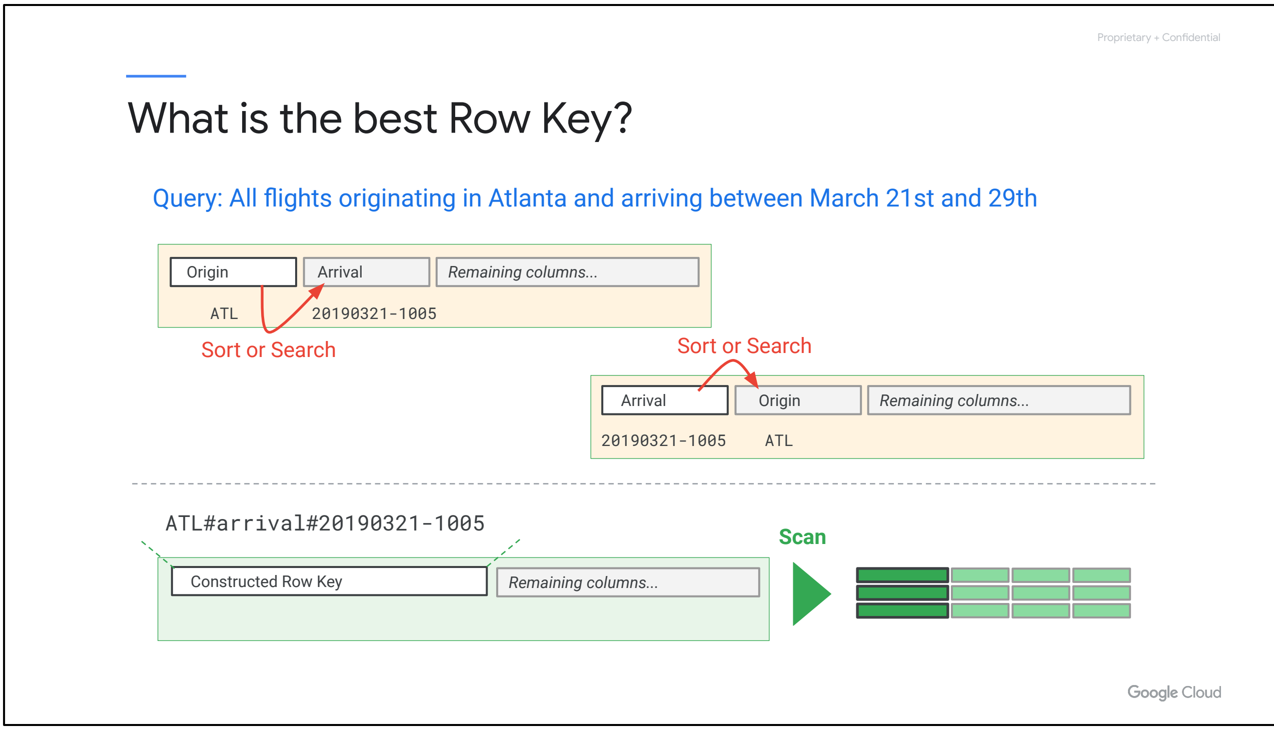


Each entry records the occurrence of one flight.

The data include city of origin and the date and time of departure, and destination city and date and time of arrival.

Each airplane has a maximum capacity, and related to this is the number of passengers that were actually aboard each flight.

Finally, there is information about the aircraft itself, including the manufacturer, called the make, the model number, and the current age of the aircraft at the time of the flight.



In this example, the Row Key will be defined for the most common use case. The Query is to find all flights originating from the Atlanta airport and arriving between March 21st and 29th. The airport where the flight originates is in the Origin field. And the date when the aircraft landed is listed in the Arrival field.

If you use Origin as the Row Key, you will be able to pull out all flights from Atlanta -- but the Arrival field will not necessarily be in order. So that means searching through the column to produce the solution set.

If you use the Arrival field as the Row Key, it will be easy to pull out all flights between March 21st and 29th, but the airport of origin won't be organized. So you will be searching through the arrival column to produce the solution set.

In the third example, a Row Key has been constructed from information extracted from the Origin field and the Arrival field -- creating a constructed Row Key. Because the data is organized lexicographically by the Row Key, all the Atlanta flights will appear in a group, and sorted by date of arrival. Also, with the word “arrival” present in the key there is no need to verify that the timestamp is for the Arrival rather than the Departure. Using this Row Key you can generate the solution set with only a scan.

In this example, the data was transformed when it arrived. So constructing a Row Key during the transformation process is straightforward.

Cloud Bigtable schema organization

Column Families

	Flight_Information					Aircraft_Information			
Row Key	Origin	Destination	Departure	Arrival	Passengers	Capacity	Make	Model	Age
ATL#arrival#20190321-1121	ATL	LON	20190321-0311	20190321-1121	158	162	B	737	18
ATL#arrival#20190321-1201	ATL	MEX	20190321-0821	20190321-1201	187	189	B	737	8
ATL#arrival#20190321-1716	ATL	YVR	20190321-1014	20190321-1716	201	259	B	757	23

Cloud Bigtable also provide Column Families. By accessing the Column Family, you can pull some of the data you need without pulling all of the data from the row or having to search for it and assemble it. This makes access more efficient.

https://cloud.google.com/bigtable/docs/schema-design

Queries that use the row key, a row prefix, or a row range are the most efficient

Query: Current arrival delay for flights from Atlanta

1

row key based on atlanta arrivals
e.g. `ORIGIN#arrival`
(`ATL#arrival#20190321-1005`)

`Puts latest flights at bottom of table`

2

reverse timestamp to the rowkey
e.g. `ORIGIN#arrival#RTS`
(`ATL#arrival#12345678`)

`Puts latest flights at top of table`

The most common query is for current arrival delay in Atlanta. That will involve averaging flight delays over the last 30 minutes. Hence, origin#arrival. We want this at at the top of the table, hence RTS.

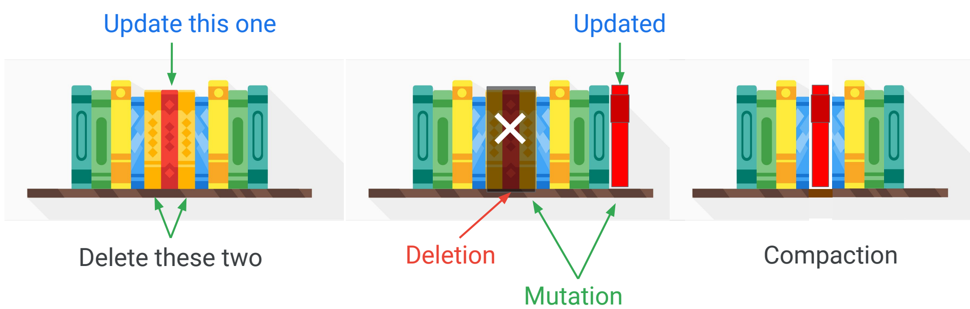
Use reverse timestamps when your most common query is for the latest values.

Query: Current arrival delay for flights from Atlanta

```
// key is ORIGIN#arrival#REVTS
String key = info.getORIGIN() //
   + "#arrival"  //
   + "#" + (Long.MAX_VALUE - ts.getMillis()); // reverse timestamp
```


You can reverse timestamps by subtracting the timestamp from your programming language's maximum value for long integers (such as Java's java.lang.Long.MAX_VALUE, for example LONG_MAX - timestamp.millisecondsSinceEpoch()). By reversing the timestamp, you can design a row key where the most recent event appears at the start of the table instead of the end. As a result, you can get the N most recent events simply by retrieving the first N rows of the table.

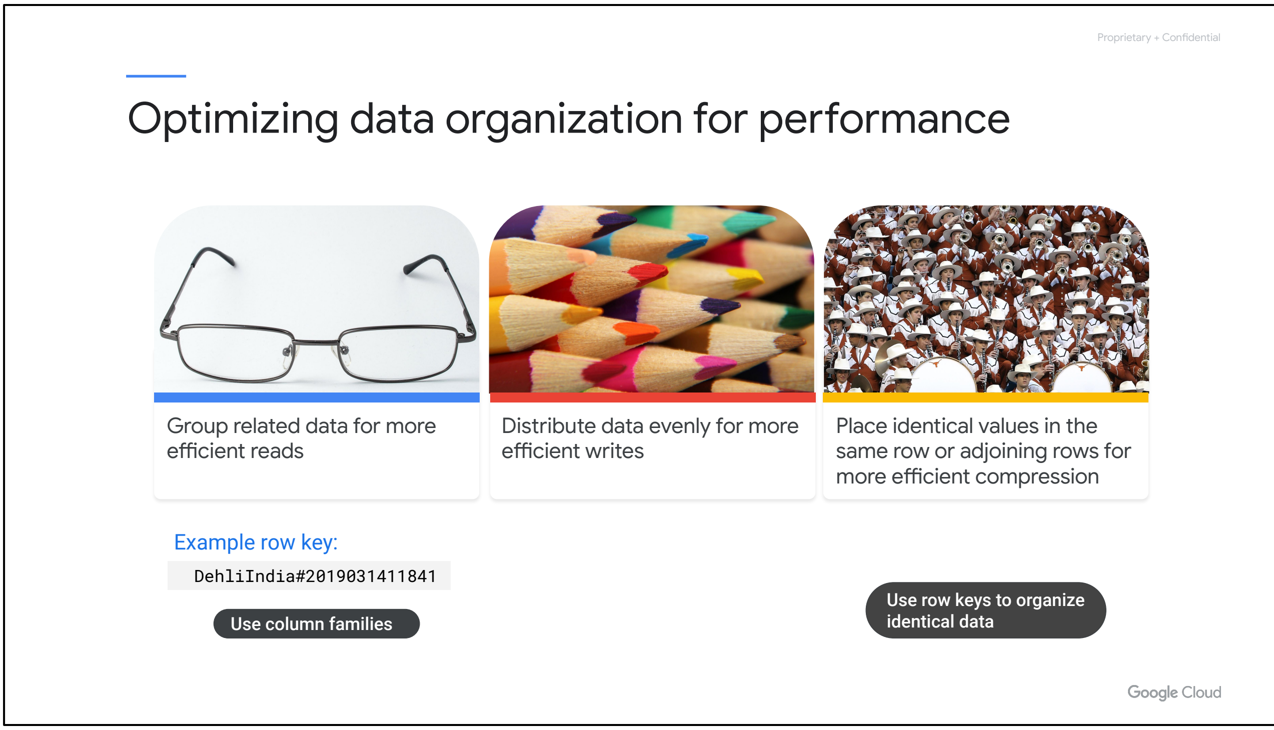
What happens when data in Cloud Bigtable is changed?



When you delete data, the row is marked for deletion and skipped during subsequent processing. It is not immediately removed.

If you make a change to data, the new row is appended sequentially to the end of the table, and the previous version is marked for deletion. So both rows exist for a period of time.

Periodically, Cloud Bigtable compacts the table, removing rows marked for deletion and reorganizing the data for read and write efficiency.



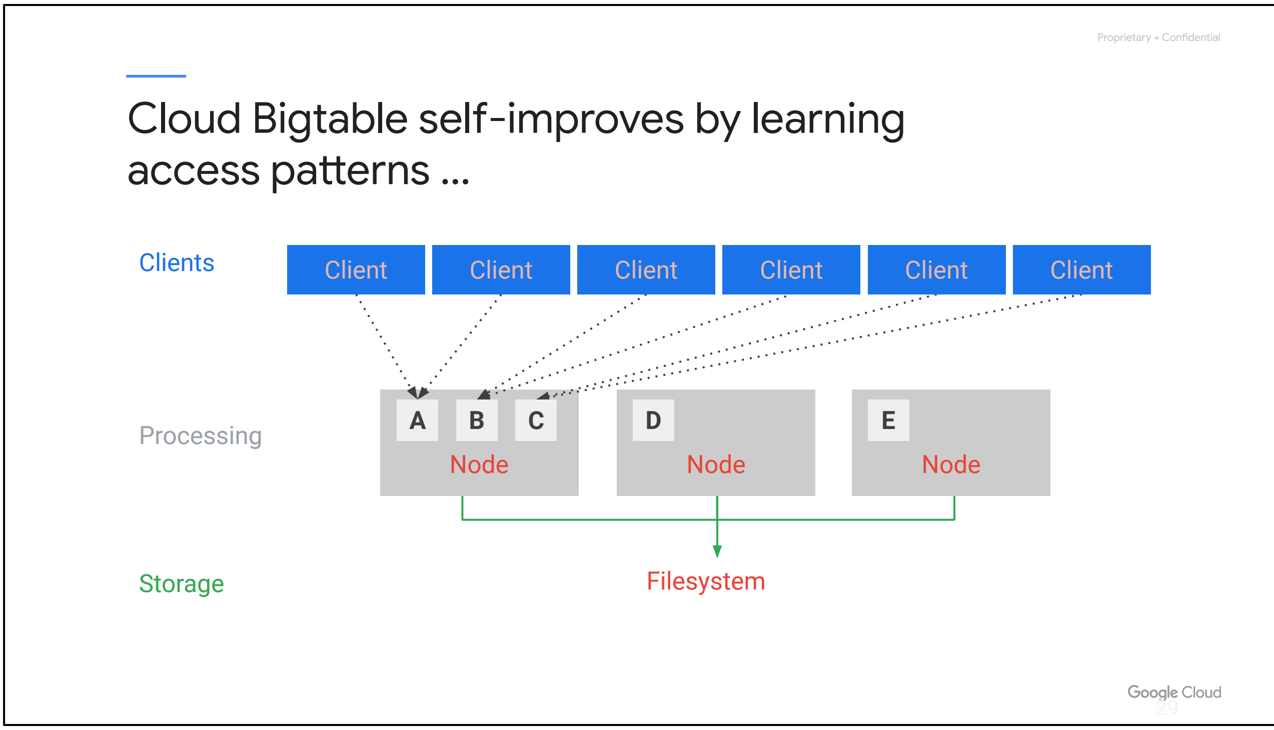
Distributing the writes across nodes provides the best write performance. One way to accomplish this is by choosing row keys that are randomly distributed.

However, choosing a row key that groups related rows so they are adjacent makes it much more efficient to read multiple rows at one time.

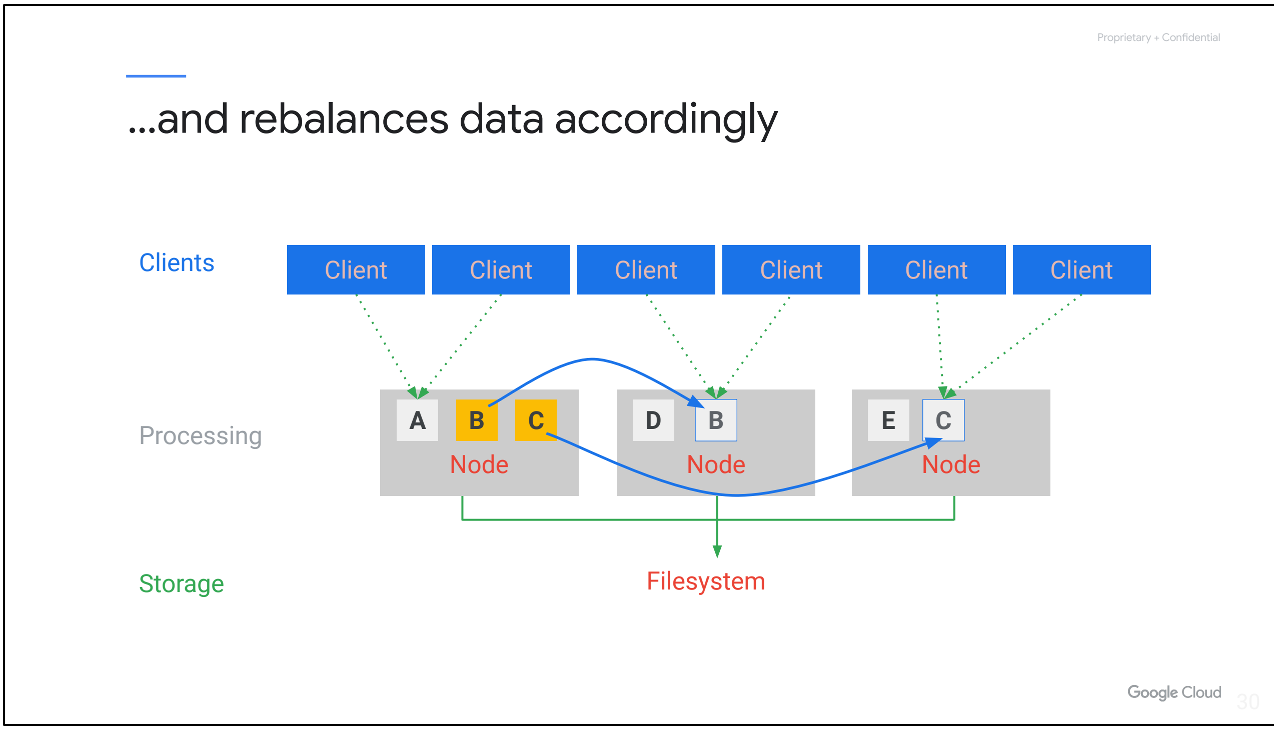
In our airline example, if we were collecting weather data from the airport cities, we might construct a key consisting of a hash of the city name along with a timestamp. The example row key shown would enable pulling all the data for Delhi, India as a contiguous range of rows.

Whenever there are rows containing multiple column values that are related, it is a good idea to group them into a column family. Some NoSQL databases suffer performance degradation if there are too many column families. Cloud Bigtable can handle up to 100 column families without losing performance. And it is much more efficient to retrieve data from one or more column families than retrieving all of the data in a row.

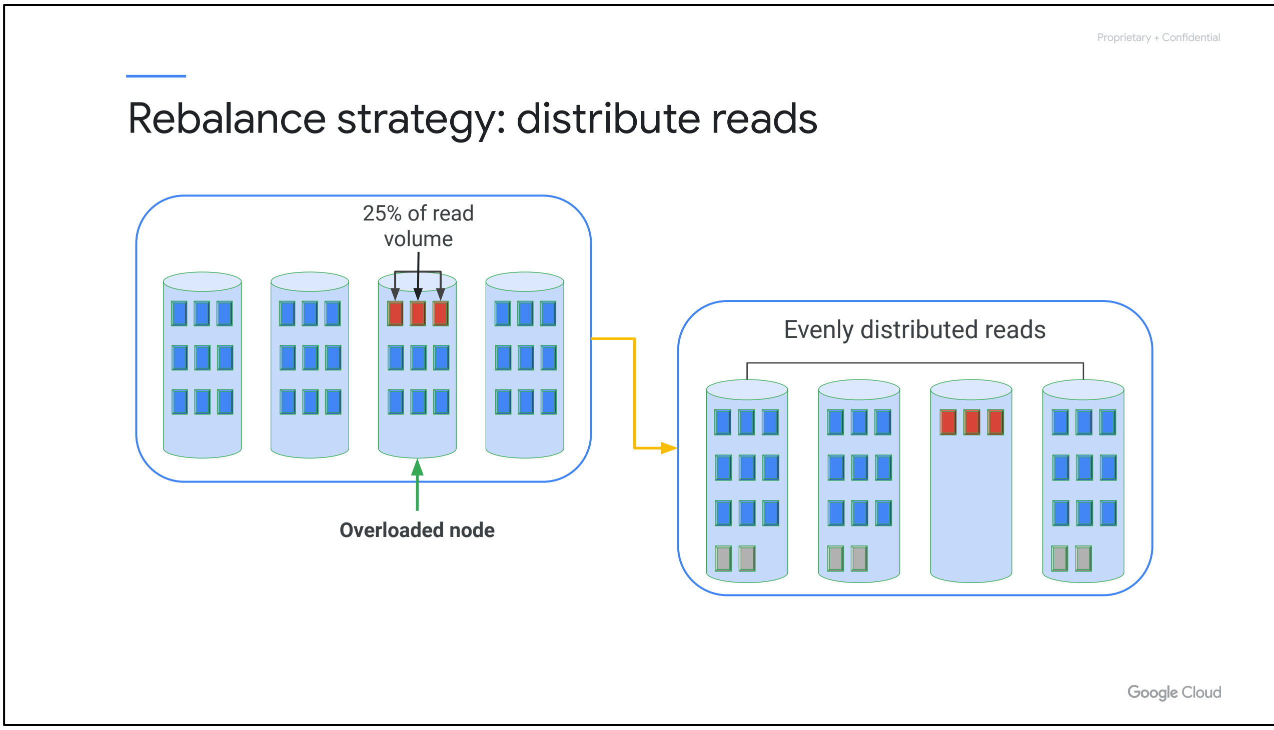
There are currently no configuration settings in Cloud Bigtable for compression. However, random data cannot be compressed as efficiently as organized data. Compression works best if identical values are near each other, either in the same row or in adjoining rows. If you arrange your row keys so that rows with identical data are adjacent, the data can be compressed more efficiently.



Cloud Bigtable periodically rewrites your table to remove deleted entries, and to reorganize your data so that reads and writes are more efficient. It tries to distribute reads and writes equally across all Cloud Bigtable nodes. In this example, A, B, C, D, E are not data, but rather pointers or references and cache, which is why re-balancing is not time-consuming. We are just moving pointers. Actual data is in tablets in Colossus file system.



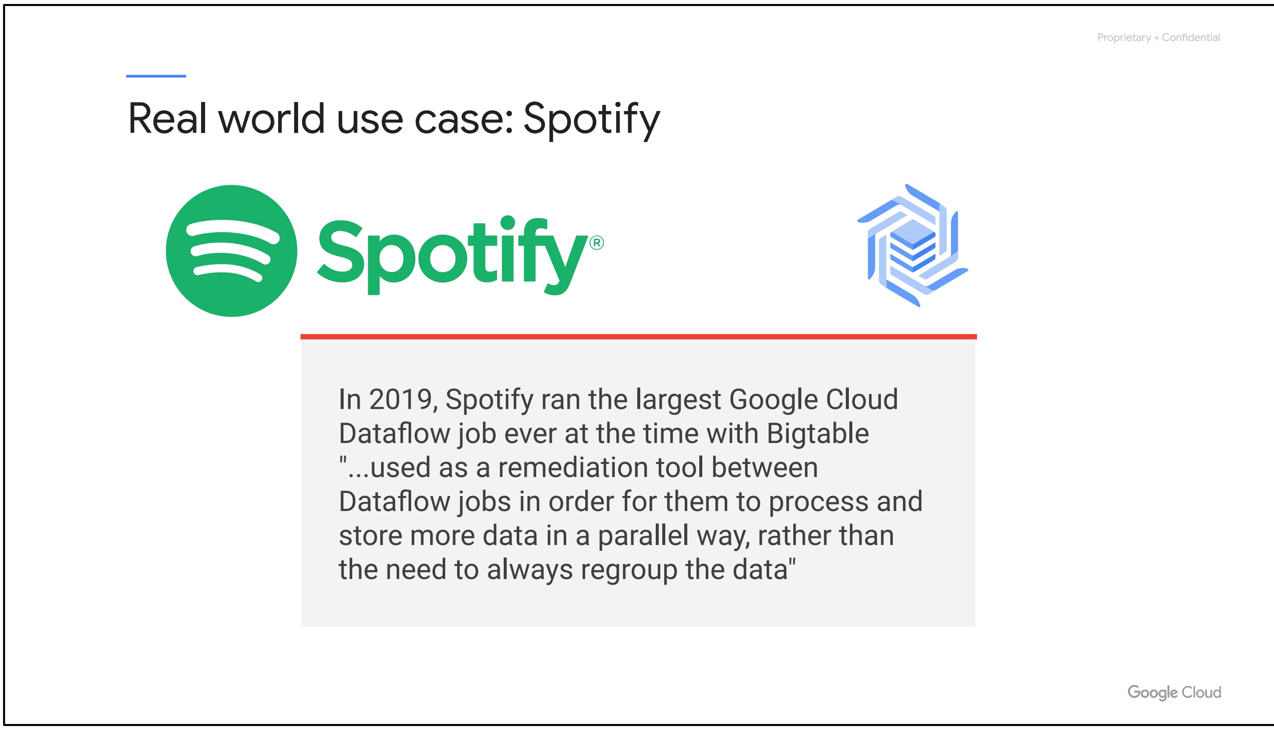
Based on the learned access patterns, Bigtable re-balances data accordingly, and balances the workload across the nodes.



With a well-designed schema, reads and writes should be distributed fairly evenly across an entire table and cluster. However, in some cases, it is inevitable that certain rows will be accessed more frequently than others.

In these cases, Cloud Bigtable will redistribute tablets so that reads are spread evenly across nodes in the cluster.

Note that ensuring an even distribution of reads has taken priority over evenly distributing storage across the cluster.



In 2019 Spotify ran the largest Google Cloud Dataflow job ever at the time with Bigtable "...used as a remediation tool between Dataflow jobs in order for them to process and store more data in a parallel way, rather than the need to always regroup the data"

By using Bigtable, Spotify was able to break down Dataflow jobs into smaller components — and reusing core functionality — and was able to speed up jobs and make them more resilient.

See:
https://techcrunch.com/2020/02/18/how-spotify-ran-the-largest-google-dataflow-job-ever-for-wrapped-2019/
Source Logo - Spotify:
https://storage.googleapis.com/pr-newsroom-wp/1/2018/11/Spotify_Logo_CMYK_Green.png

Proprietary + Confidential

Agenda

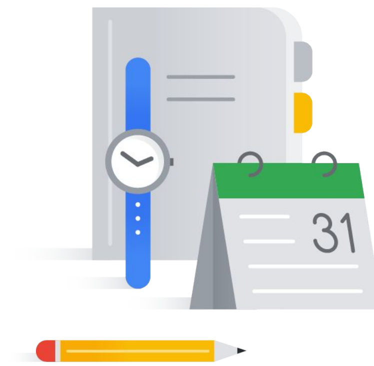
Streaming into BigQuery and Visualizing Results

Lab: Streaming Analytics and Dashboards

High-Throughput Streaming with Cloud Bigtable

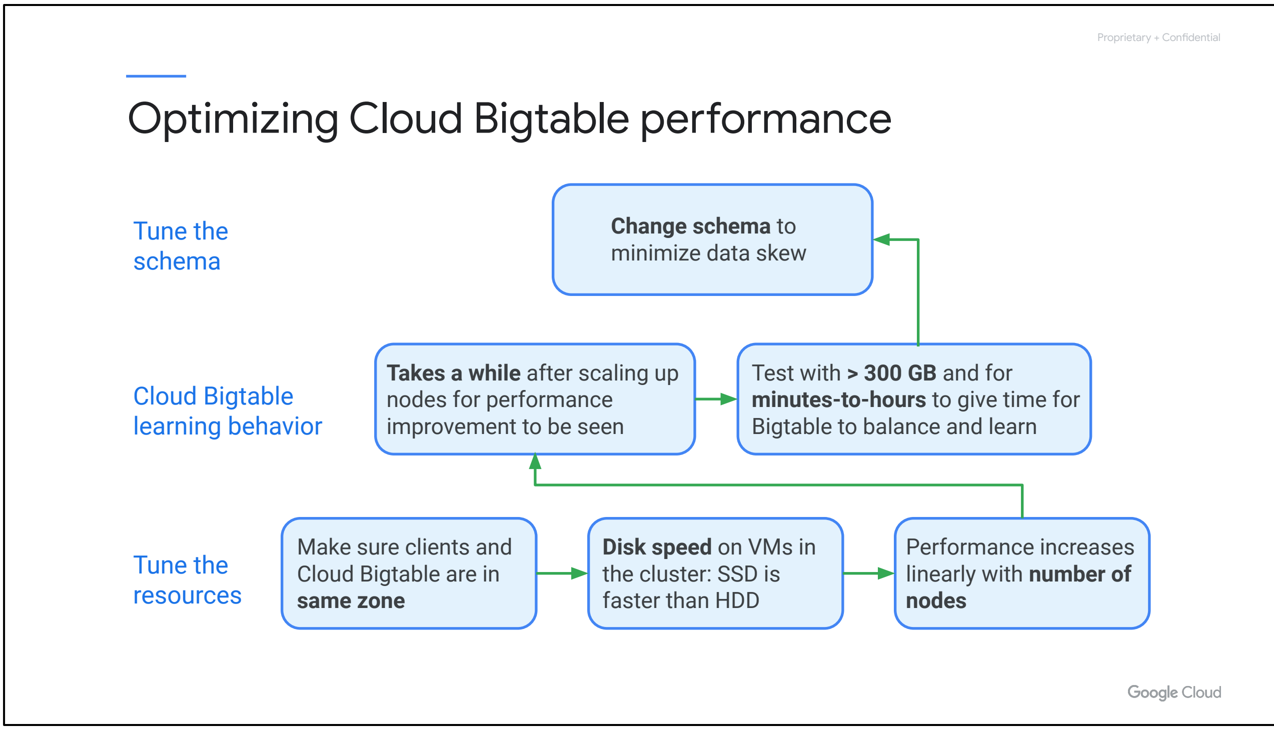
Optimizing Cloud Bigtable Performance

Lab: Streaming Data Pipelines into Bigtable



Google Cloud

We will look at how you can further optimize Bigtable performance.



There are several factors that can result in slower performance:

The table's schema is not designed correctly. It's essential to design a schema that allows reads and writes to be evenly distributed across the Cloud Bigtable cluster. Otherwise, individual nodes can get overloaded, slowing performance.

The workload isn't appropriate for Cloud Bigtable. Testing with a small amount (< 300 GB) of data, or for a very short period of time (seconds rather than minutes or hours), Cloud Bigtable won't be able to properly optimize your data. It needs time to learn your access patterns, and it needs large enough shards of data to make use of all of the nodes in your cluster.

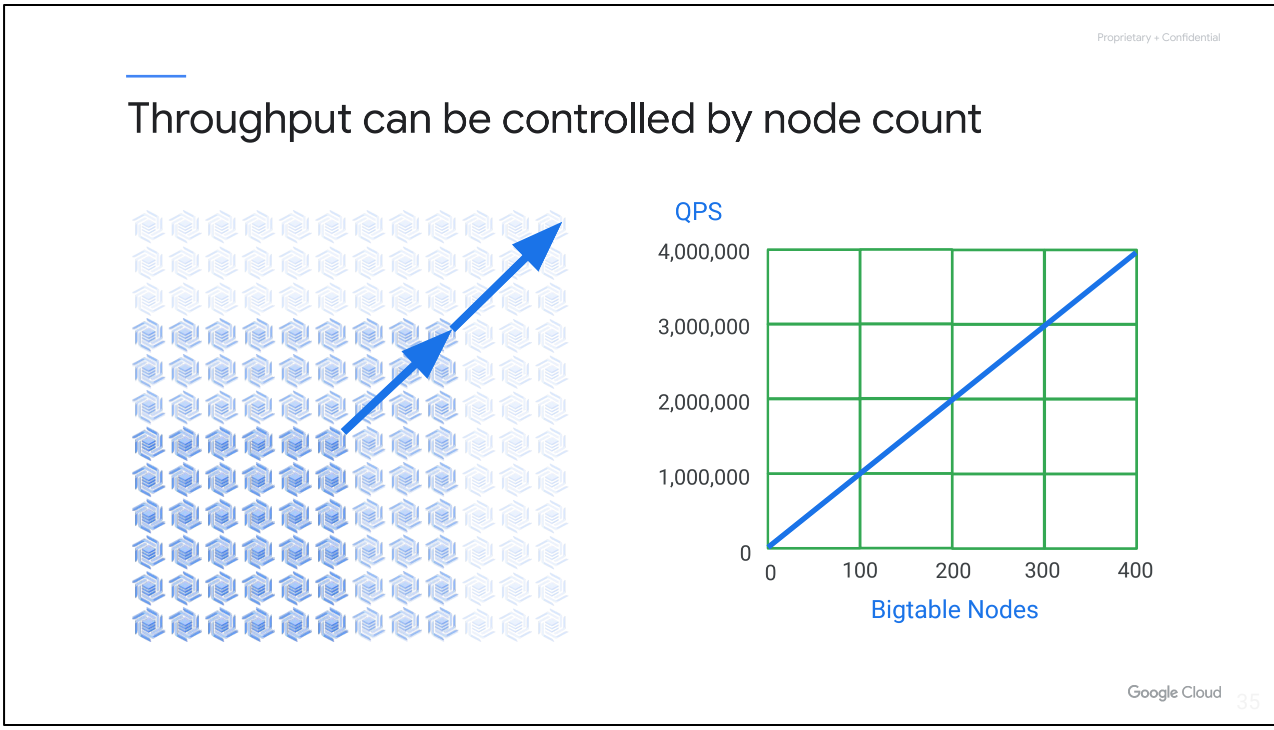
The Cloud Bigtable cluster doesn't have enough nodes. Typically, performance increases linearly with the number of nodes in a cluster. Adding more nodes can therefore improve performance. Use the monitoring tools to check whether a cluster is overloaded.

The Cloud Bigtable cluster was scaled up very recently. While nodes are available in your cluster almost immediately, Cloud Bigtable can take up to 20 minutes under load to optimally distribute cluster workload across the new nodes.

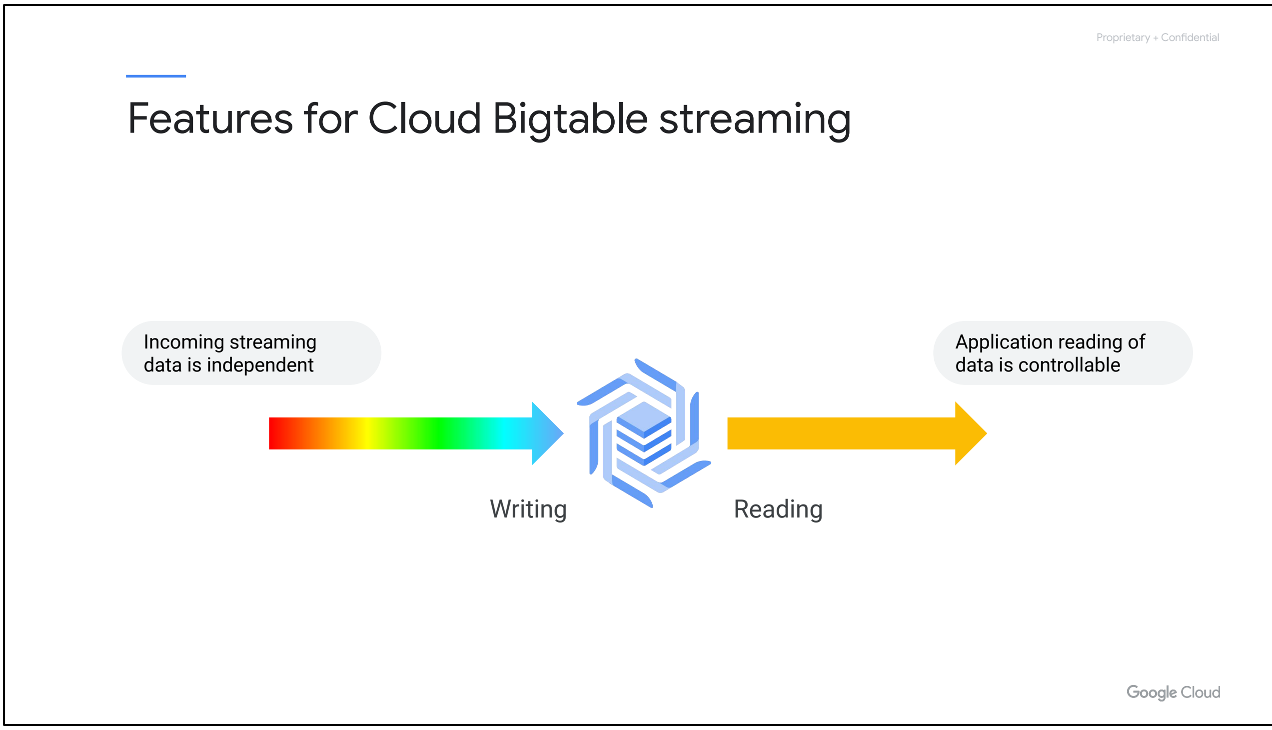
The Cloud Bigtable cluster uses HDD disks. Using HDD disks instead of SSD disks means slower response times and a significantly lower cap on the number of read requests handled per second (500 QPS for HDD disks vs. 10,000 QPS for SSD disks).

There are issues with the network connection. Network issues can reduce throughput and cause reads and writes to take longer than usual. In particular, you'll see issues if your clients are not running in the same zone as your Cloud Bigtable cluster.

Because different workloads can cause performance to vary, you should perform tests with your own workloads to obtain the most accurate benchmarks.

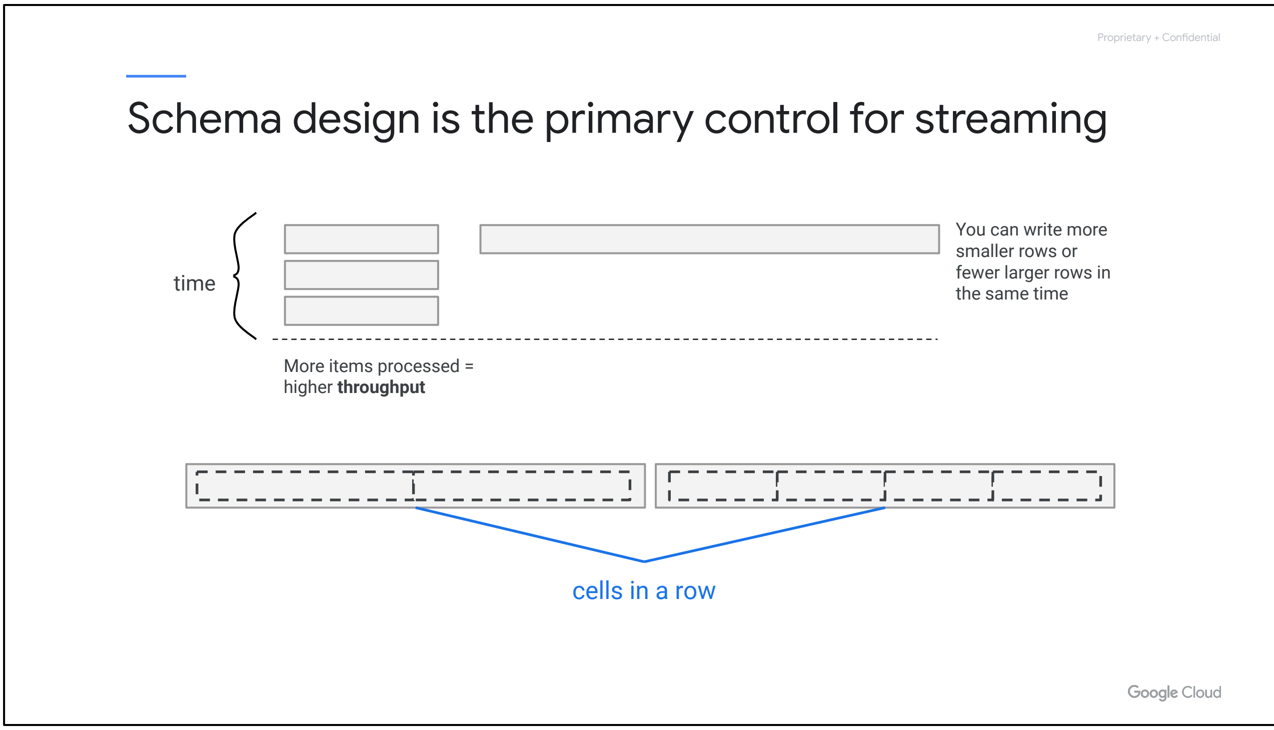


This is an example of some of the numbers that are possible in terms of throughput. With 100 nodes, you can handle 1 million queries per second. Throughput scales linearly welled up into the hundreds of nodes.



There are some things you can do that will improve write performance and read performance.

There are some things you can do that are a trade-off where improving write may cost you on read



A higher throughput means more items are processed in a given amount of time. If you have larger rows, then fewer of them will be processed in the same amount of time. In general, smaller rows offers higher throughput, and therefore is better for streaming performance.

Cloud Bigtable takes time to process cells within a row. So if there are fewer cells within a row, it will generally provide better performance than more cells.

Finally, selecting the right row key is critical. Rows are sorted lexicographically. The goal when optimizing for streaming is to avoid creating hotspots when writing, which would cause Cloud Bigtable to have to split tablets and adjust loads. To accomplish that, you want the data to be as evenly distributed as possible.

https://cloud.google.com/bigtable/docs/performance

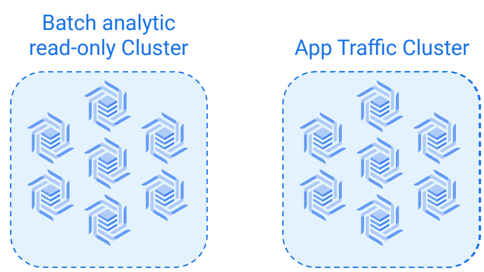
reading delay + processing delay = response time

Use Cloud Bigtable replications to improve availability

Why perform replication?

- Isolate serving applications from batch reads
- Improve availability
- Provide near-real-time backup
- Ensure your data has a global presence

```
gcloud bigtable clusters create CLUSTER_ID \
    --instance=INSTANCE_ID \
    --zone=ZONE \
    [--num-nodes=NUM_NODES] \
    [--storage-type=STORAGE_TYPE]
```



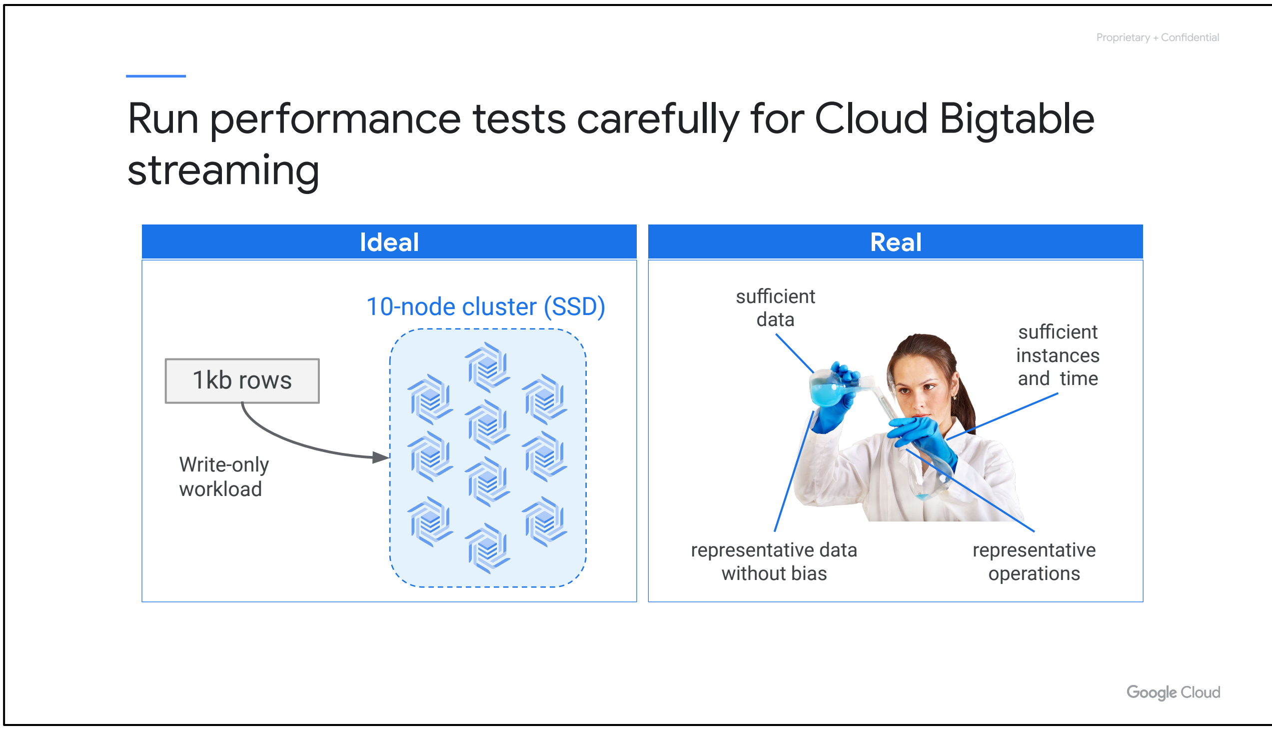
Replication for Cloud Bigtable enables you to increase the availability and durability of your data by copying it across multiple regions or multiple zones within the same region. You can also isolate workloads by routing different types of requests to different clusters.

Simple call **gcloud bigtable clusters create** to create a cluster of Bigtable replicas.

If a Cloud Bigtable cluster becomes unresponsive, replication makes it possible for incoming traffic to fail over to another cluster in the same instance. Failovers can be either manual or automatic, depending on the app profile an application is using and how the app profile is configured.

The ability to create multiple clusters in an instance is valuable for performance, as one can be for writing and the replica cluster exclusively for reading. BT also supports automatic failover for HA

https://cloud.google.com/bigtable/docs/replication-overview



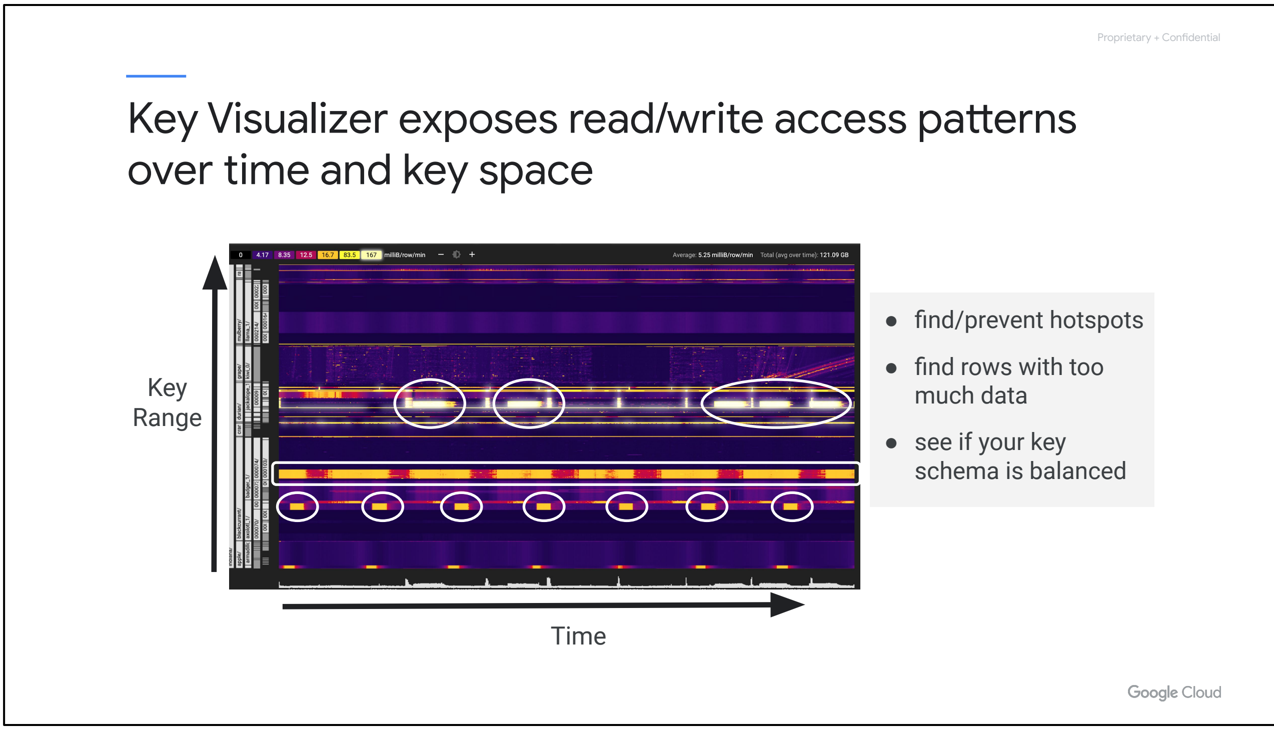
The generalizations, of isolate the write workload, increase number of nodes, and decrease row size and cell size will not apply in all cases. In most circumstances, experimentation is the key to defining the best solution.

A performance estimate is given in the documentation online for write-only workloads. Of course, the purpose of writing data is to eventually read it, so the baseline is an ideal case.

At the time of this writing, a 10-node SSD cluster with 1kb rows and a write-only workload can process 10,000 rows per second at a 6 ms delay. This estimate will be affected by average row size, the balance and timing of reads distracting from writes, and other factors.

You will want to run performance tests with your actual data and application code. You need to run the tests on at least 300 GB of data to get valid results. Also, to get valid results your test needs to perform enough actions over a long enough period of time to give Cloud Bigtable the time and conditions necessary to learn the usage pattern and perform its internal optimizations.

https://cloud.google.com/bigtable/docs/performance



Key Visualizer is a tool that helps you analyze your Cloud Bigtable usage patterns. It generates visual reports for your tables that break down your usage based on the row keys that you access. Key Visualizer automatically generates hourly and daily scans for every table in your instance that meets at least one of the following criteria:

- During the previous 24 hours, the table contained at least 30 GB of data at some point in time.
- During the previous 24 hours, the average of all reads or all writes was at least 10,000 rows per second.

The core of a Key Visualizer scan is the heatmap, which shows the value of a metric over time, broken down into contiguous ranges of row keys. The x-axis of the heatmap represents time, and the y-axis represents row keys. If the metric had a low value for a group of row keys at a point in time, the metric is "cold," and it appears in a dark color. A high value is "hot," and it appears in a bright color; the highest values appear in white.

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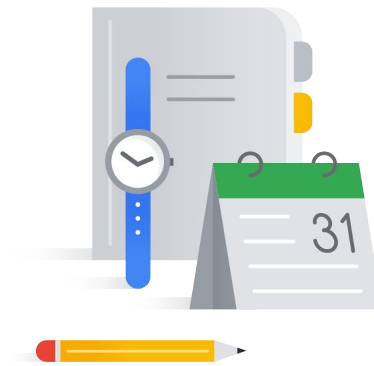

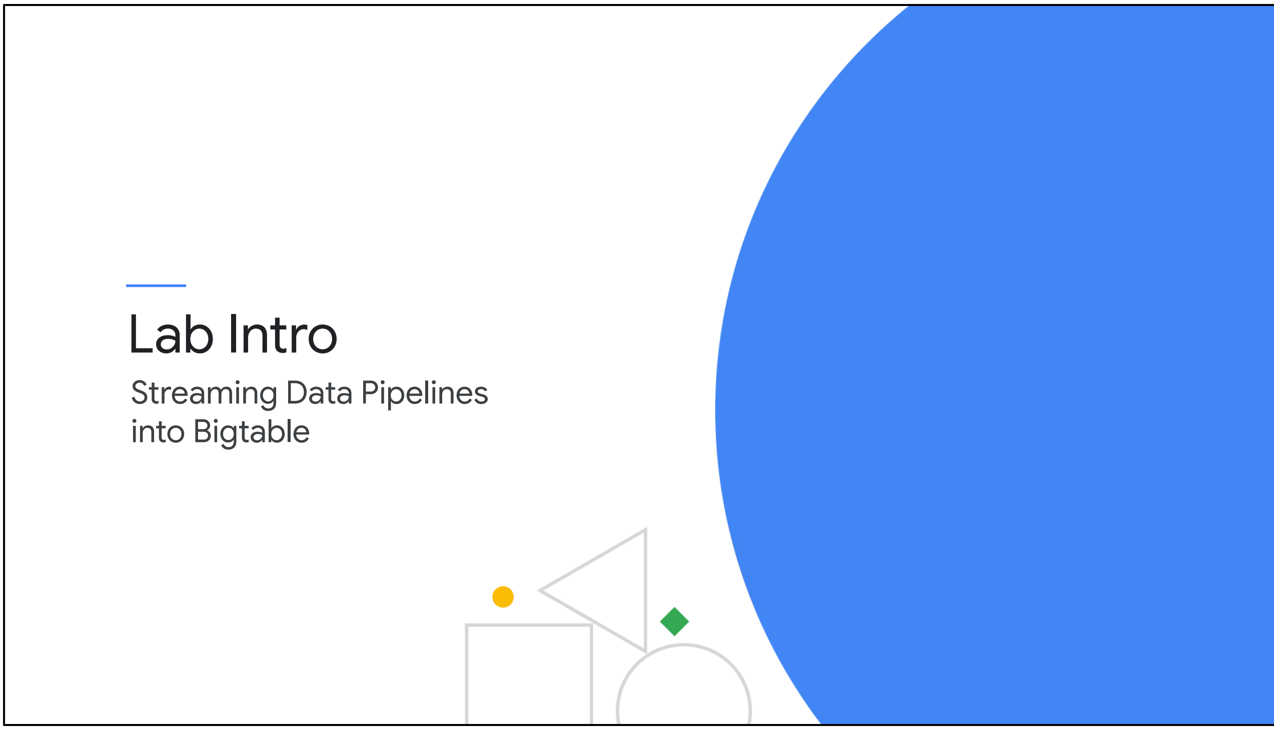

In this lab, you will perform the following tasks:

- Launch Dataflow pipeline to read from Pub/Sub and write into Bigtable.
- Open an HBase shell to query the Bigtable database.