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ANALYTICS ANYWHERE

Presto Training Series, Session 4: Cluster Sizing & Performance Tuning

Try Presto: www.prestosql.io

Dain Sundstrom and Manfred Moser

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Today's Speakers

Manfred Moser

**Developer, author,
and trainer at Starburst**

Manfred is an open source developer and advocate. He is an Apache Maven committer, co-author of the book Presto: The Definitive Guide, and a seasoned trainer and conference presenter. He has trained over 20,000 developers for companies such as Walmart Labs, Sonatype, and Telus.

Dain Sundstrom

**Co-creator of Presto and
CTO at Starburst**

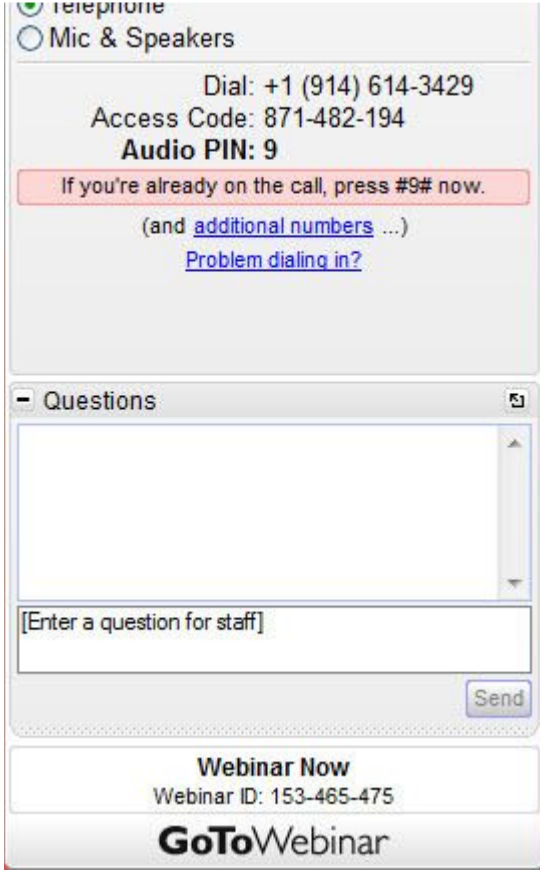
Dain is a co-creator of Presto, co-founder of the Presto Software Foundation, and CTO at Starburst. Prior to Starburst, Dain was a Software Engineer at Facebook, A Software Architect at Proofpoint, founded the Apache Geronimo project, and was one of the original JBoss authors.

Agenda

- Presto overview / review
- Cluster configuration
- Machine sizing
- Five minute break and Q&A
- Workload tuning
- Making queries faster
- Sharing resources
- Q&A

Questions

- Ask any time
- Use the meeting **Questions** feature
- Manfred screens, collects and interjects
- Dedicated Q&A in break and at end



Some advice for attendees

- This is a fast-paced overview – don't try to follow along during class
- Instead focus and pay attention
- Use the demo video after class to setup Presto and CLI locally
- Learn at your own pace
- Use video recording and slides from class as reference to learn more
- Apply skills for your own use case

Presto overview

… probably just a recap for you

What is Presto?

High performance ANSI SQL engine

- SQL support for any connected data source - SQL-on-anything
- Cost-based query optimizer
- Proven horizontal scalability

Open source project

- Very active, large community
- User driven development
- Huge variety of users
- Prestosql.io

Separation of compute and storage

- Scale query processing and data sources independently
- Query storage directly
- No ETL or data integration necessary

Presto everywhere

- No cloud vendor lock-in
- No storage engine vendor lock-in
- No Hadoop distro vendor lock-in
- No database lock in

Why use Presto?

Fastest time-to-insight

- High performance query processing
- Low barrier of entry for users
- Massive scalabilty
- High concurrency
- Direct access to storage

Lower cost

- Reduced need to copy and move data
- Avoid complex data processing
- Scale storage and compute independently
- Only run computes when processing queries
- One data consumption layer

Avoid data lock in

- No more data silos, departmental copies
- Query data with the existing skills and tools - SQL + BI tools
- Query any data source
- Move data
- Create optionality

Cluster sizing and performance tuning

Agenda

- Sizing
  - How big should my cluster be?
  - What machine size should I us?
- Break and Q&A

General strategy

- Create a big cluster
  - Bigger than you think you need
- Verify everything works and is stable
  - Don’t try to stabilize and tune at the same time
- Tune
  - Performance and efficiency are follow up tasks

Presto is unlike most systems

- Query can, and will, use all computers for a single query
  - Most expect one computation per HTTP request
- Presto will use all available resources
  - Memory, CPU, and network allocated
- Presto uses one process per machine
- Presto uses multiple threads for a single query per machine
  - Query data structures are shared across threads for efficiency

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Baseline advice

- Disable OS spilling (JVM is not designed for spilling)
  - Spilling = OS swap memory to disk
  - Java uses a compacting GC, so there aren't *cold* sections to spill
- Disable "runaway" process detector
  - Presto uses **all** available resources
  - Presto should be the only active process on the machine
- Upgrade regularly
  - Improvements all the time - active healthy community
  - Security fixes

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Cluster sizing

CPU and memory

CPU: Process data for the query

- More CPUs == shorter queries (generally)

Memory: data structures required to run the query

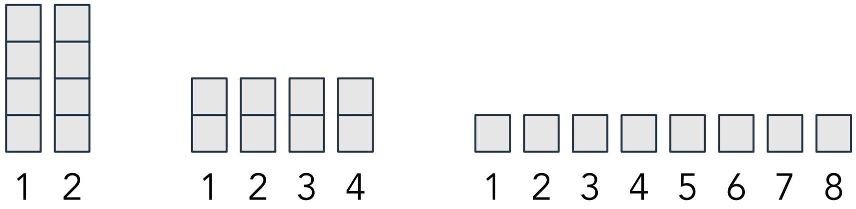
- Memory limit concurrency
- Either you have enough or you don’t

If you have 2x the CPU, you can run 2x the workload with same memory

… just not at the same time.

CPU

- Presto queries requires a certain amount of CPU
  - Run query a few times to see the stable cost
- Generally:
  - Double the CPU and the query takes half the time
  - Run two concurrent copies, and query takes twice as long



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Memory

Memory is needed for JOIN, GROUP BY, ORDER BY, and window functions

- Hash tables and sorting

Peak memory is generally stable

- JOIN: build hash table from one table
- GROUP BY: hash table of group by keys and aggregate values
- ORDER BY: sort the results
- Window: partitioned sorted window frames

Query plan matters

- Join order: smaller table in memory
- Phases: How many joins are in memory

Cluster sizing

- What is the workload?
  - It all *depends!*
- What queries are run?
  - Operations: JOIN, GROUP BY, ORDER BY, window
  - Table sizes
  - Filter selectivity
- Expected latency? (more CPU)
- Expected consistency? (readily available CPU)
- What is the concurrency?
  - Do big memory queries run at the same time?
  - What is the peak?

What if I don’t know?

- Engage a vendor
  - Vendors have expertise in sizing
- Build a big cluster (bigger than you think you need)
  - Limit query memory and runtime
  - Onboard one team at a time
  - Seek out diversity in teams
  - Measure and resize

So we are done!

… with the first steps.

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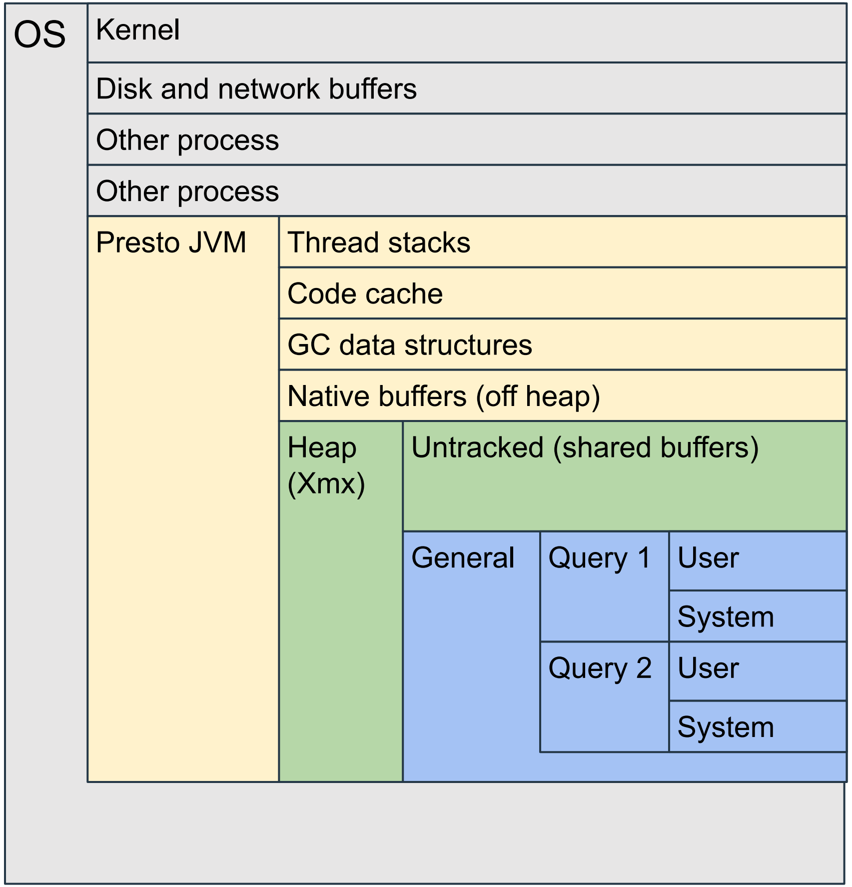
Machine sizing

Memory

- OS has limits
  - Must leave spaces for others
- Other processes
- JVM is not just heap size (Xmx)
- You MUST have free space



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Memory allocations

- How much memory does the OS really have available?
  - Disk/network buffers are used when needed
- Allocate 80% of machine to Java heap (-Xmx)
  - 20% is for OS overhead, JVM overhead, and shared Presto stuff
- Presto max query memory 70% of heap
  - Only memory accountable to a single query (major structures)
  - Does not include temporary or shared data structures

128 GB machine = 100 GB JVM heap = 70 GB query memory

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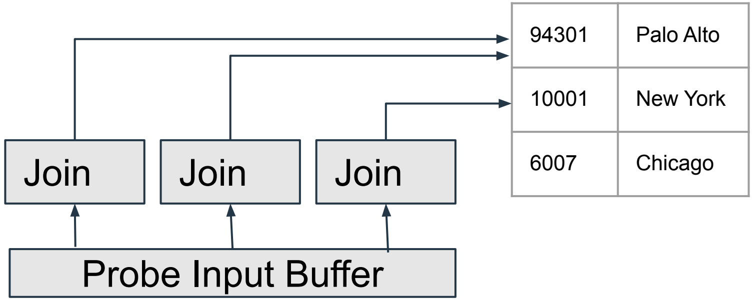
Shared JOIN hash

- JOIN performs lookup into hash table for each row
- Hash table is shared for all JOIN threads
- More CPUs can finish query faster… freeing up the memory!



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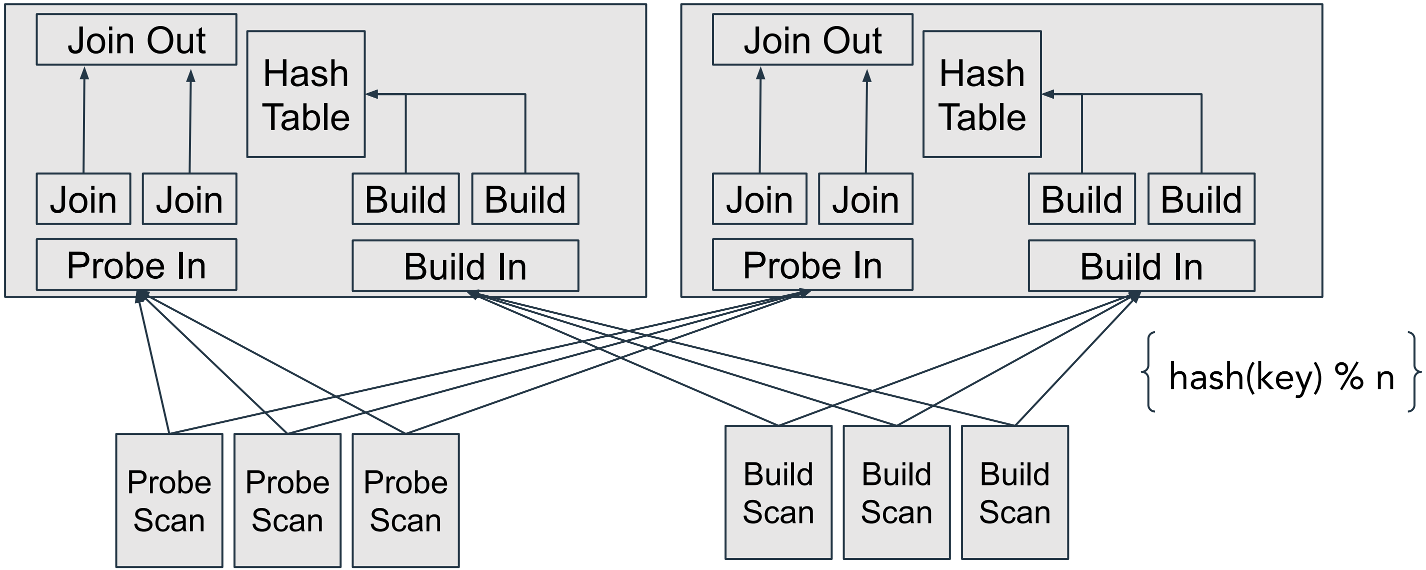
Distributed JOIN



Skew

Each machine has `1/machine_count` keys

```
SELECT * FROM views JOIN user USING (user_id)
SELECT count(*) FROM views GROUP BY user_id
```

Some keys will have more rows than others

Active users see more pages

What happens when one key has half the rows?

User_id 0 is the anonymous user

Skew impact

JOIN build

- Uneven memory distribution across machines
- Likely more output data (depends on matches)

JOIN probe

- Some machine will process way more rows
- Likely more output data (depends on matches)

GROUP BY

- More effective partial aggregations on workers*
- Likely less data to distribute
- Possibly more partials for a machine to process

Use bigger machines

Fewer bigger machines is better than more smaller machines

- Less memory overhead per machine
- Mitigate problems with scheduler
    - Scheduler makes decisions with very little information
- Mitigate the problems from skew
    - More cores to for parallel JOIN
    - More memory for hash table
- Less overhead for broadcast joins
- Less coordination work

What machine type should I use

Start with bigger balanced machines:

Type	vCPU	Cores	Memory GiB	Network Gbps
m5.16xl	64	32	256	20
r5.8xl	32	16	256	10
m5.8xl	32	16	128	10
r5.4xl	16	8	128	5
c5.24xl	96	48	192	25

CPU kind

- AMD: ~10% less $
- Graviton: 64 cores, 256 mem, 25 net for ~20% less $ than m5.16xl

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Additional thoughts

Hash join vs. (sort) merge join

- Hash join loads one table into memory as a hash table and the does a lookup for each row
  - One table in distributed memory
  - Memory cache unfriendly
- Merge join takes two *sorted* tables worked on join key, advance "lower" table until a match is found
  - Stream buffer for each table
  - Memory cache friendly

- What if tables are not sorted?
  - Sort them… which is very expensive
- What about parallelism?

What about spilling?

Spilling can reduce memory… at the cost of latency.

JOIN

- Part of hash table and matching probe rows are written to disk
- Later each part is loaded and probe continues

Aggregation

- Dump partial aggregation results (sorted)
- Merge back together

Spilling: Don't do it

- Disks are slow and SSD is expensive
- CPU cost for read/write occurs (and maybe compress and encrypt)
- Completely changes workload profile when triggers
- Queries become much slower
  - May become IO bound (idle CPUs)
  - May cause workload queueing
  - Users find the system "unreliable" (is it down?)
- Rather than buying disks, buy some more machines
- Change workload to not need spilling
- Scale up cluster before big queries

Small clusters

- A small cluster that needs most resources for a single query
- Workload can easily exceed cluster limits
  - Can be any resource (CPU, memory, network)
  - Bigger clusters get a mix of queries to even out usage
  - Skew kills here
- Can feel unreliable to users
  - Single big query can cause queuing (is it down?)

Sizing summary

Summary

- Don't treat Presto like Hive, Spark, micro-services, ...
- Upgrade regularly - each release has performance improvements
- Determine workload
  - Consider concurrency and workload mix
  - CPU requirements
  - Peak memory required
- Divide required resources into machines
  - Favor fewer bigger machines
- Never spill (not in the OS, not in Presto)

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Plan for growth!

- Plan for growth because Presto is awesome!
  - Presto is easy to use, so people use it more
  - Presto is fast, so people run more queries
  - Presto can access all data, so people will use it for new things
- It is not unusual to see demand double (or triple) every year
- Put this in the budget (don't surprise your boss)

5 minute break

And if you stick around:

- Browse prestosql.io
- Join us on Slack
- Submit questions

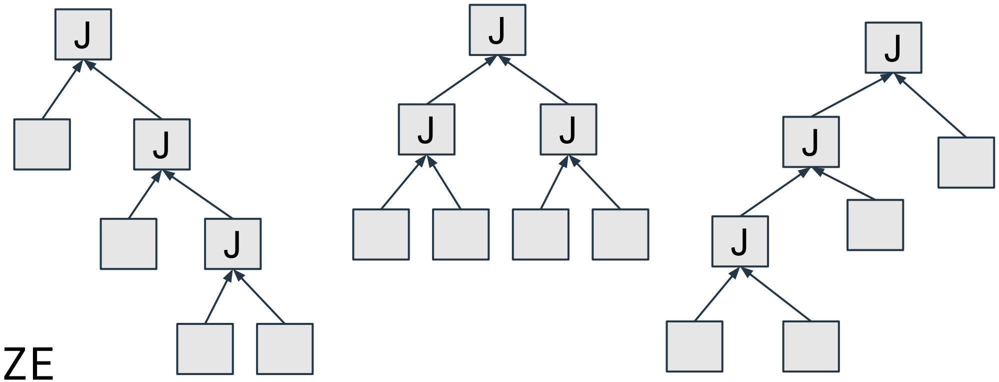
Tuning the workload

Doing more with less

Agenda

- Workload tuning
  - How do I reduce work?
  - How do I make queries faster?
  - How do I share resource?
- Q&A

Query plan



- Watch Martin's training
  - Join order is critical
  - Join type is important
  - Stats are required: `ANALYZE`
- Watch David's advanced SQL training
  - `GROUPING SETS, CUBE, ROLLUP`
  - Top N `row_number` (top by group)
  - Aggregate with filter
    - `count(name) FILTER (WHERE name < 10)`
  - Approximate functions
    - `approx_distinct`
    - `approx_most_frequent`
    - `approx_percentile`
- Train your users!

Precompute

- For a regular or expected queries
  - Commonly dashboards or daily reports
- Easy:
  - Store full precomputed results
  - Copy source tables into a faster store or format (ZSTD ORC)
- Medium:
  - Store expensive subquery
- Hard:
  - Store partial aggregations (for example, daily counts by user)
  - Requires application changes
- Very, very hard:
  - Sample data - any non-trivial query requires deep statistics knowledge

Connectors

- Hive connector is normally biggest CPU user
  - Reading data is parallel distributed across all machines
  - Typically data is highly compressed on network
  - Typically CPU bound, but maybe network bound
- JDBC based connectors
  - MySQL, PostgreSQL, SQL Server, Oracle, Redshift, etc.
  - Single reader per table
  - Starburst has parallel versions of many connectors
  - Typically not compressed on network
  - Expect ~5 MBps per connection
- For others, check the docs

Hive data organization

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Organize the data for the Hive connector

- Presto can take advantage of physical data organization
- Partition
  - Each value written to a different directory (date is common)
- Bucket (a.k.a, hash partitioning)
  - Data is hashed on some columns and divided into N buckets
  - `hash(column) % n`
  - Can be sorted on a column (sorted bucket)
- A table can only be organized one way, but both partitioning and bucketing can be used

Hive partitioning

- One directory per value (e.g., each day in a different directory)
- Filters can be applied directly
  - WHERE ds >= DATE `2020-09-08`
  - WHERE month(ds) = 9
- All values are known
  - Powerful in inference and predicate move around
  - For JOIN, possible matches can be known
- Reduce scan size significantly
- Mostly used for data management (possibly already taken)
- Only apply this to lower cardinality values

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Hive bucketing

- Data is hashed on some columns and divided into N buckets
- Reduces reads for equality filters
    - WHERE x = 42
    - WHERE x in (42, 55, 99)
- One file per bucket per INSERT
- Can reduce scan size significantly
- Planner can take advantage of bucketing for planning
    - Session property `bucket_execution_enabled`
    - Node local GROUP BY or JOIN which removes redistribution costs
- Sorting can help reduce scans for some file formats (more later)
- Only apply this to high cardinality columns

ORC and Parquet

- Use ORC or Parquet… ORC is faster in Presto
- Always compress
  - High compression: ZSTD over ZIP
  - Low compression: LZ4 over Snappy
  - Don't use LZO
- Both are read optimized
  - Writes are expensive in CPU and memory
  - Columns can be read independently
  - Lots of columns (or nested columns) result in small IOs
- Both have min and max per column (and nested columns)
  - Stats are used to skip sections that won't match filters
  - Sorting helps narrow the range

File Size

- File size in Hive is a big deal
- Any file less than 8 MB is considered small
- Small files result in small IOs
  - Object store: increase latency and can get throttled
  - HDFS: disks can run out of IO capacity
- Lots of small files make file listing slow
- Each file becomes a job, which increases scheduling time and cost
- For ORC and Parquet, whole file is loaded into memory
  - No lazy loading, but lazy decode still works

Bad Parquet Files

Be wary of Parquet files written non-Hadoop systems

- A common bug (feature?) is tiny row groups
- Typical size is 4k for a bad row group, when default is 128 MB
- Writing good Parquet files is CPU and memory intensive
- We have seen this from Snowflake and Greenplum
- Use Parquet dump tools to check sizes
- Tiny row groups compress poorly
- Tiny row groups cause bad IO patterns
- Increase network usage, IO latency, and costs

Rewrite table with Presto ORC writer

- Presto ORC writer has optimizations not in Hive ORC
    - Focuses on writing files that are easy to read
- Automatically collects stats
    - This is true for any insert operation in Presto
- Can switch to more efficient ZSTD compression algorithm
- Can change partitioning and bucketing
- Writes well sized files
    - Consider using `scale-writers` option

Making queries faster

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Faster queries

Advice from earlier:

- Tune workload: query plan, approx functions
- Precompute if possible
- Use parallel connectors
- Organize data in Hive
- Use ZSTD ORC (or at least Parquet)
- Watch out for small files

Faster queries

Obvious, but worth asking:

- Are you out of CPU at peak times?
- Is the network saturated at peak times?
- Is your storage IO (HDFS, etc) saturated at peak times?
- Is your HMS or the database out of CPU at peak times?

What to look for in a query

Read the query

- If query is huge, you will need to narrow it down
- Does it have tons of distincts? Use approx distinct
- Does it have tons of unions?
    - Did they use UNION ALL? If not use, UNION ALL
    - Is this just an unrolled grouping set? Use grouping sets
- Are there a million regular expressions or other expensive functions?
- Is there a lot of JSON processing?

What to look for in a query

Run EXPLAIN?

- Do you get what you want?
- Do you have tons of mark distinct? Use approx distinct and union all
- Do the JOINs look right (order and type)? Check for stats

And don't forget to revisit the training material from Martin!

What to look for

- Run EXPLAIN ANALYZE on your query
    - Find the most expensive stage (largest CPU time)
        - Find the most expensive operation

- If table scan (expected):
    - Is it reading too much data?
    - Did pushdown work? Did they forget partition filters?
- If JOIN:
    - Is it an expanding join? Did you want an expanding join?
    - Is the filter really expensive?
- Everything else
    - Check out row count and look for expanding joins
    - Look for very expensive functions
    - Look for raw data parsing (regex, json, etc)

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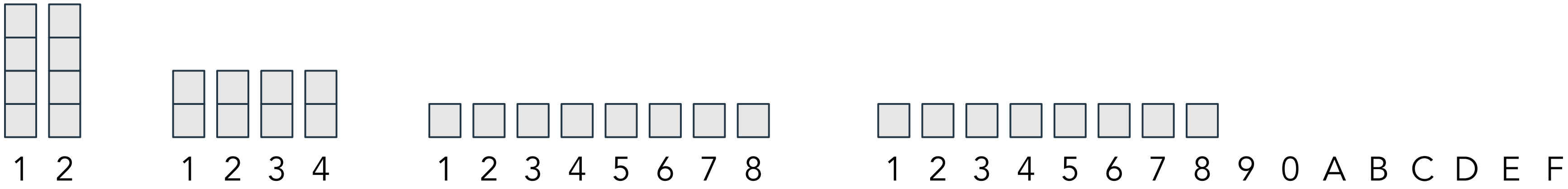
More hardware

- Can I throw more hardware at it?
  - Easiest way is to just try it!
- Most effective at speeding up scans
  - Make sure the connector is parallel
  - Do you have more splits than cores?



Underutilization

- There is plenty of work to do but CPU is idle
- Common causes:
  - Hive metastore is slow
    - Check metastore and database load
    - Check Presto JMX stats for metastore operations (list partitions)
  - File listing is slow
    - Check for tiny files in tables
    - Check HDFS name node is load
    - Check for S3 throttling
  - Reads are slow
    - Check for tiny files in tables
    - Check for network overload
    - Check Presto JMX stats for read performance
  - Skew

Hive caching

- NOT a silver bullet
- Cache Hive metastore data:
  - See `hive.metastore-cache*`
  - Possibly miss new table and partitions
- Cache file listings:
  - See `hive.file-status-cache*`
  - Possibly miss new files
- File data (new):
  - Cached on Presto nodes local disks
  - Uses network between Presto nodes
  - Uses some CPU and memory on Presto nodes
  - Doesn't help much with S3

Sharing resource

Resource groups

- Define resource and concurrency limits (a.k.a., queues)
- Focus on maximizing user happiness
  - Psychology not computer science
- User experience should match expectations
  - Small, fast, trivial queries should run immediately
- People hate waiting in line
  - Allow everyone to run one query
  - Add more hardware at peak times if necessary
- Lean on social dynamics
  - Divide users into groups of people they know
  - Let everyone know those in their group using the resources
  - Let users kill any query in their group

Wrapping up

Presto Training Series

Review our past sessions:

- Advanced SQL in Presto with David - recording available
- Presto Query Processing with Martin - recording available
- Securing Presto with Dain - recording available

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Presto Summit series

Diverse information about Presto and real world usage

- State of Presto - recording available
- Presto as Query Layer at Zuora - recording available
- Presto Migration at Arm Treasure Data - recording available
- Presto for Analytics at Pinterest - recording available

And finally ...

- Learn more from our website and documentation at prestosql.io
- Join us on slack at prestosql.io/slack
- Get a free digital copy of Presto: The Definitive Guide
- Thank you for hanging out with us
- See you next time

Your question
Our answers ...