CS213
Principles of Database Systems(H)

Chapter 13

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13.1 Query Optimizer

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Most contents are from Stéphane Faroult and Yuxuan Ma's slides

ORACLE

1978 Version 1

1985 Version 5

1988 Version 6

SYBASE

1987 Version 1

1989

Microsoft SQL Server

PostgreSQL

1988 Prototype

MySQL

1994 First release

ALL major DBMS products were designed in the 1980s (MySQL is more recent but was based on SQL Server). They CANNOT change their architecture because it would be, business-wise, suicidal for them to require from customers dumping and reloading today's massive databases for a migration. Only incremental improvements are possible.

This is what a $M 1 machine was looking like in the 1980s.

Mid 1980s

VAX 8600 (high-end)

32-bit architecture

Processor, ~10 to 20MHz clock

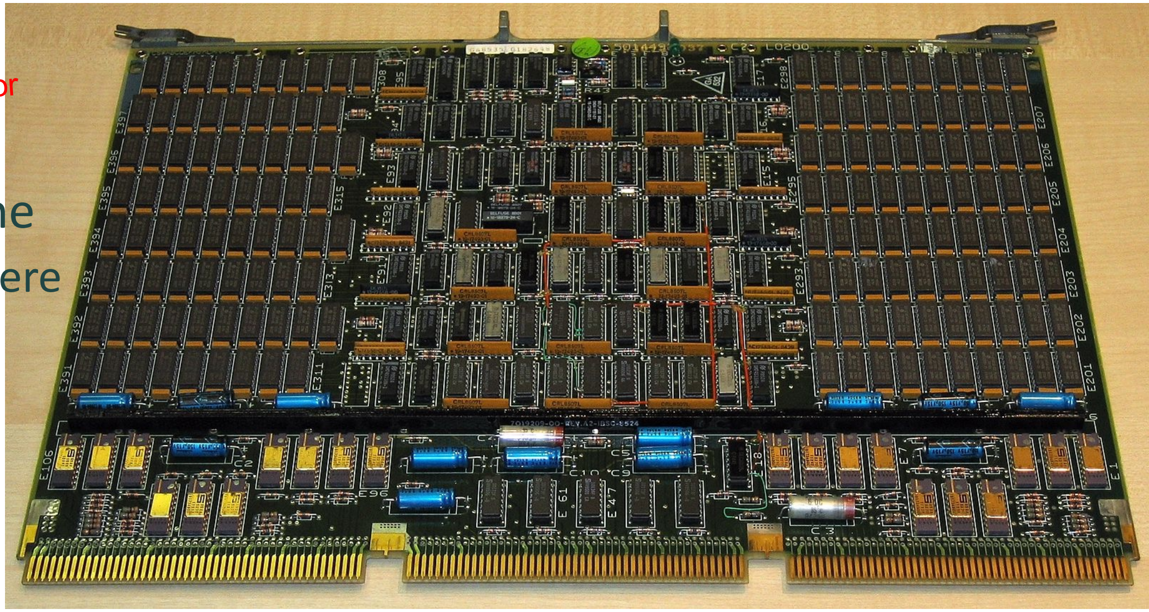
Beginning of multi-processor computers

4 to 256 Mb of memory

Keep in mind that the big DBMS products were designed for this.

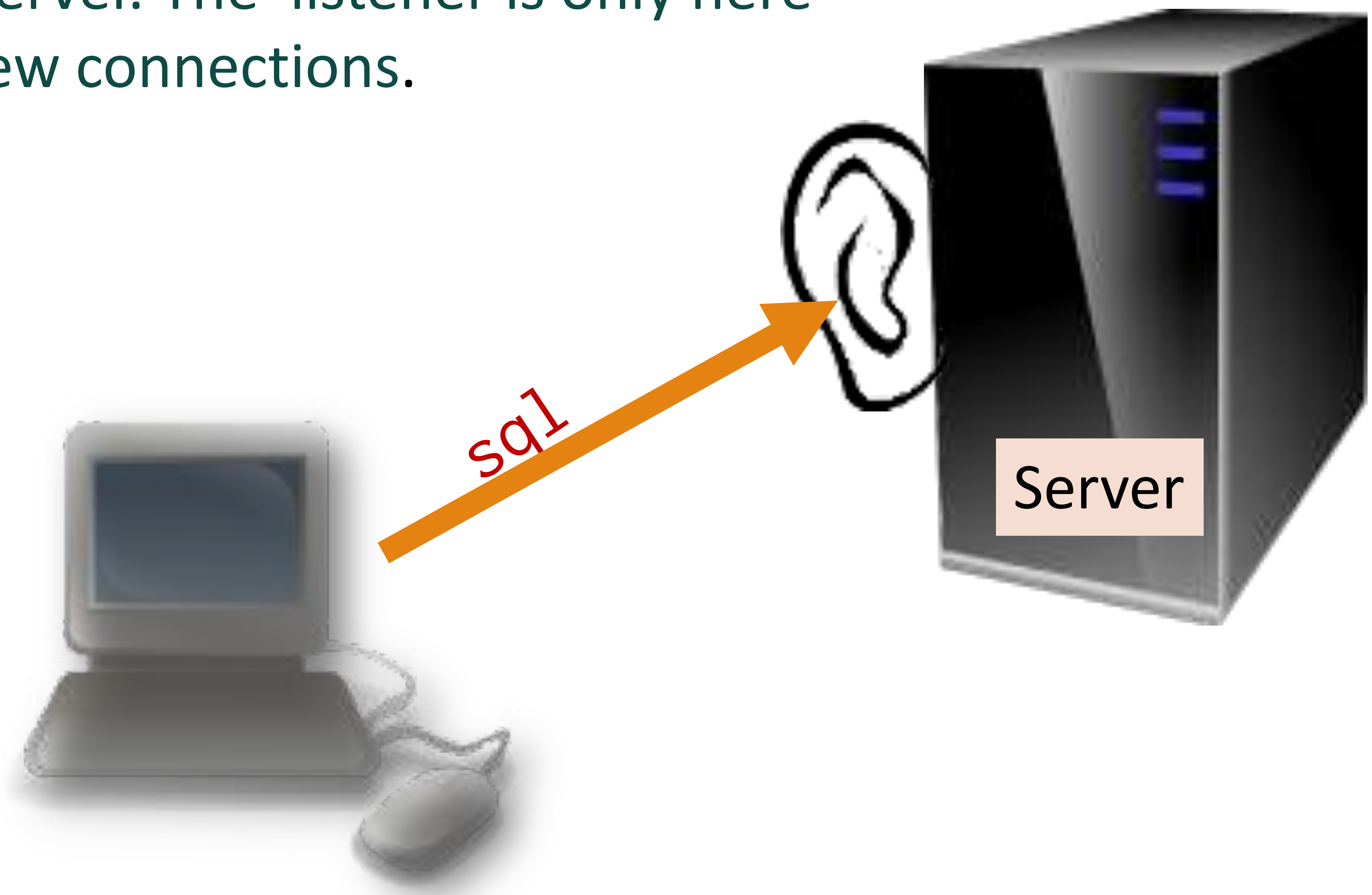
I/Os ~10 to 30 Mb/s

digital

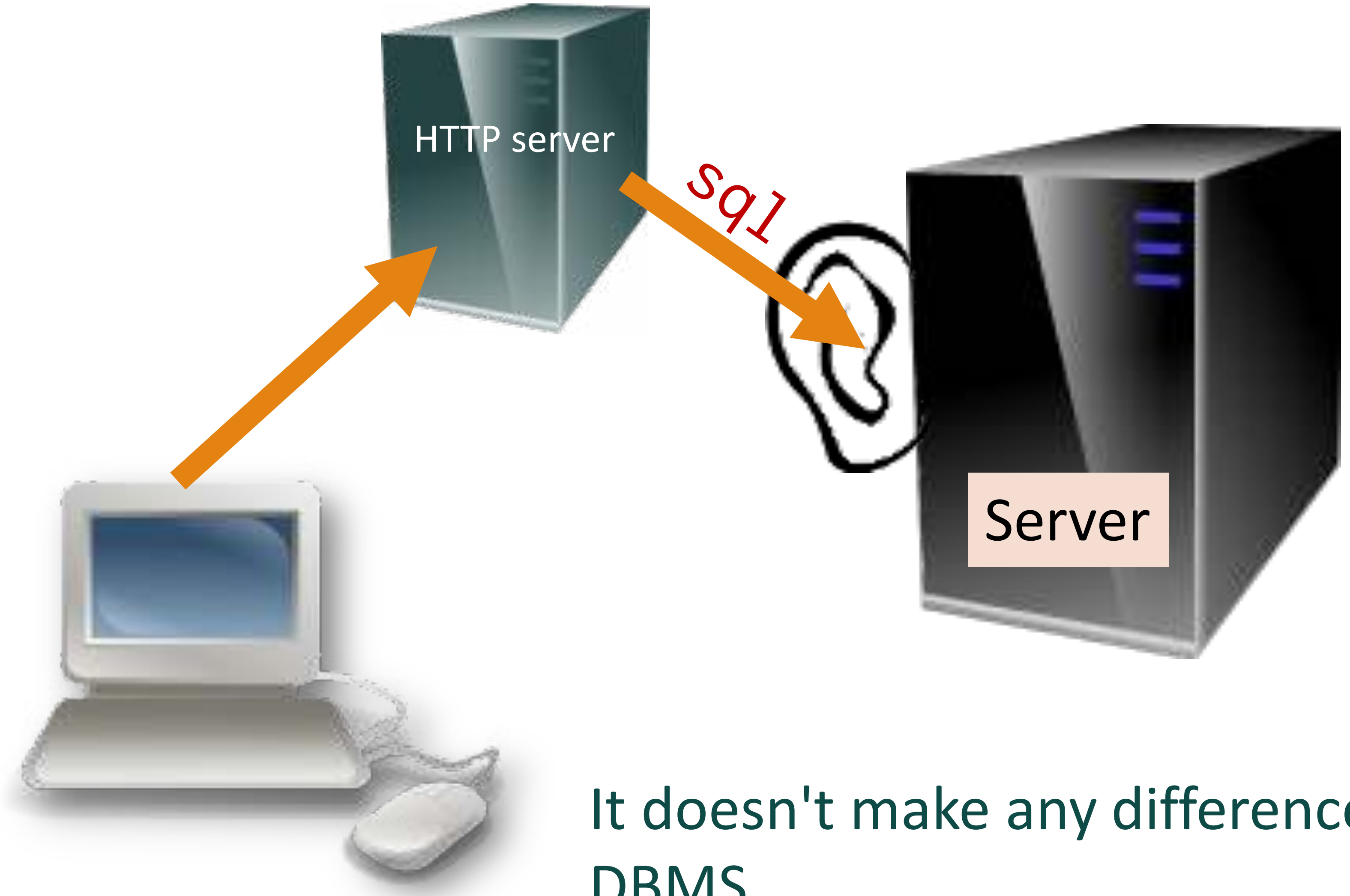


A 4 MB memory board for the VAX 8600

SQL queries will be directly sent to this server. The listener is only here for new connections.



In many cases (HTTP server, application server) the end user isn't directly talking to the DBMS server.



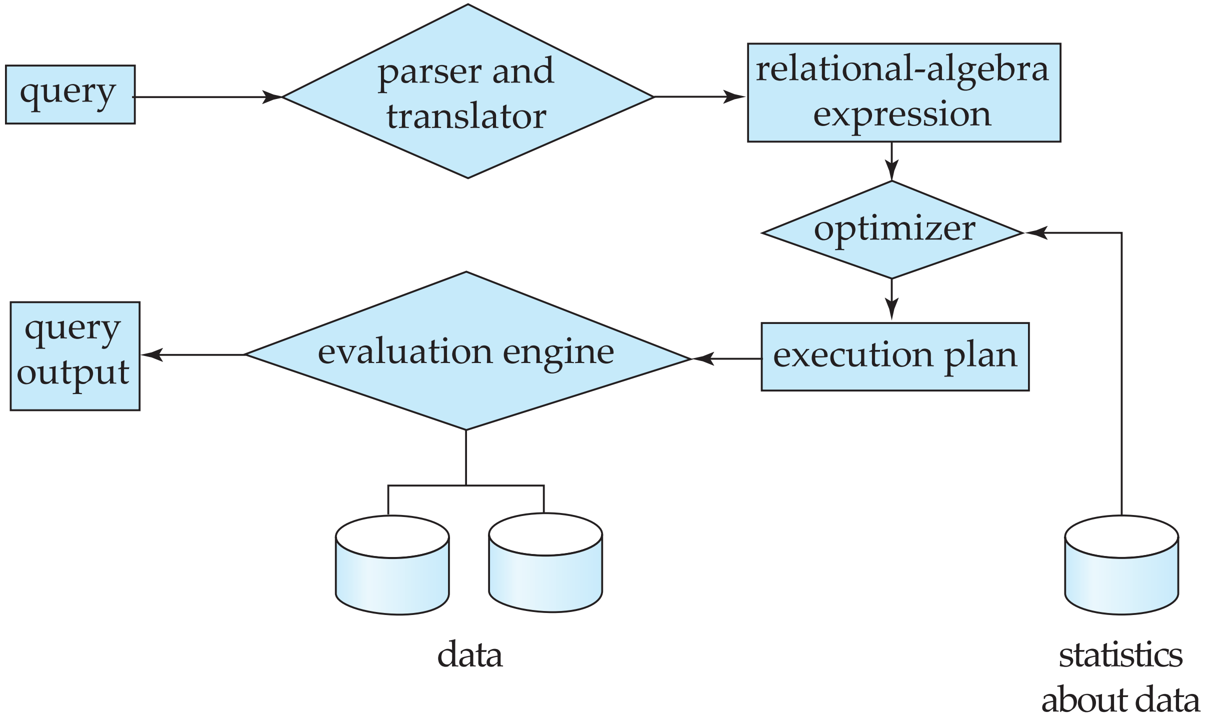
It doesn't make any difference for the DBMS.

Basic Steps in Query Processing

Parsing and Translation

Optimization

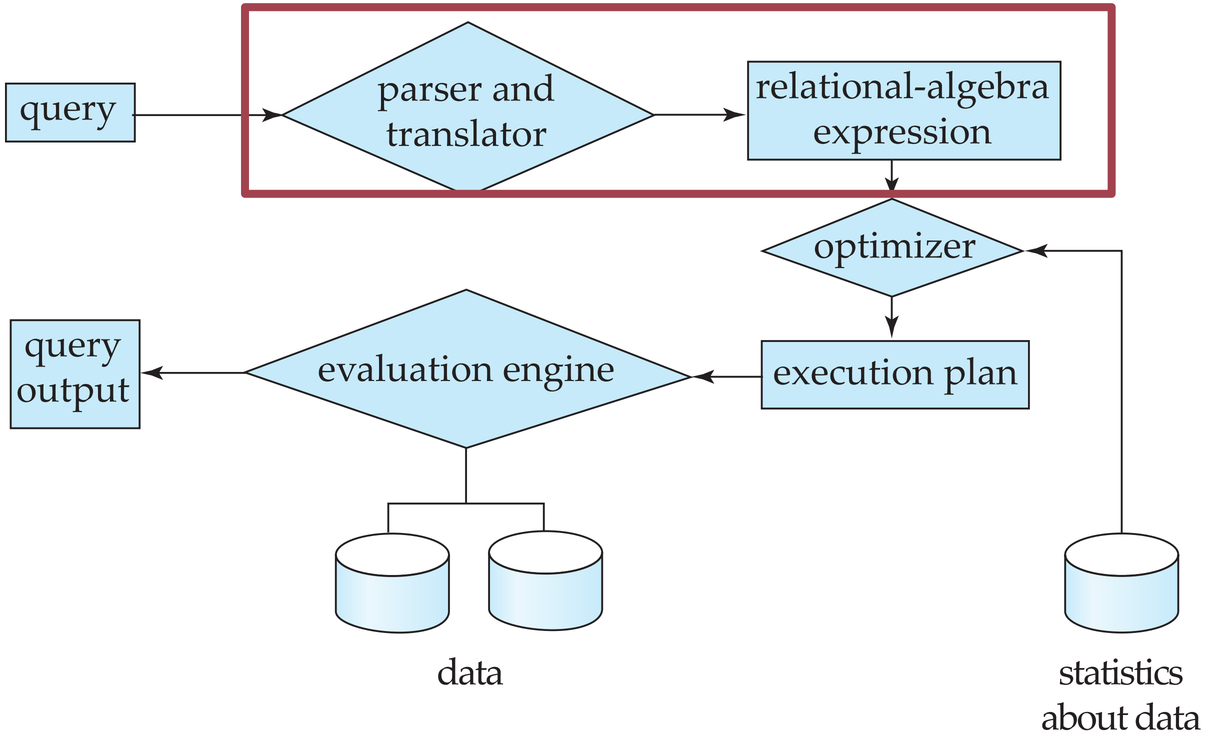
Evaluation



Basic Steps in Query Processing

Parsing and Translation

- Translate the query into its internal form
  - The internal form is then translated into relational algebra
- Parser checks syntax and verifies relations



Basic Steps in Query Processing

Optimization

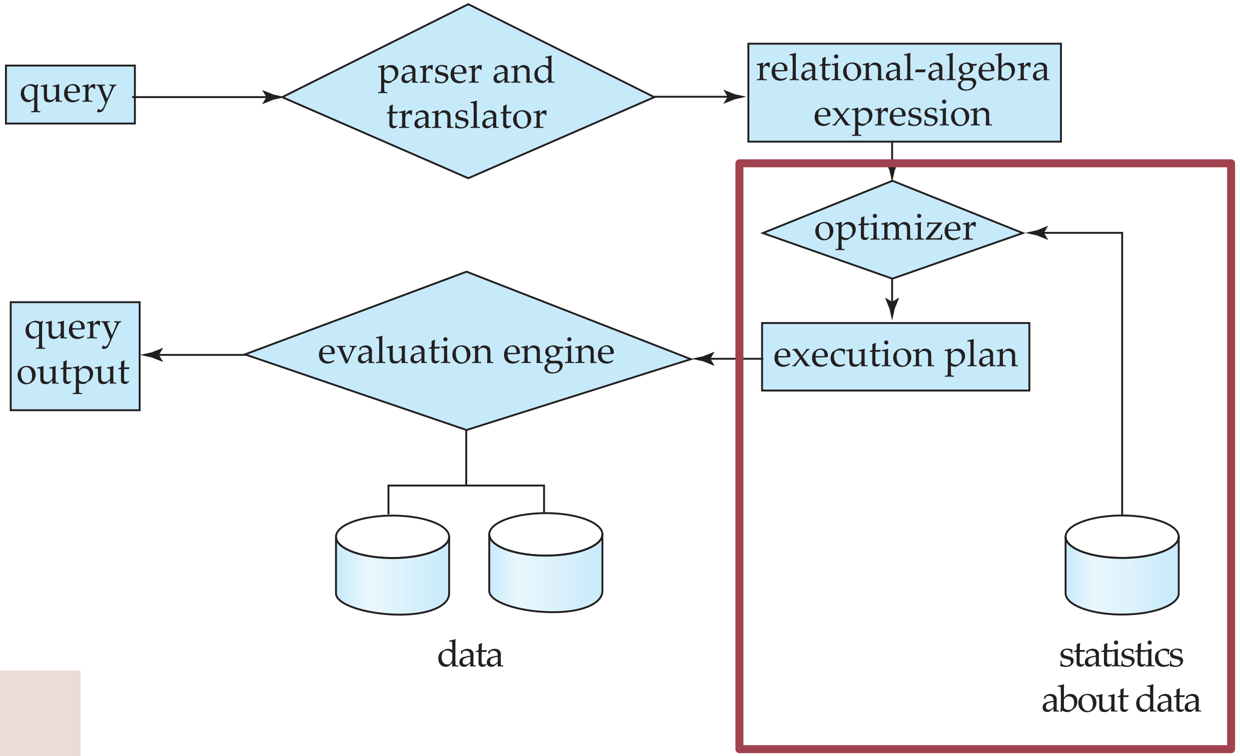
- A relational algebra expression may have many equivalent expressions
- E.g.,

$$\sigma_{salary<75000}(\Pi_{salary}(instructor))$$

is equivalent to

$$\Pi_{salary}(\sigma_{salary<75000}(instructor))$$

But the number of rows involved in the projection operation may be (significantly) smaller in the second expression



Basic Steps in Query Processing

Optimization

- A relational algebra expression may have many equivalent expressions
  - … and each relational algebra operation can be evaluated using one of several different algorithms

- *Correspondingly, a relational-algebra expression can be evaluated in many ways*

Basic Steps in Query Processing

Optimization

- **Evaluation Plan**: Annotated expression specifying detailed evaluation strategy
- E.g.,:
  - Use an index on `salary` to find instructors with `salary<75000`
  - Or perform complete relation scan and discard instructors with `salary<75000`

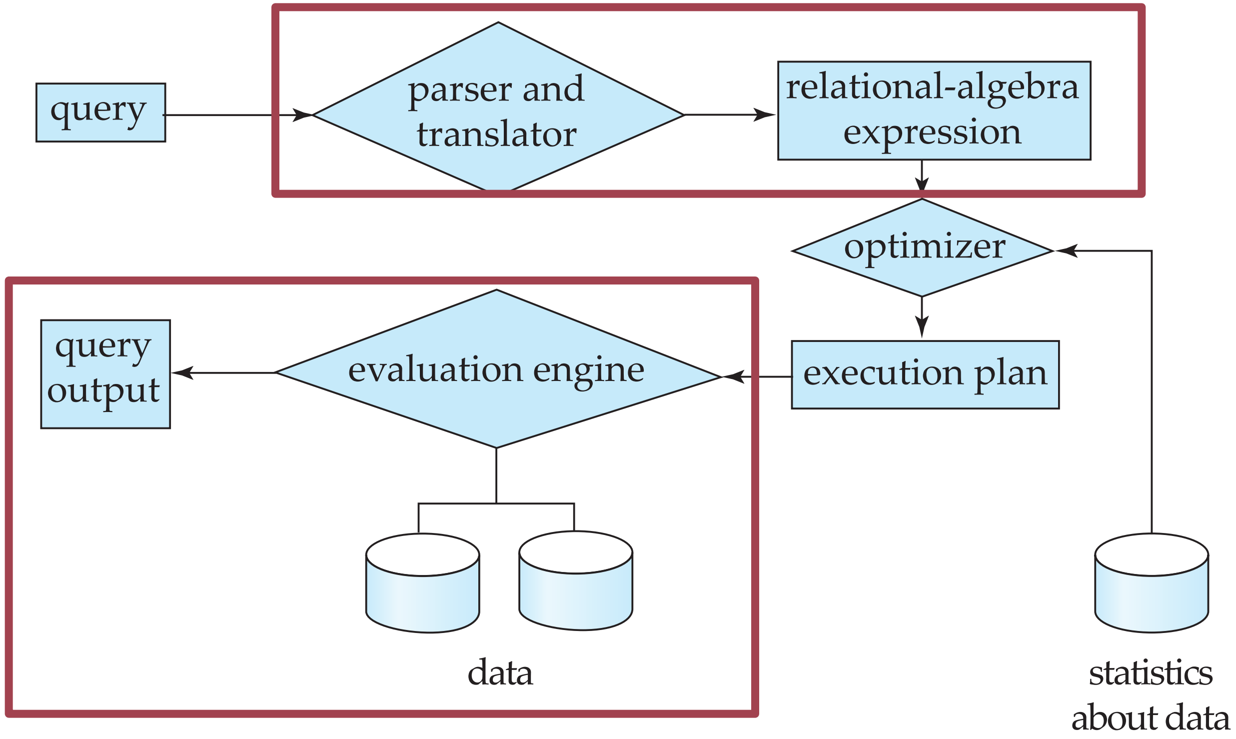
Query Optimization: Choose the one with the lowest cost among all equivalent evaluation plans

- Cost can be estimated using statistical information from the database catalog
  - E.g., Number of tuples in each relation, size of tuples, etc.

Basic Steps in Query Processing

Evaluation

- The query-execution engine takes a query-evaluation plan, executes that plan, and returns the answers to the query



```
select m.title, m.year_released
from movies m
 inner join credits c
 on c.movieid = m.movieid
 inner join people p
 on p.peopleid = c.peopleid
where p.first_name = 'Tim'
 and p.surname = 'Burton'
 and c.credited_as = 'D'
```

Syntax ✓
Do tables exist? ✓
Right to access? ✓
Do columns exist? ✓
Indexes we can use? Best way to access data? ✓

One way to improve efficiency is to keep data dictionary information (meta-data) in a shared cache to avoid additional queries.

shared

meta-data

Kept in memory

```sql
select m.title, m.year_released
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where p.first_name = 'Tim'
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 and c.credited_as = 'D'
```

Syntax ✓

Do tables exist? ✓

Right to access? ✓

Do columns exist? ✓

Indexes we can use? Best way to access data? ✓

Another crucial phase is the one when the optimizer tries to determine the most efficient way to access data.

Kept in memory

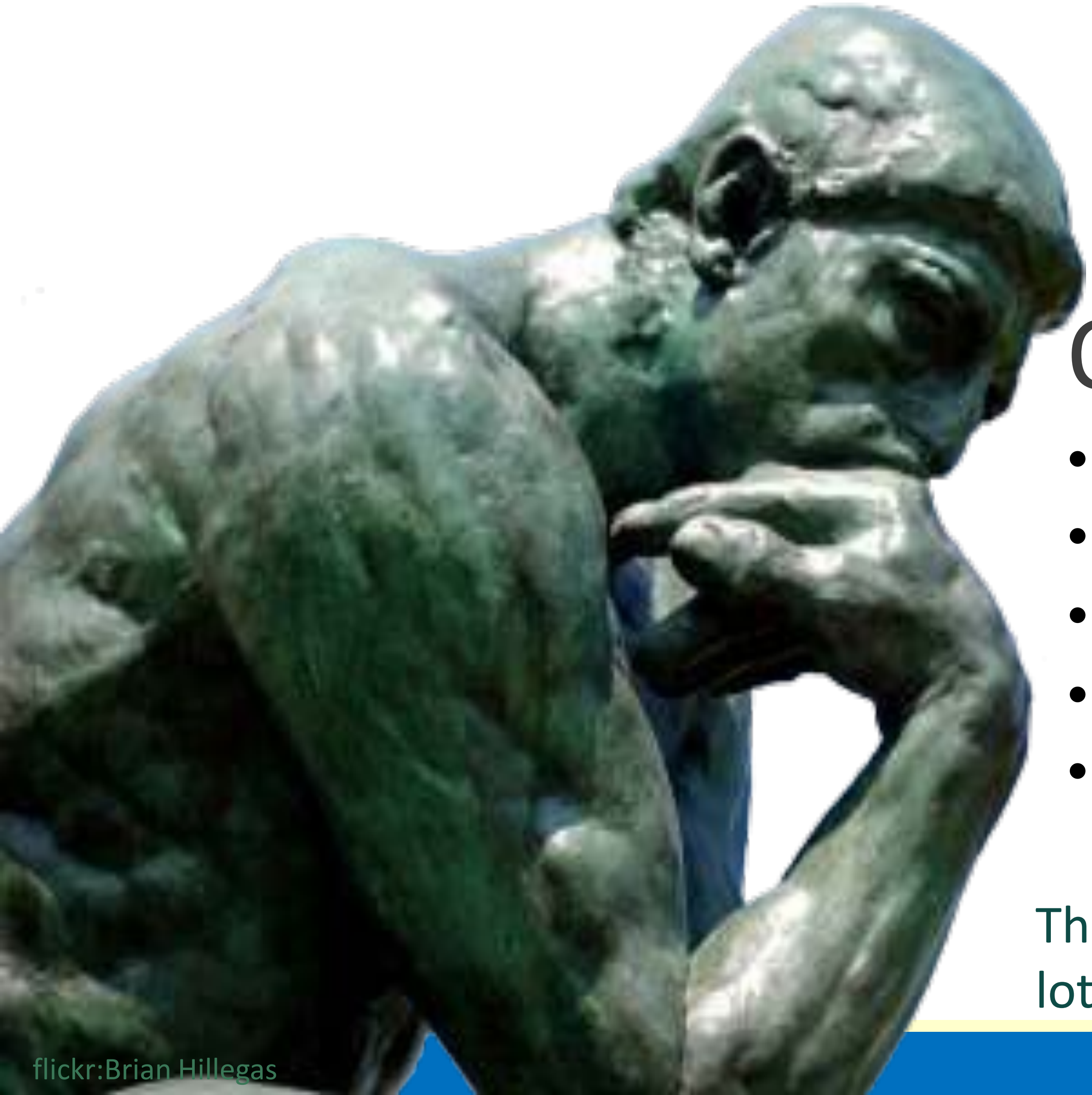
shared

meta-data

QUERY OPTIMIZER

- Logical transforms
- Indexes Volumes Storage
- Hardware performance
- System load
- Settings

The optimizer has to (or can) take into account a lot of factors.



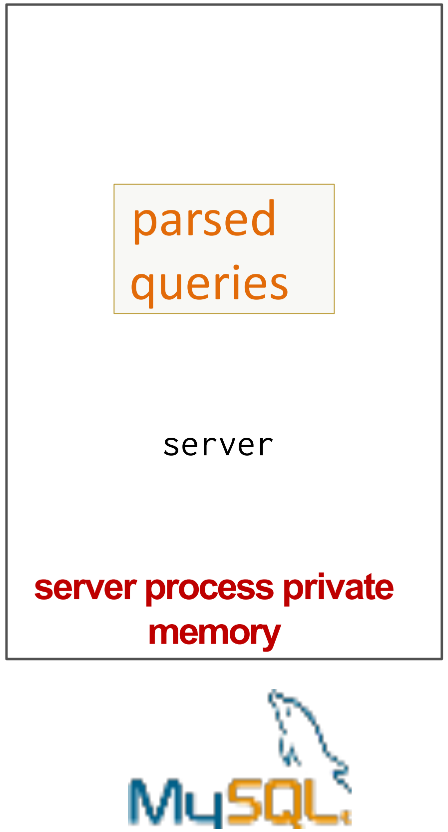
flickr:Brian Hillegas

As a result

PARSING takes time

Let's put it another way: we'd rather not parse exactly the same query many times.

Keep parsed queries in memory



As most applications run exactly the same SQL statements again and again, a DBMS will cache a parsed query for reuse. For MySQL, it will be cached for a session.

Query cache management
LRU

Least Recently Used

Of course we cannot hold in cache zillions of parsed queries. We need to manage the cache, and replace queries that haven't been executed in a while with new ones.

```sql
select m.title, m.year_released
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where p.first_name = 'Tim'
 and p.surname = 'Burton'
 and c.credited_as = 'D'
```

Checksum

We primarily recognize identical queries by computing a text checksum.

+ check tables are same and context identical

Query Compilation

Especially for main-memory database

To avoid the overhead due to interpretation

To compile the query plans into machine code or byte-code

Up to 10x faster

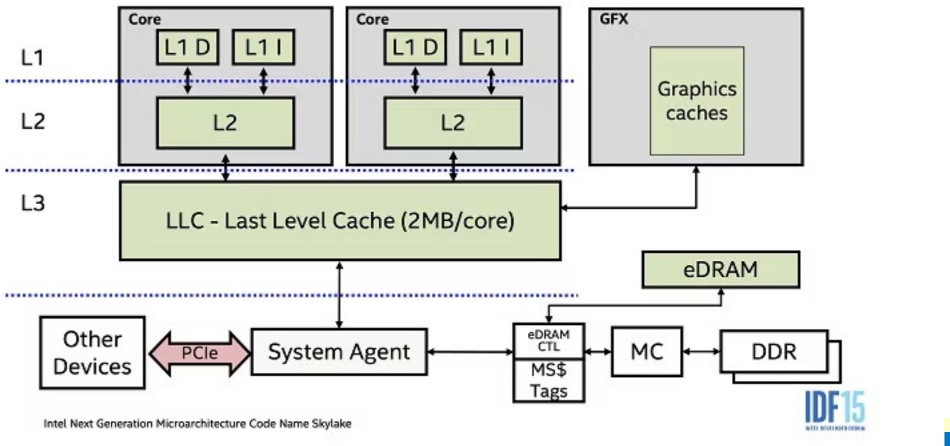
Cache-Conscious Algorithms

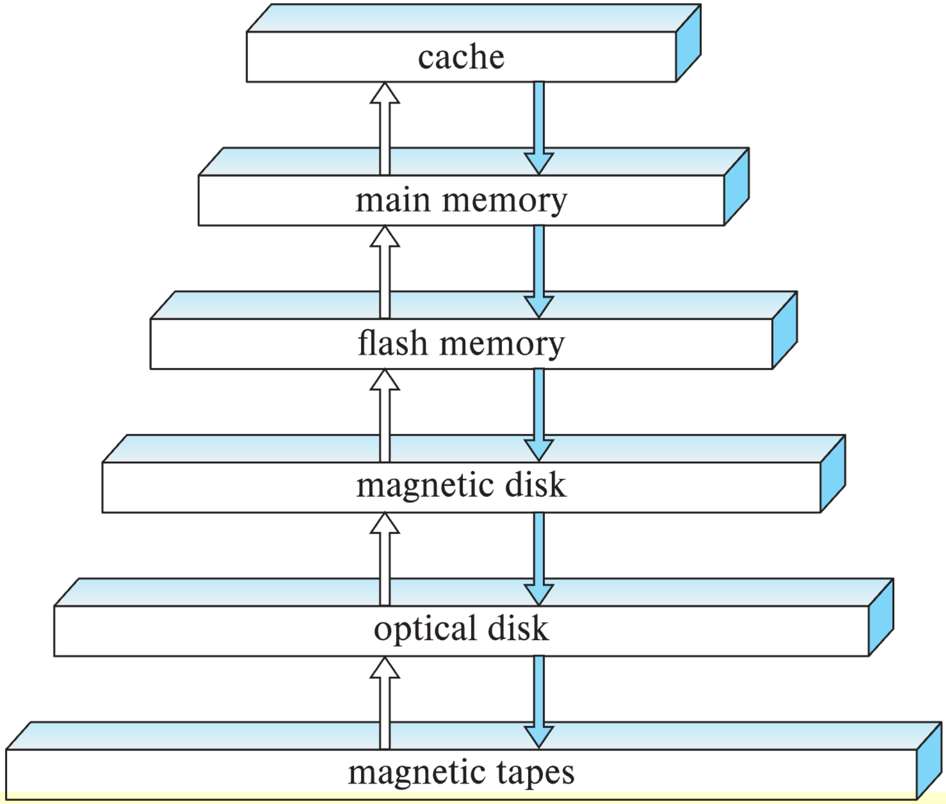
Cache, 100x faster than the main memory

13th Generation Intel® Core™ i9 Processor i9-13900K

- L1: 2.1MB, ~1ns
- L2: 32MB, ~5ns
- L3: 36MB, ~50ns

Main memory: 1-256GB, ~100ns or more





Some Cache-Conscious algorithms

* Put some sorting algorithms in L3

* Hash-join: partitioning the relations into smaller pieces to fit in the cache

* Arranging the attributes in a row consecutively, including some frequently used aggregations

For data larger than the cache, the algorithms should load the data into the cache from memory, and improve the cache hits

There are a lot of things to do for optimization because the resource is limited even we have a powerful server.

13.2 SCALING

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Most contents are from Stéphane Faroult's slides

SCALING UP

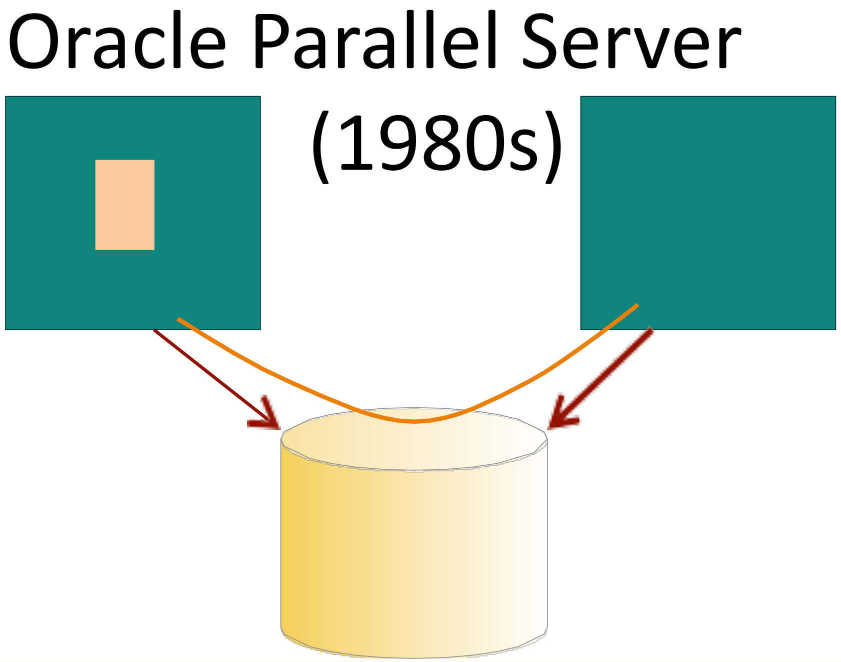
For many years, the answer to a database outgrowing the processing power of its server has been to replace the server by a bigger server.

Having a single server is taking a risk if it breaks, and additionally migrating to another server is disruptive.

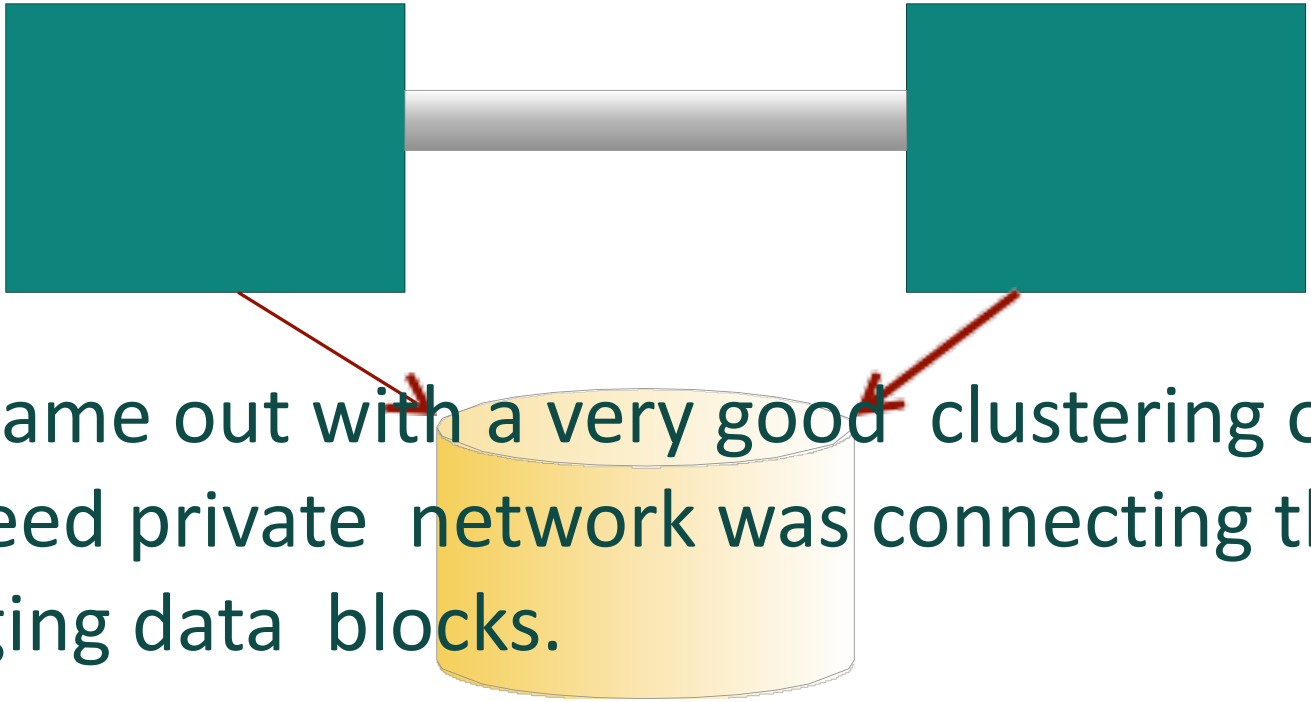
SCALING OUT

This is why people quickly thought of an alternative, adding more servers and making them share the load.

In the 1980s, Oracle tried connecting multiple servers to a single database. Complete disaster when the two servers wanted to modify the same data (or simply when one wanted to see what had just been modified by the other), data had to transit via the files.



Oracle RAC
(2001)
Real Application Clusters



Oracle came out with a very good clustering offer, in which a very-high-speed private network was connecting the servers for exchanging data blocks.

Neil Gunther’s

Universal Law of Computational Scalability

Relative capacity C(*N*) of a computational platform:

$$C(N) = \frac{N}{1 + \alpha\,(N-1) + \beta\,N\,(N-1)}$$

$0 <= \alpha, \beta < 1$

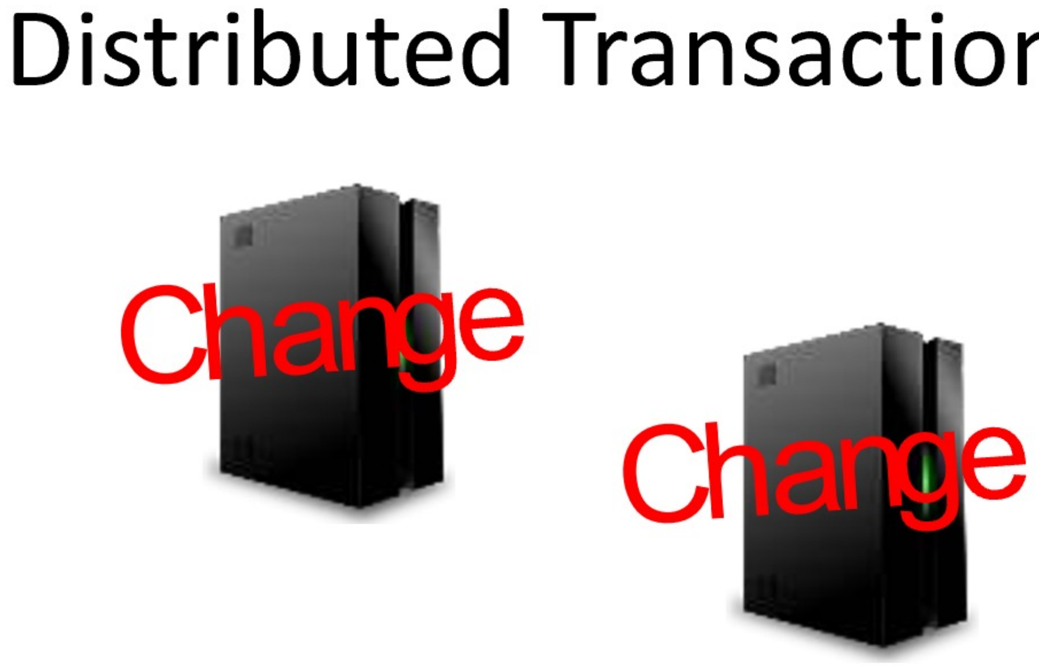
α Level of contention

β Coherency delay (latency for data to become consistent)

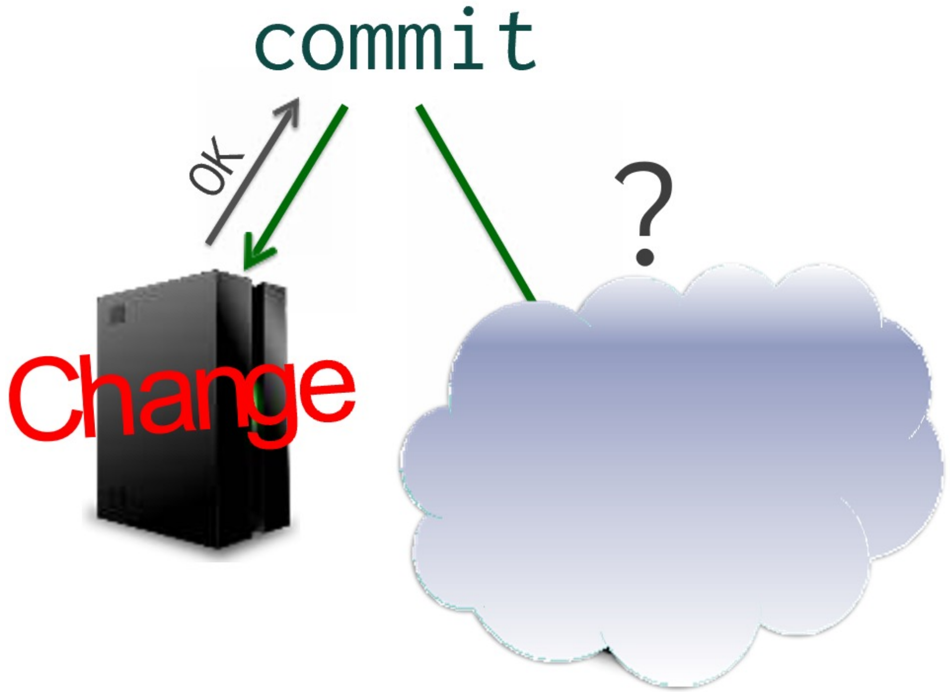
www.perfdynamics.com

The problem with clustering is that it follows a law of diminishing returns: adding a second server will less than double your capacity, and in practice people have clusters of 2, 3 or 4 machines at most (Neil Gunther is a famous Australian consultant/academic specializing on performance)

One big problem is with transactions that involve several servers. Remember that transactions are meant to be atomic operations.



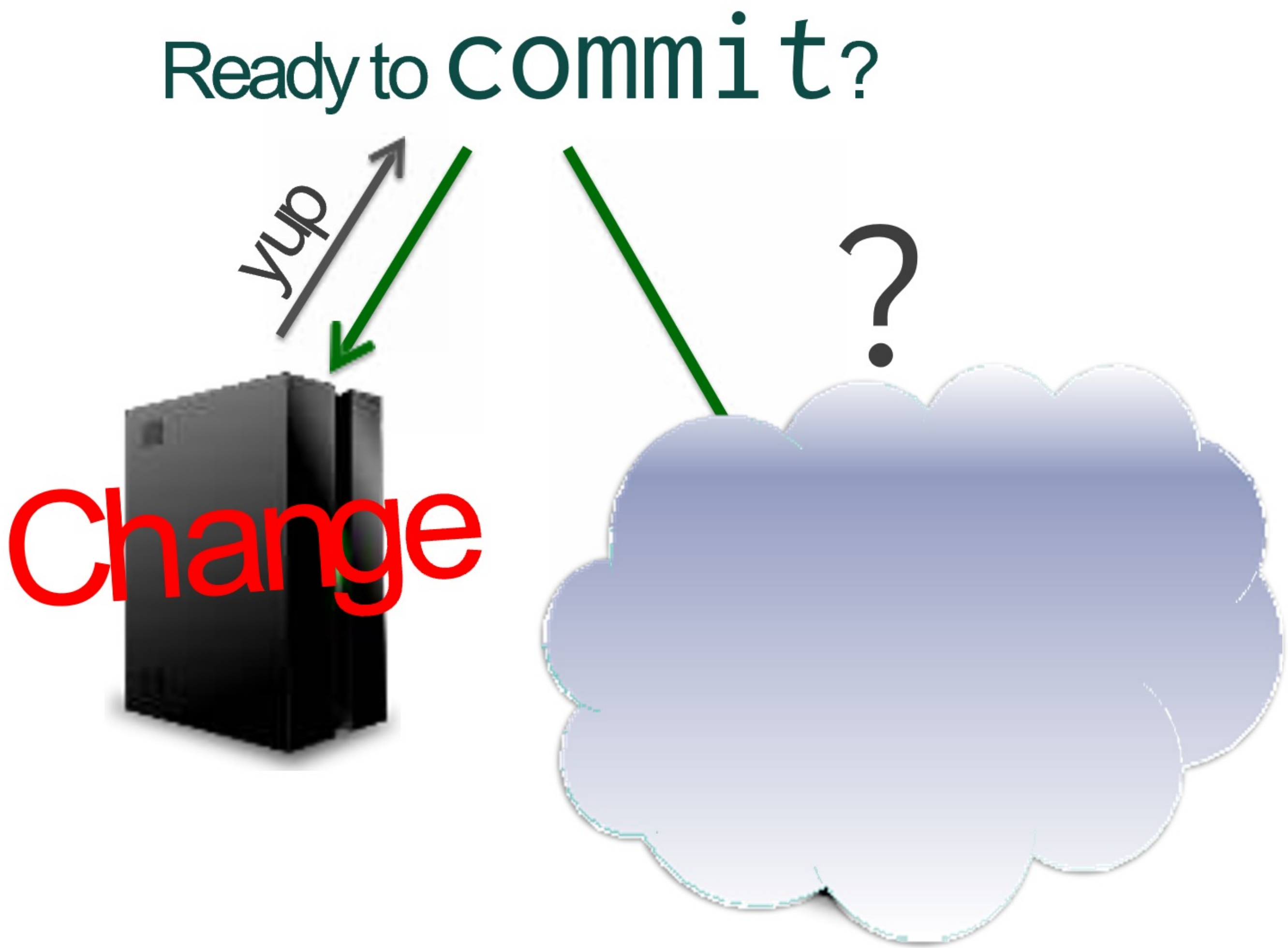
It may happen that when we commit we know for sure it worked on one server, and we get no acknowledgment from the other.



No way to rollback where it's committed, and we don't know if the other node failed before or after having committed the change.

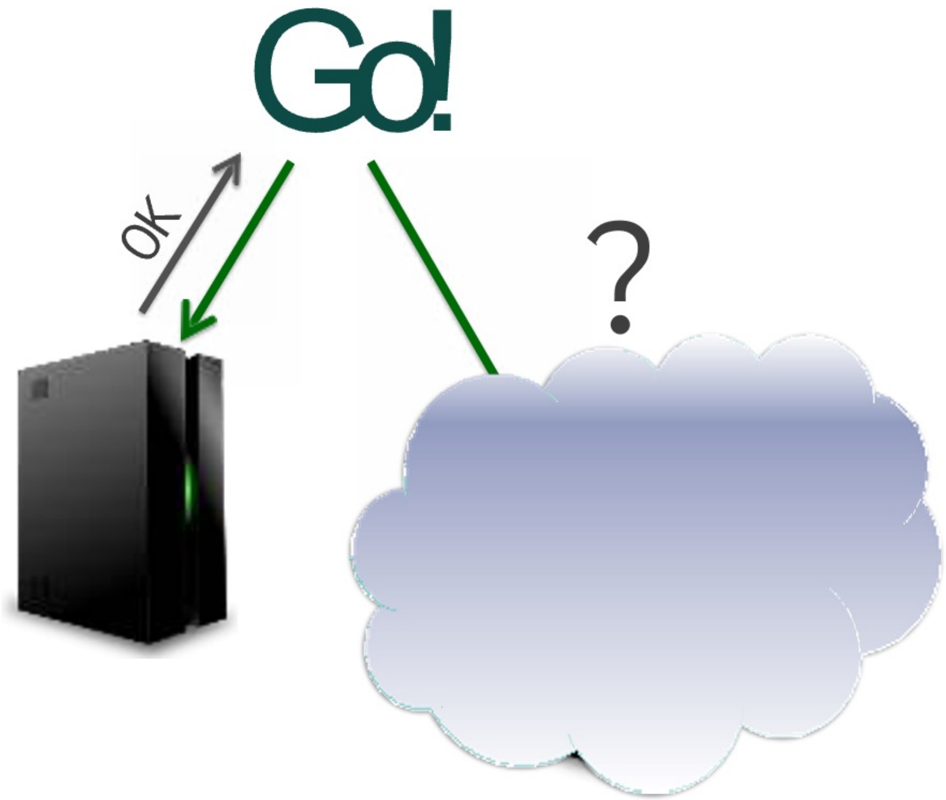
TWO-PHASE COMMIT

One algorithm was devised (a long time ago), called a "two-phase commit".



JUST before committing, you ask to all servers involved whether they are ready to commit. If you don't get an all clear, you can rollback.

Otherwise, you can then (2nd phase) send the official "commit" signal



Odds that something will fail are far lower than with a single-phase commit, but not zero.

Latency

Additionally, you have latency issues. All machines in a cluster may not be sitting next to each other, they may be a few miles apart in different data centers for security reasons (fire, flood ...)

1 KM = 0.0033ms
2000 KM = 6.6ms

Distance from Shenzhen to Beijing

Even if information travels fast, multiplying exchanges (two-phase commit) may become a sensitive issue.