Introduction to Data Management CSE 344

Lecture 22: Parallel Databases

Announcements

- WQ7 due tomorrow (Tuesday), HW7 due on Thursday

- Please fill out the survey and give feedback
  - If possible by 5:30 pm today, but do submit even later.
  - Thanks to all who already did!
  - We will let know what will be covered in the remaining sections a day ahead, and details of the review sessions soon.
- Extra office hours (Sudeepa, cse 344, Thursdays, 4:30-5:30)

- Today: transaction wrap up,
  parallel databases (next four lectures)
  - Traditional, MapReduce+PigLatin

Parallel Computation Today

Two Major Forces Pushing towards Parallel Computing:

- Change in Moore's law
- Cloud computing

Parallel Computation Today

Change in Moore's law* (exponential growth in transistors per chip density) no longer results in increased clock speeds

- Increased hardware performance available only through parallelism
- Think multicore: 4 cores today, perhaps 64 in a few years

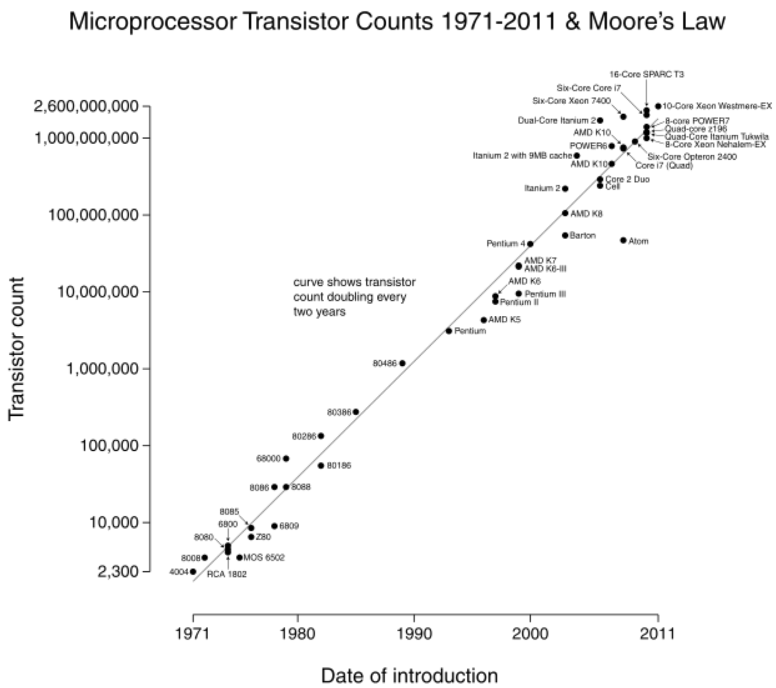


fig. source: wiki

* Moore's law says that the number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years [Intel co-founder Gordon E. Moore described the trend in his 1965 paper and predicted that it will last for at least 10 years]

Parallel Computation Today

2. Cloud computing commoditizes access to large clusters
   - Ten years ago, only Google could afford 1000 servers;
   - Today you can rent this from Amazon Web Services (AWS)

Jeff Dean, SOCC'2010:

Numbers Everyone Should Know

L1 cache reference	0.5 ns
Branch mispredict	5 ns
L2 cache reference	7 ns
Mutex lock/unlock	25 ns
Main memory reference	100 ns
Compress 1K w/cheap compression algorithm	3,000 ns
Send 2K bytes over 1 Gbps network	20,000 ns
Read 1 MB sequentially from memory	250,000 ns
Round trip within same datacenter	500,000 ns
Disk seek	10,000,000 ns
Read 1 MB sequentially from disk	20,000,000 ns
Send packet CA->Netherlands->CA	150,000,000 ns

Google

Memory access

Local access is significantly faster than communication

Communication

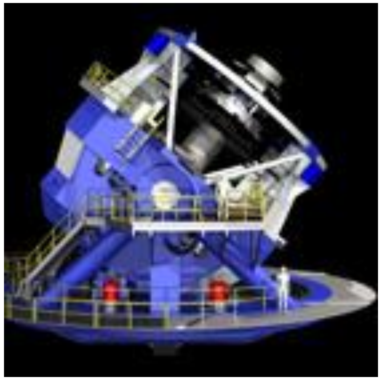
Big Data

- Companies, organizations, scientists have data that is **too big, too fast, and too complex** to be managed without changing tools and processes

Science is Facing a Data Deluge!

- Astronomy: Large Synoptic Survey Telescope LSST: 30TB/night (high-resolution, high-frequency sky surveys)

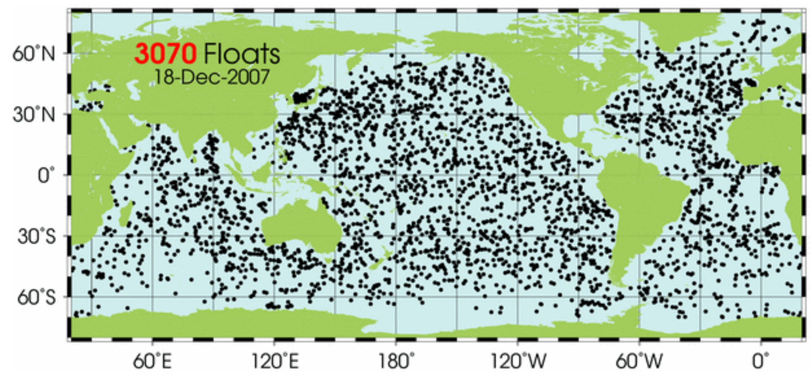
- Physics: Large Hadron Collider 25PB/year

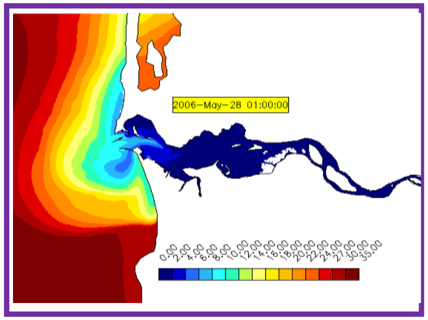


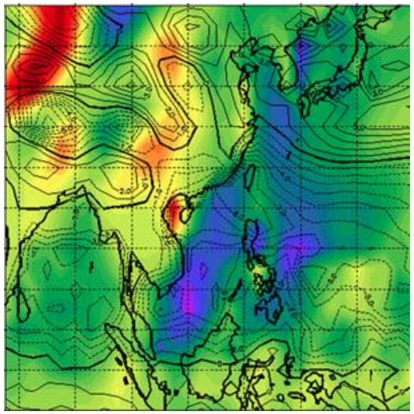
10^9 B = GB, 10^{12}B = TB, 10^{15}B = PB

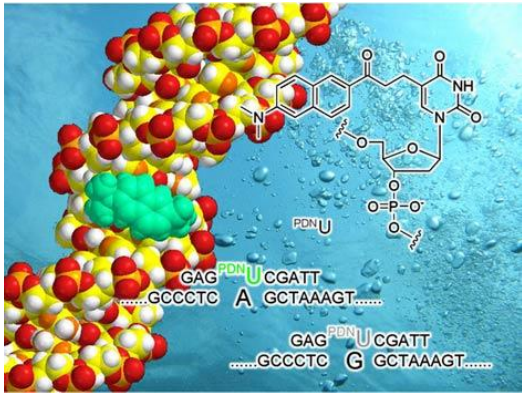
Science is Facing a Data Deluge!

- Biology: lab automation, high-throughput sequencing
- Oceanography: high-resolution models, cheap sensors, satellites
- Medicine: ubiquitous digital records, MRI, ultrasound









Industry is Facing a Data Deluge!

Clickstreams, search logs, network logs, social networking data, RFID data, etc.

- Facebook:
  - 15PB of data in 2010
  - 60TB of new data every day
- Google:
  - In May 2010 processed 946PB of data using MapReduce
- Twitter, Google, Microsoft, Amazon, Walmart, etc.

10^9 B = GB, 10^{12}B = TB, 10^{15}B = PB

Big Data

- Companies, organizations, scientists have data that is **too big, too fast, and too complex** to be managed without changing tools and processes
- 3Vs: Volume, Velocity, Variety
- Relational algebra and SQL are easy to parallelize and parallel DBMSs have already been studied in the 80's!

Data Analytics Companies

As a result, we are seeing an explosion of and a huge success of db analytics companies (massive-scale parallel data processing)

- Greenplum founded in 2003 acquired by EMC in 2010; A parallel shared-nothing DBMS (this lecture)
- Vertica founded in 2005 and acquired by HP in 2011; A parallel, column-store shared-nothing DBMS (see 444 for discussion of column-stores)
- DATAllegro founded in 2003 acquired by Microsoft in 2008; A parallel, shared-nothing DBMS
- Aster Data Systems founded in 2005 acquired by Teradata in 2011; A parallel, shared-nothing, MapReduce-based data processing system (next lecture). SQL on top of MapReduce
- Netezza founded in 2000 and acquired by IBM in 2010. A parallel, shared-nothing DBMS.

Great time to be in the data management, data mining/statistics, or machine learning!

Two Kinds to Parallel Data Processing

- Parallel databases, developed starting with the 80s (this lecture)
  - OLTP (Online Transaction Processing)
  - OLAP (Online Analytic Processing, or Decision Support)

- MapReduce, first developed by Google, published in 2004 (next lecture)
  - Only for Decision Support Queries

Today we see convergence of the two approaches (Greenplum,Dremmel)

http://technet.microsoft.com/en-us/library/aa933056%28v=sql.80%29.aspx

Parallel DBMSs

- Goal
  - Improve performance by executing multiple operations in parallel
- Key benefit
  - Cheaper to scale than relying on a single increasingly more powerful processor
- Key challenge
  - Ensure overhead and contention do not kill performance

Performance Metrics for Parallel DBMSs

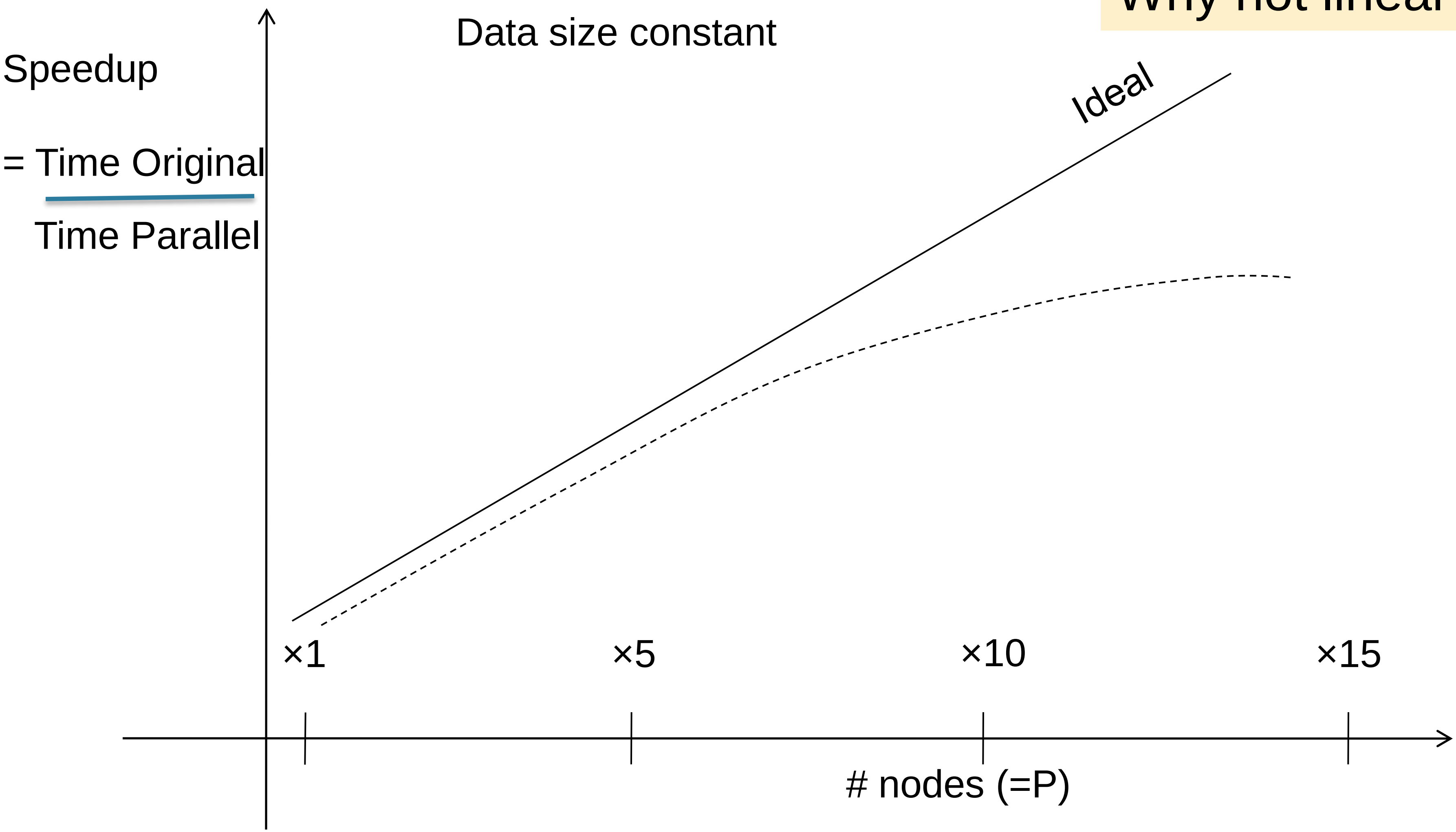
P = the number of nodes (processors, computers)

- Speedup:
  - More nodes, same data ➔ higher speed
- Scaleup:
  - More nodes, more data ➔ same speed

- OLTP: "Speed" = transactions per second (TPS)
- Decision Support: "Speed" = query time

Linear v.s. Non-linear Speedup

Why not linear?



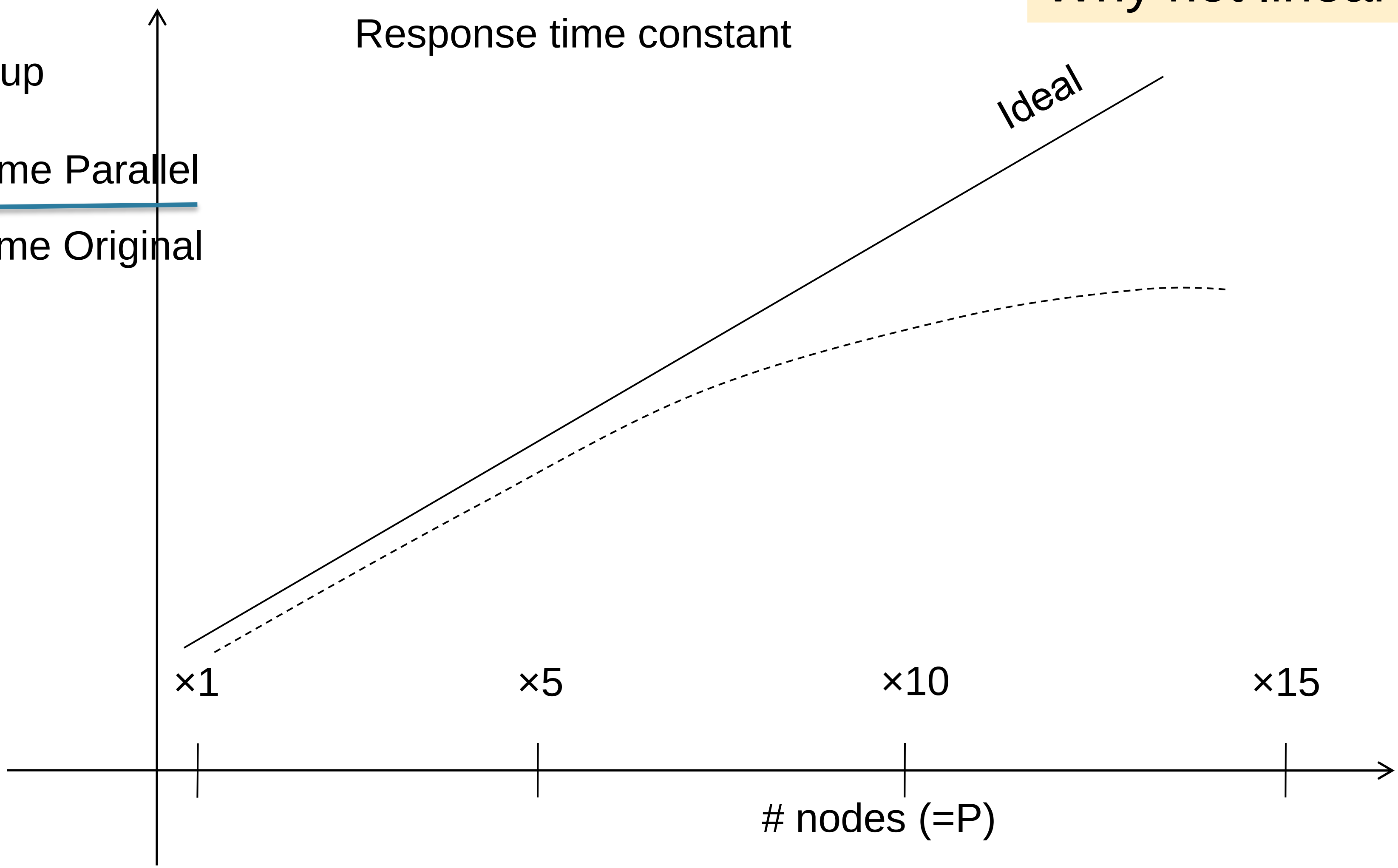
Linear v.s. Non-linear Scaleup

Why not linear?

Response time constant

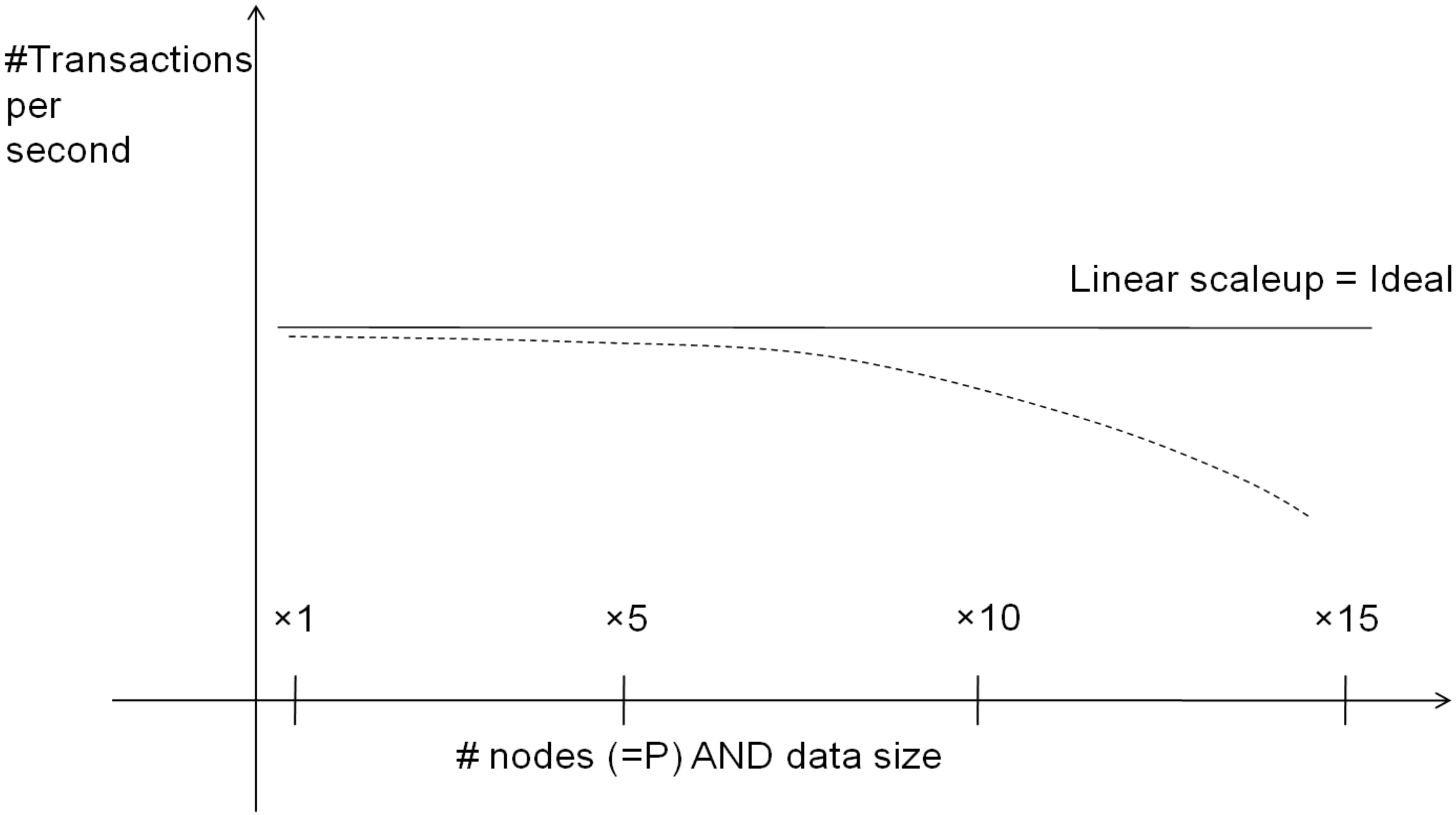
Speedup

$$= \frac{\text{Volume Parallel}}{\text{Volume Original}}$$



Linear v.s. Non-linear Scaleup (alternative plot)

Why not linear?



Challenges to Linear Speedup and Scaleup

- Startup cost
  - Cost of starting an operation on many nodes
- Interference
  - Contention for resources between nodes
- Skew
  - Slowest node becomes the bottleneck

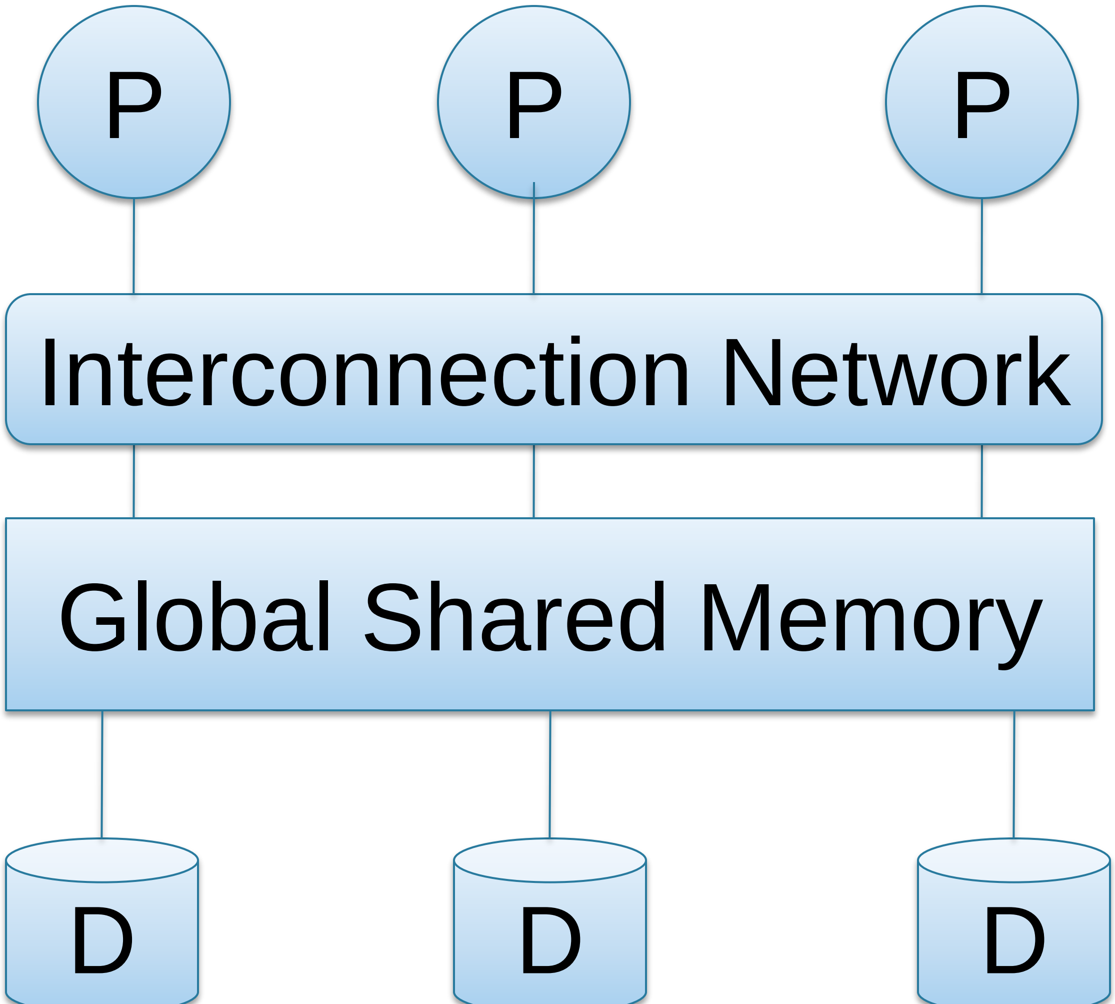
Architectures for Parallel Databases

- Shared memory

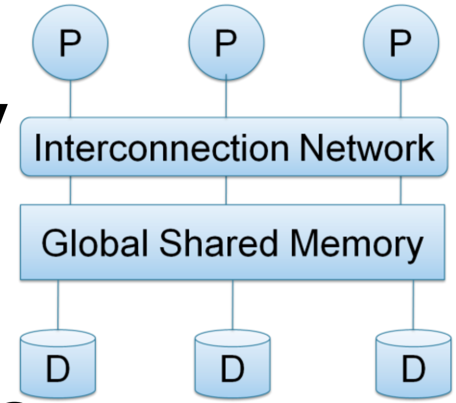
- Shared disk

- Shared nothing

Shared Memory



Shared Memory

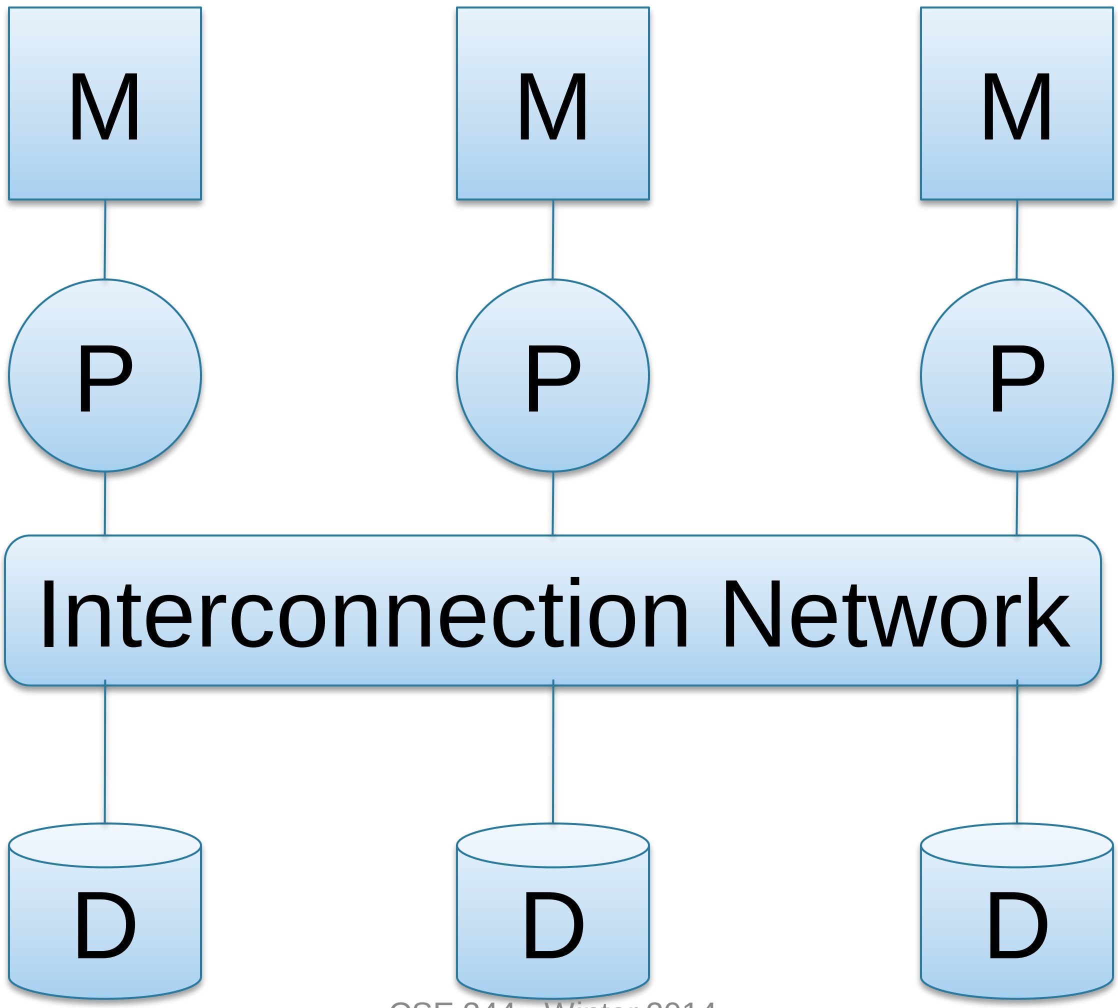


- Nodes share both RAM and disk
- Dozens to hundreds of processors

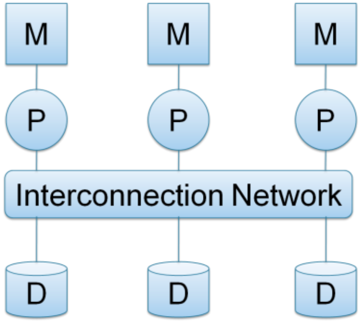
Example: SQL Server runs on a single machine and can leverage many threads to get a query to run faster (can be seen in query plans)

- Easy to use and program
- But very expensive to scale: last remaining cash cows in the hardware industry

Shared Disk



Shared Disk



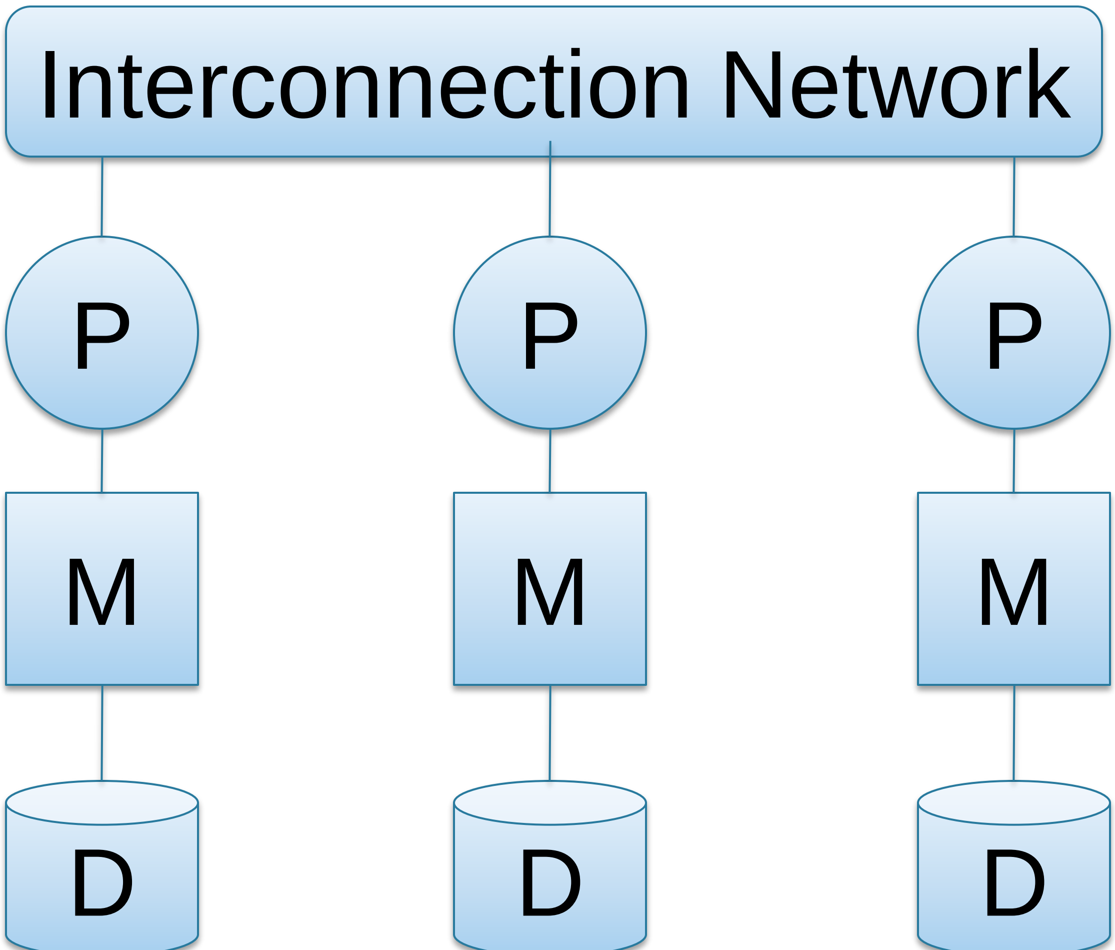
- All nodes access the same disks
- Found in the largest "single-box" (non-cluster) multiprocessors

e.g. Oracle dominates this class of systems.

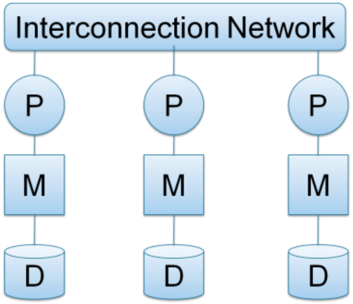
Characteristics:

- Also hard to scale past a certain point: existing deployments typically have fewer than 10 machines

Shared Nothing



Shared Nothing



- Cluster of machines on high-speed network
- Called "clusters" or "blade servers"
- Each machine has its own memory and disk: lowest contention.

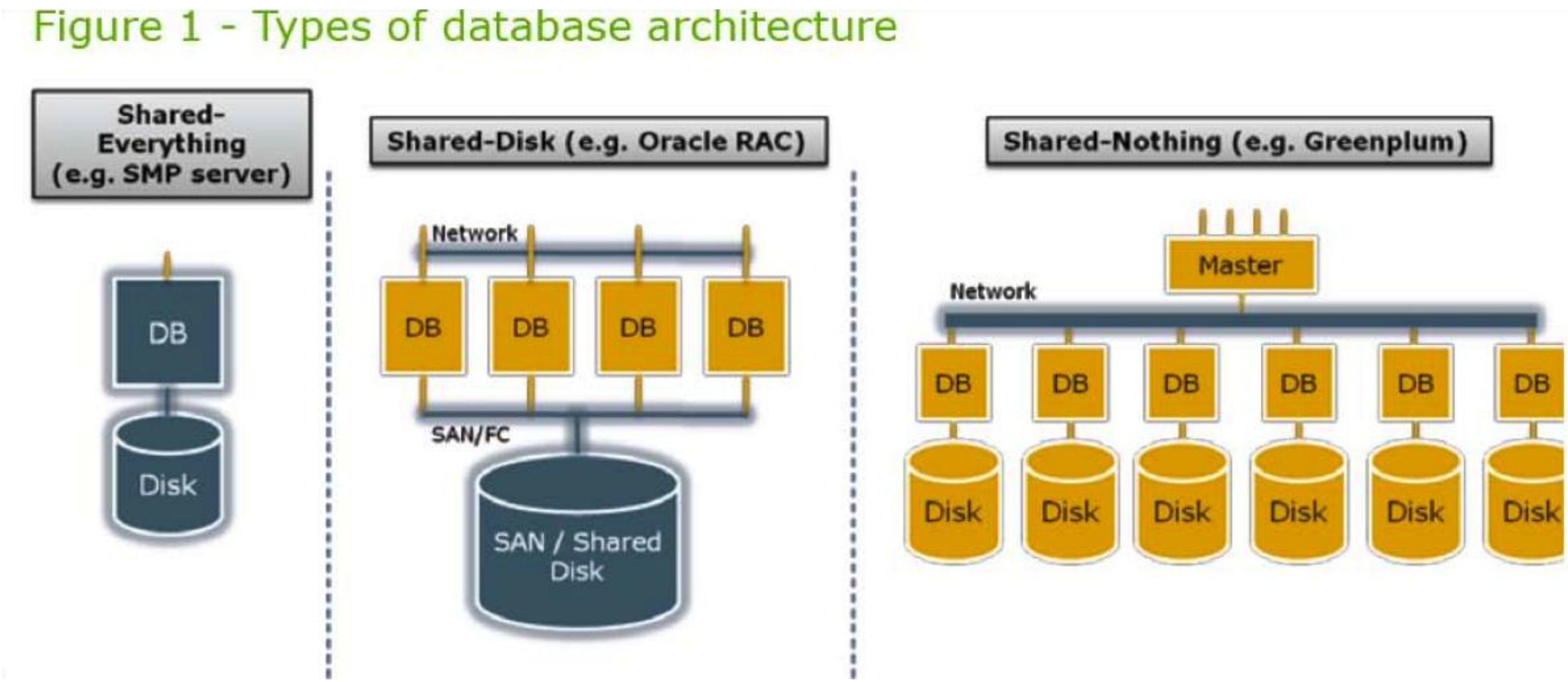
NOTE: Because all machines today have many cores and many disks, then shared-nothing systems typically run many "nodes" on a single physical machine.

Characteristics:

- Today, this is the most scalable architecture.
- Most difficult to administer and tune.

We discuss only Shared Nothing in class

A Professional Picture…



From: Greenplum Database Whitepaper

SMP= “Symmetric Multi-Processing”

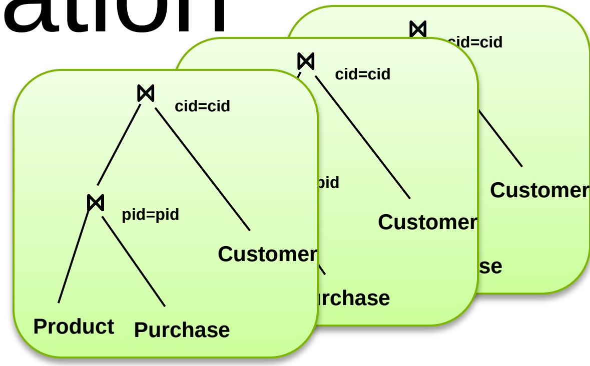
SAN = “Storage Area Network”

In Class

- You have a parallel machine. Now what?
- How do you speed up your DBMS?

Approaches to Parallel Query Evaluation

- Inter-query parallelism
  - Transaction per node
  - OLTP



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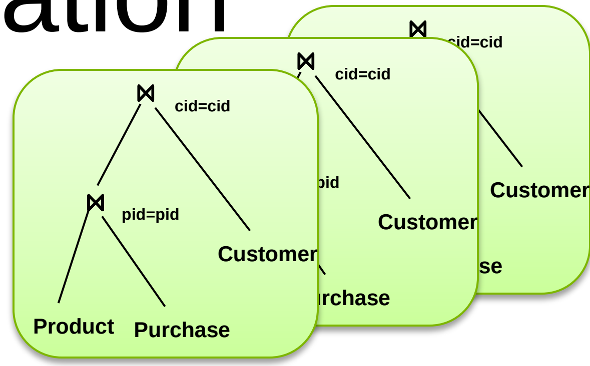
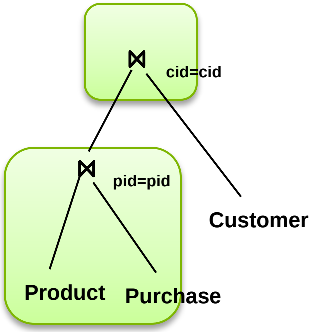


- Inter-operator parallelism
  - Operator per node
  - Both OLTP and Decision Support



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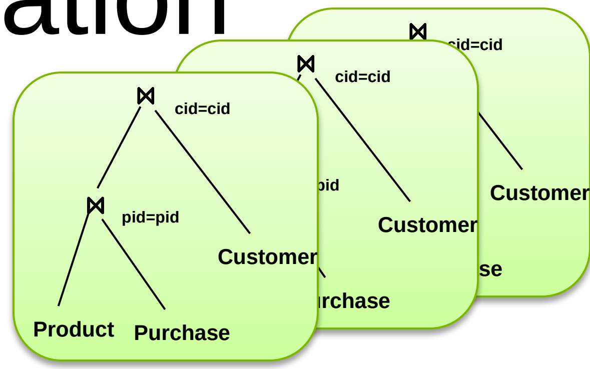

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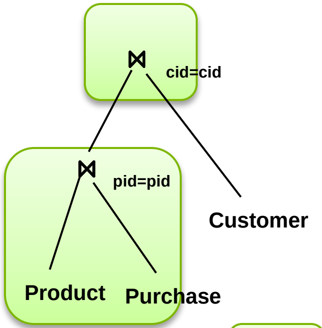
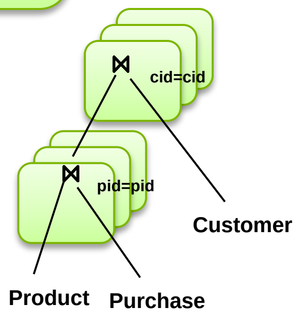


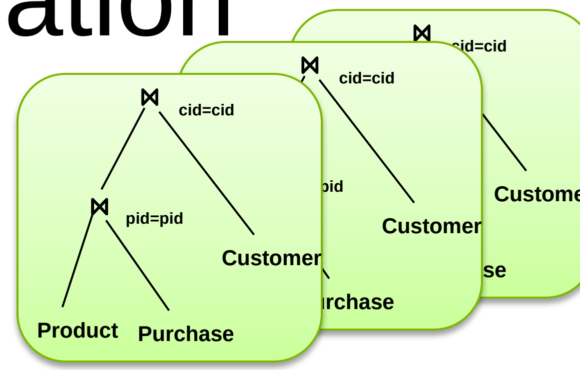
- Intra-operator parallelism
  - Operator on multiple nodes
  - Decision Support



END OF LECTURE 22

Approaches to Parallel Query Evaluation

- Inter-query parallelism
  - Transaction per node
  - OLTP



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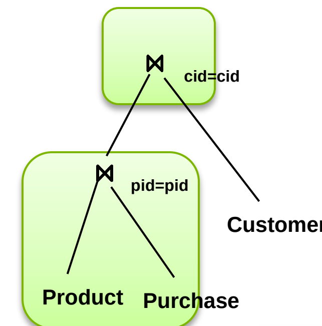

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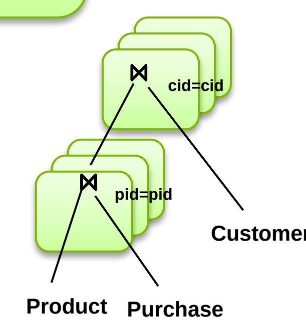

We study only intra-operator parallelism: most scalable