Introduction to Data Management CSE 344

Lectures 23: Parallel Databases

Announcements

- WQ7 due tomorrow
- HW7 due on Wednesday
- HW8 (last one!) will be out on Wednesday

- Final on 12/12 (Monday), 2:30-4:20pm
  - Location TBD
  - You can bring 2 sheets of notes

HW8 Preview

- HW8 will require using Amazon EC2 compute cloud
  - If you do not already have an Amazon account, go to http://aws.amazon.com/ and sign up.
    - Amazon will ask you for your credit card information.

  - Apply for credits on https://aws.amazon.com/education/awseducate/apply/ (choose students)
    - **Use your @uw.edu email address**

Outline

- Review of transactions

- Parallel databases

Transactions Recap

- Why we use transactions?
  - ACID properties
- Serializability
  - Conflict-serializable / non-serializable
- Implementation using locks
  - 2PL and strict 2PL
  - Serialization levels

In-Class Exercise

- Given these 3 transactions: (Co = commit)
  - T1 : $R_1(A)$, $R_1(B)$, $W_1(A)$, $W_1(B)$, Co_1
  - T2 : $R_2(B)$, $W_2(B)$, $R_2(C)$, $W_2(C)$, Co_2
  - T3 : $R_3(C)$, $W_3(C)$, $R_3(A)$, $W_3(A)$, Co_3
- And this schedule:
  - $R_1(A)$, $R_1(B)$, $W_1(A)$, $R_3(C)$, $W_3(C)$, $R_3(A)$, $W_3(A)$, Co_3, $W_1(B)$, $R_2(B)$, $W_2(B)$, Co_1, $R_2(C)$, $W_2(C)$, Co_2
- Determine:
  - If the schedule conflict-serializable? If yes, indicate a serialization order. 1, 3, 2
  - Is this schedule possible under the strict 2PL protocol?

Parallel DBMS

Why compute in parallel?

- Multi-cores:
  - Most processors have multiple cores
  - This trend will increase in the future

- Big data: too large to fit in main memory
  - Distributed query processing on 100x-1000x servers
  - Widely available now using cloud services

Big Data

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

- Complex data processing:
  - Decision support queries (SQL w/ aggregates)
  - Machine learning (adds linear algebra and iteration)

Two Kinds of Parallel Data Processing

- Parallel (relational) databases, developed starting with the 80s (this lecture)
  - OLTP (Online Transaction Processing)
  - OLAP (Online Analytic Processing, or Decision Support)
  - Will only cover parallel query execution in 344
  - Parallel transactions and recovery (444)
  - Schema design for parallel DBMS (544)

- General purpose distributed processing: MapReduce, Spark (next lectures)
  - Mostly for Decision Support Queries

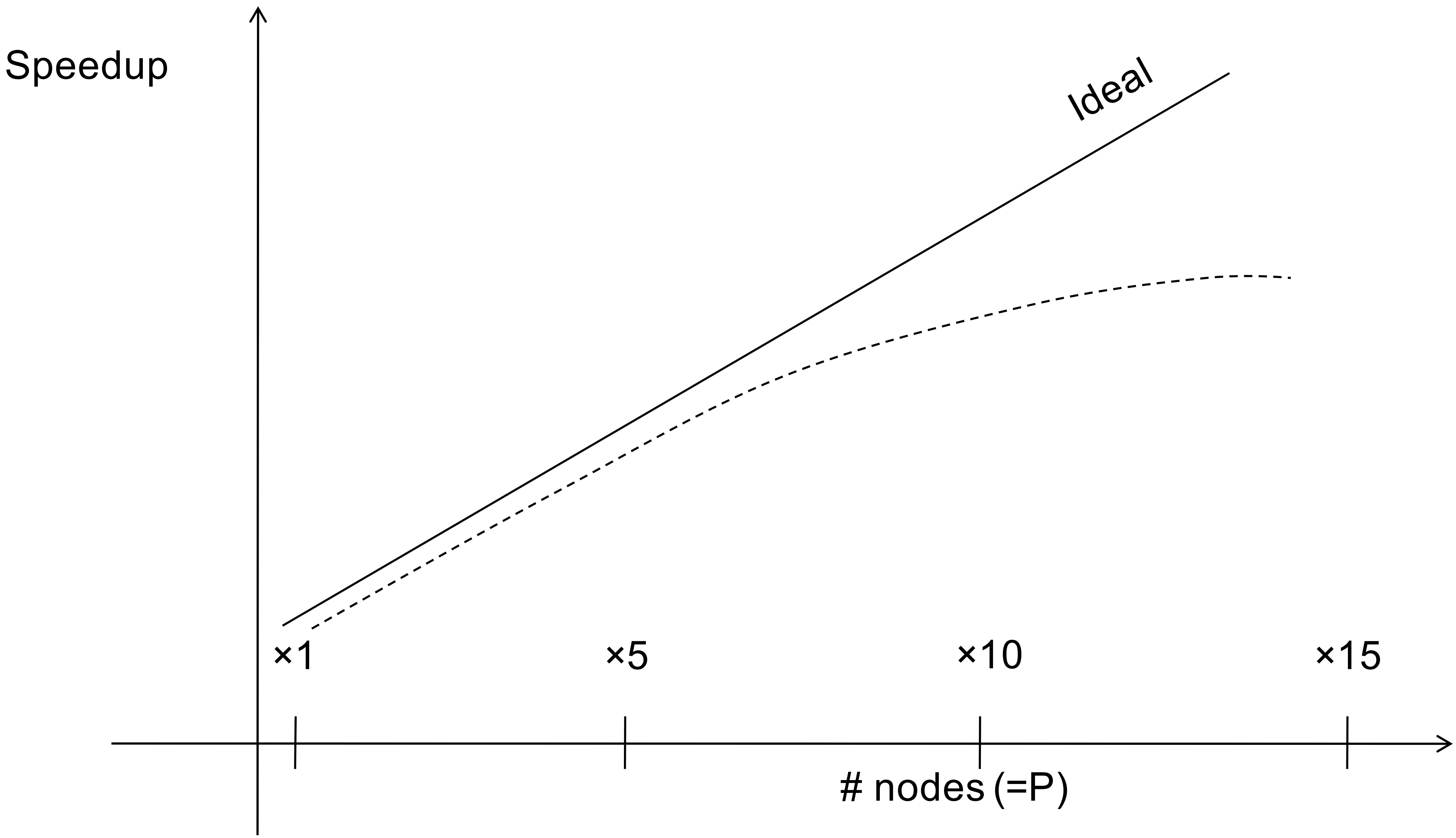
Performance Metrics for Parallel DBMSs

P = the number of nodes (processors, computers)

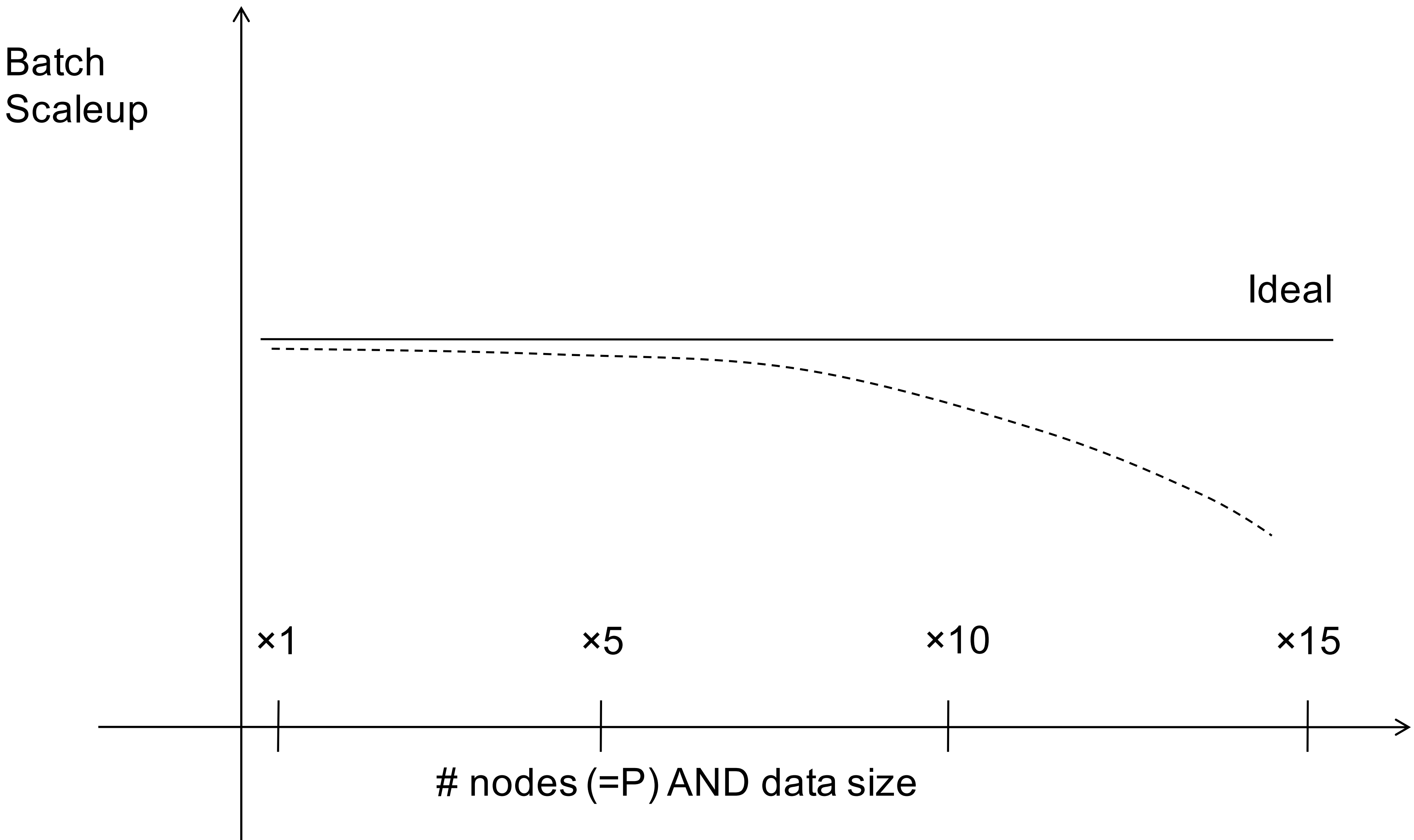
- Speedup:
  - More nodes, same data ➔ higher speed
- Scaleup:
  - More nodes, more data ➔ same speed

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

Linear v.s. Non-linear Speedup



Linear v.s. Non-linear Scaleup



Challenges to Linear Speedup and Scaleup

- Startup cost
  – Cost of starting an operation on many nodes

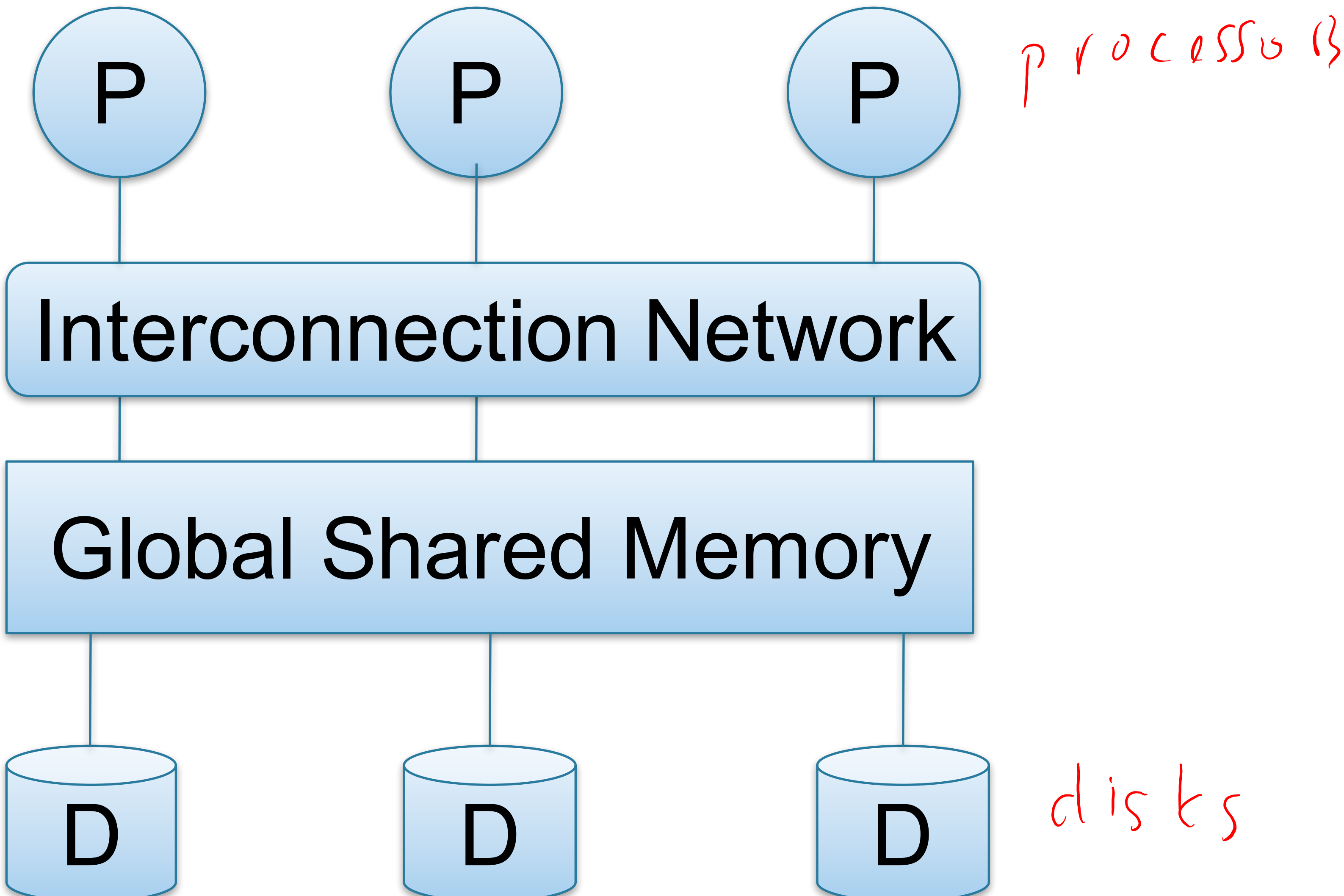
- Interference
  – Contention for resources between nodes

- Skew
  – Slowest node becomes the bottleneck

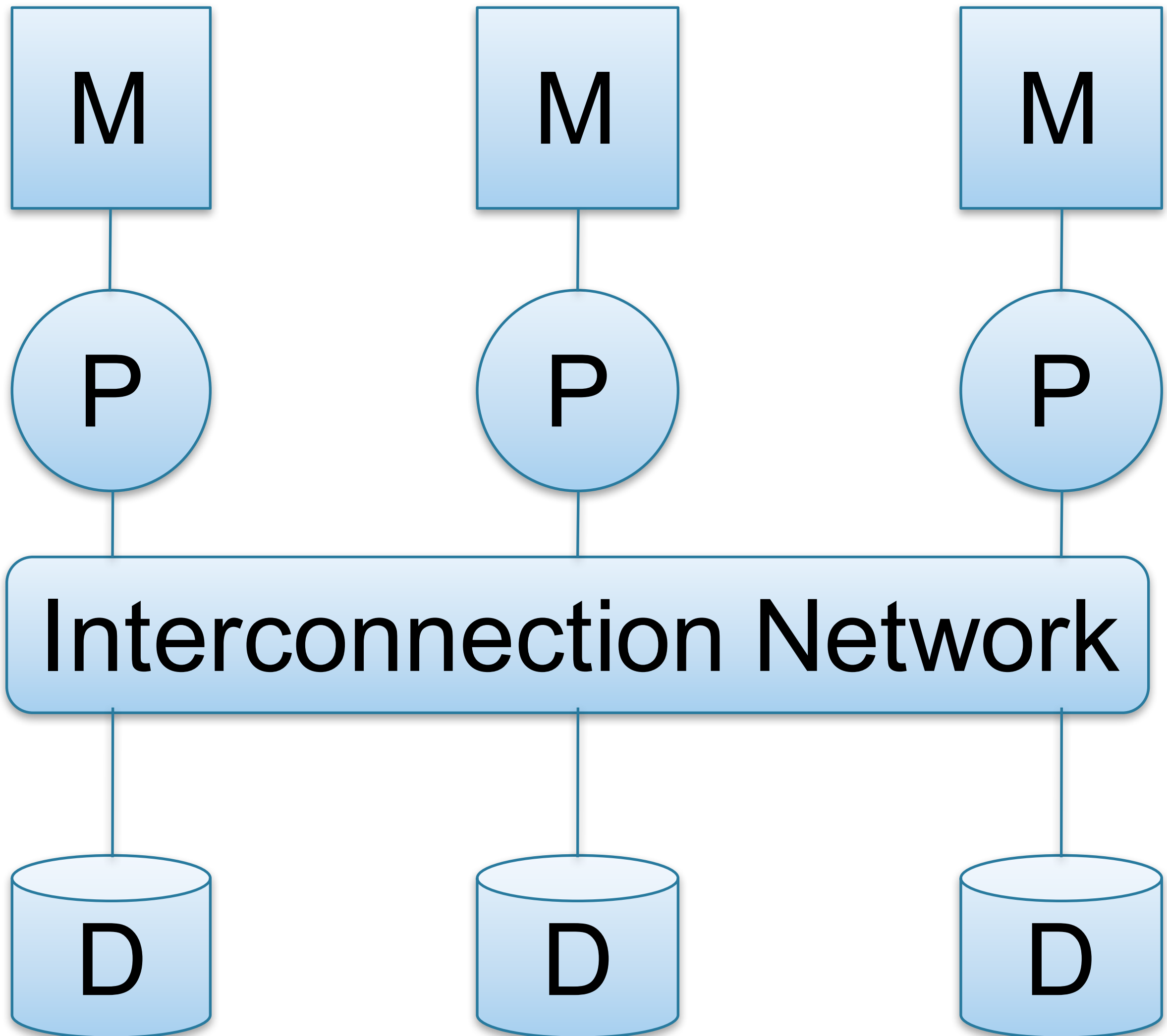
Architectures for Parallel Databases

- Shared memory
- Shared disk
- Shared nothing

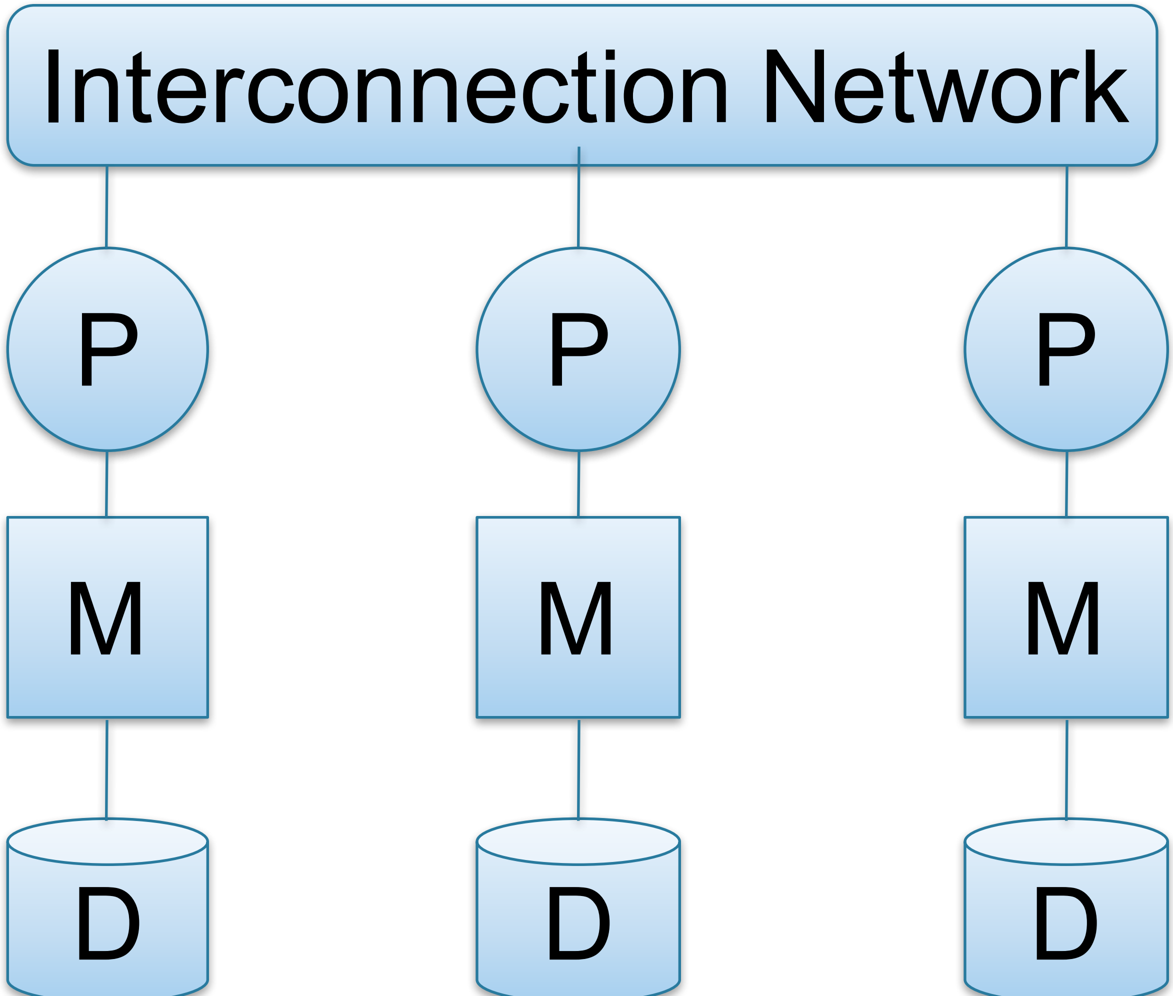
Shared Memory



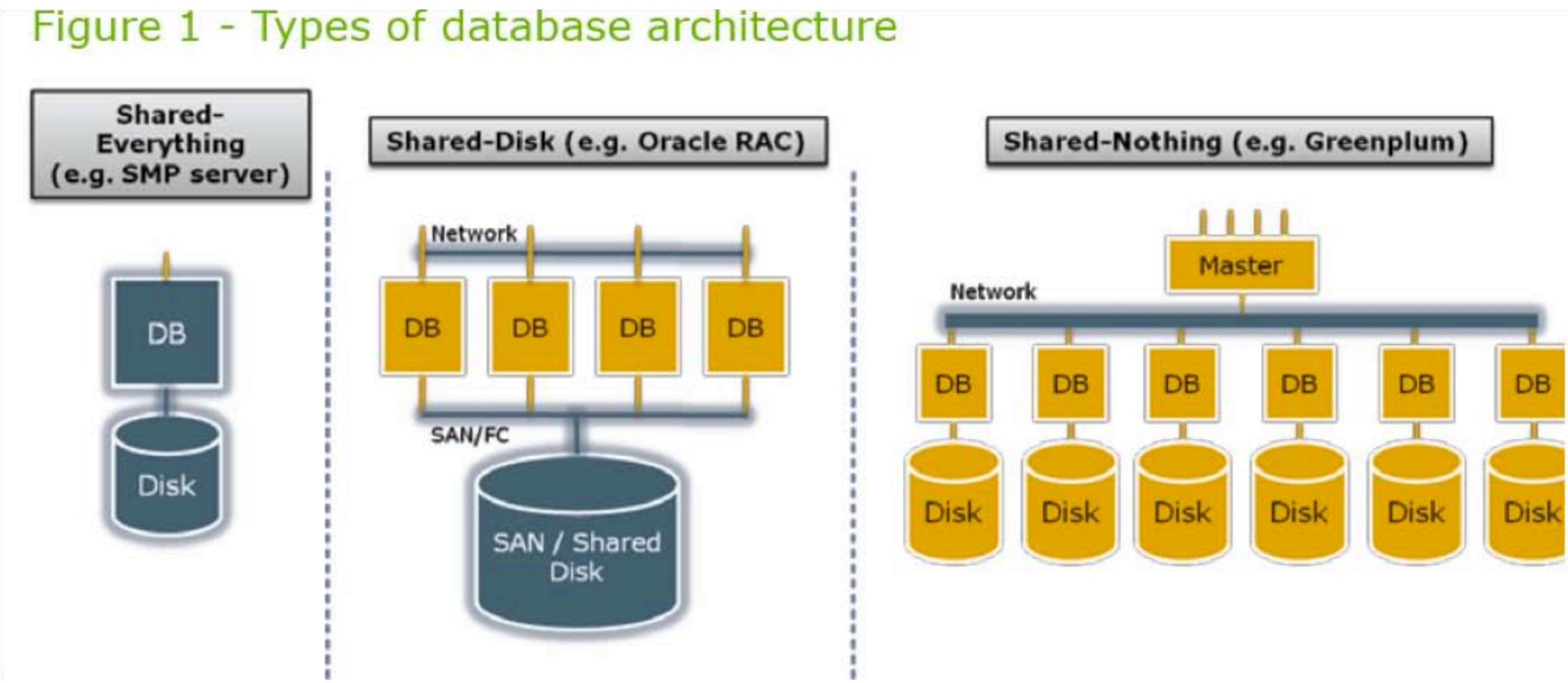
Shared Disk



Shared Nothing



A Professional Picture…



From: Greenplum (now EMC) Database Whitepaper

SAN = “Storage Area Network”

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 (check your HW3 query plans)

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

Shared Disk

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

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

- 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.

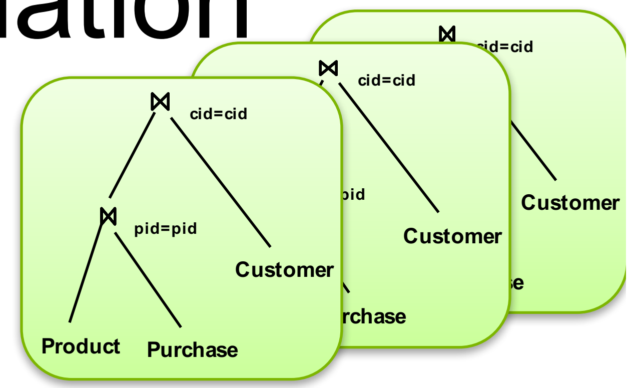
Characteristics:

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

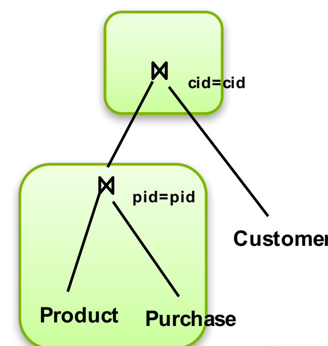
We discuss only Shared Nothing in class

Approaches to Parallel Query Evaluation

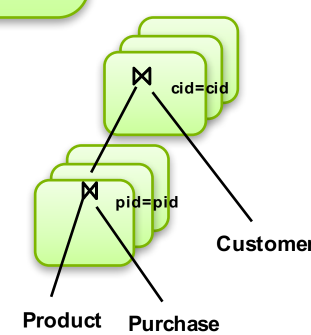
- Inter-query parallelism
  - Transaction per node
  - OLTP



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



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



We study only intra-operator parallelism: most scalable

Single Node Query Processing (Review)

Given relations R(A,B) and S(B, C), no indexes:

- Selection: $\sigma_{A=123}(R)$
  - Scan file R, select records with A=123
- Group-by: $\gamma_{A,sum(B)}(R)$
  - Scan file R, insert into a hash table using A as key
  - When a new key is equal to an existing one, add B to the value
- Join: $R \bowtie S$
  - Scan file S, insert into a hash table using B as key
  - Scan file R, probe the hash table using B

Distributed Query Processing

- Data is horizontally partitioned on many servers
- Operators may require data reshuffling

Horizontal Data Partitioning

Data:

K	A	B
…	…	

Servers:

Horizontal Data Partitioning