Introduction to Database Systems CSE 444

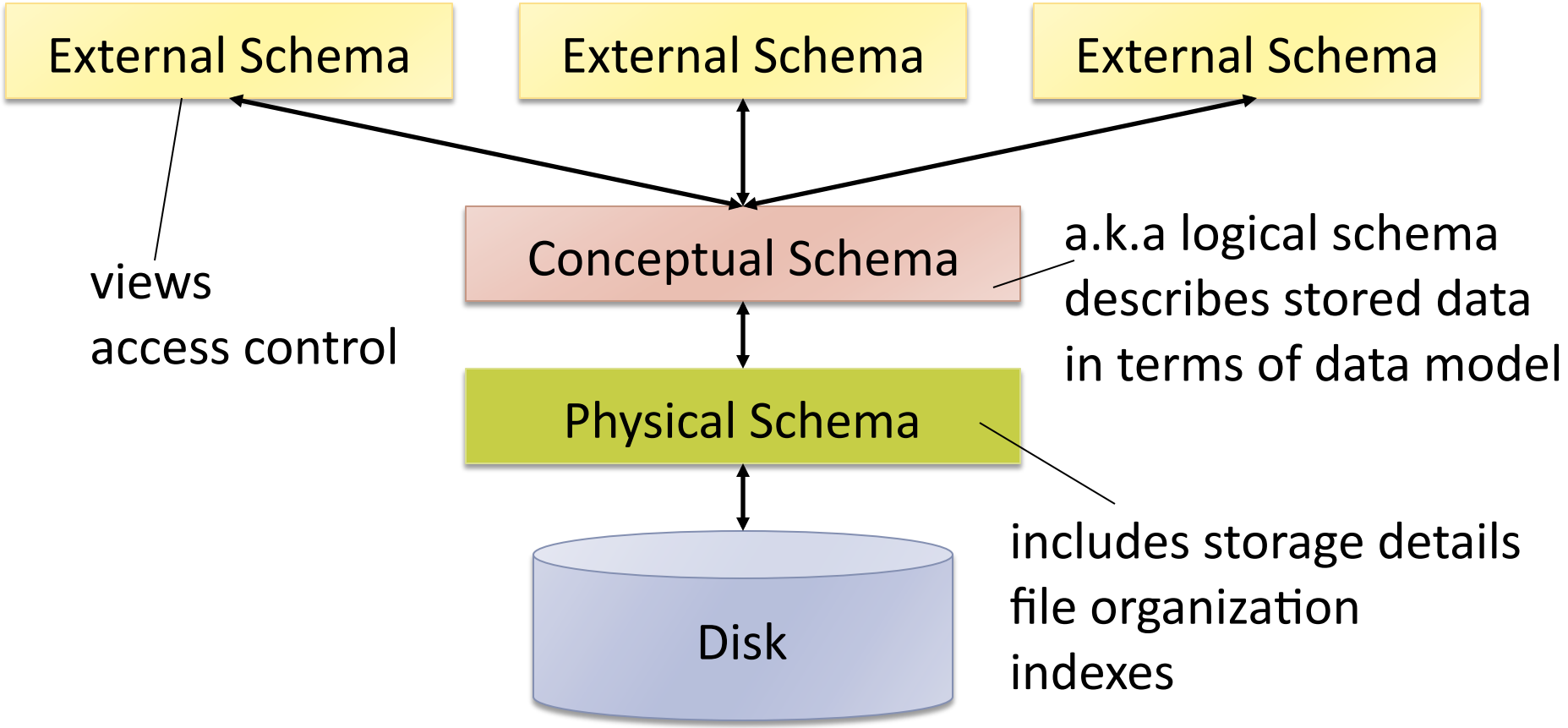
Lecture 17: Database Tuning

Database Tuning Overview

- The database tuning problem
- Index selection (discuss in detail)
- Horizontal/vertical partitioning (see lecture 4)
- Denormalization (discuss briefly)

This material is partially based on the book: “Database Management Systems” by *Ramakrishnan and Gehrke*, **Ch. 20**

Levels of Abstraction in a DBMS



The Database Tuning Problem

- We are given a workload description
  - List of queries and their frequencies
  - List of updates and their frequencies
  - Performance goals for each type of query
- Perform physical database design
  - Choice of indexes
  - Tuning the conceptual schema
    - Denormalization, vertical and horizontal partition
  - Query and transaction tuning

The Index Selection Problem

- Given a database schema (tables, attributes)
- Given a "query workload":
  - Workload = a set of (query, frequency) pairs
  - The queries may be both SELECT and updates
  - Frequency = either a count, or a percentage

- Select a set of indexes that optimizes the workload

In general this is a very hard problem

Index selection decisions

- To index or not to index?
- Which key?
- Multiple keys?
- Clustered or unclustered?
- Hash or trees?

Index Selection: Which Search Key

- Make some attribute K a search key if the WHERE clause contains:
  - An exact match on K
  - A range predicate on K
  - A join on K

The Index Selection Problem 1

V(M, N, P)

Your workload is this

100,000 queries:

```
SELECT *
FROM V
WHERE N=?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

What indexes?

The Index Selection Problem 1

V(M, N, P)

Your workload is this

100,000 queries:

```
SELECT *
FROM V
WHERE N=?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

A: V(N) and V(P) (hash tables or B-trees)

The Index Selection Problem 2

V(M, N, P)

Your workload is this

100,000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

100,000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

What indexes?

The Index Selection Problem 2

V(M, N, P)

Your workload is this

100,000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100 queries:

```
SELECT *
FROM V
WHERE P=?
```

100,000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

A: definitely V(N) must B-tree; unsure about V(P)

The Index Selection Problem 3

V(M, N, P)

Your workload is this

100,000 queries:

```
SELECT *
FROM V
WHERE N=?
```

1,000,000 queries:

```
SELECT *
FROM V
WHERE N=? and P>?
```

100,000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

What indexes?

The Index Selection Problem 3

V(M, N, P)

Your workload is this

100,000 queries:

```
SELECT *
FROM V
WHERE N=?
```

1,000,000 queries:

```
SELECT *
FROM V
WHERE N=? and P>?
```

100,000 queries:

```
INSERT INTO V
VALUES (?, ?, ?)
```

A: V(N, P)

The Index Selection Problem 2

V(M, N, P)

Your workload is this

1,000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100,000 queries:

```
SELECT *
FROM V
WHERE P>? And P<?
```

What indexes?

The Index Selection Problem 2

V(M, N, P)

Your workload is this

1,000 queries:

```
SELECT *
FROM V
WHERE N>? and N<?
```

100,000 queries:

```
SELECT *
FROM V
WHERE P>? And P<?
```

A: V(N) secondary (unclustered); V(P) primary (clustered)

The Index Selection Problem

- SQL Server
  - Automatically, thanks to *AutoAdmin* project
  - Much acclaimed successful research project from mid 90's, similar ideas adopted by the other major vendors

- PostgreSQL
  - You will do it manually, part of project 3
  - But tuning wizards also exist

Basic Index Selection Guidelines

- Consider queries in workload in order of importance
- Consider relations accessed by query
  - No point indexing other relations
- Look at WHERE clause for possible search key
- Try to choose indexes that speed-up multiple queries
- And then consider the following…

Index Selection: Multi-attribute Keys

- Consider creating a multi-attribute key on K1, K2, … if
- WHERE clause has matches on K1, K2, …
  - But also consider separate indexes
- SELECT clause contains only K1, K2, ..
  - A covering index is one that can be used exclusively to answer a query, e.g. index R(K1,K2) covers the query:

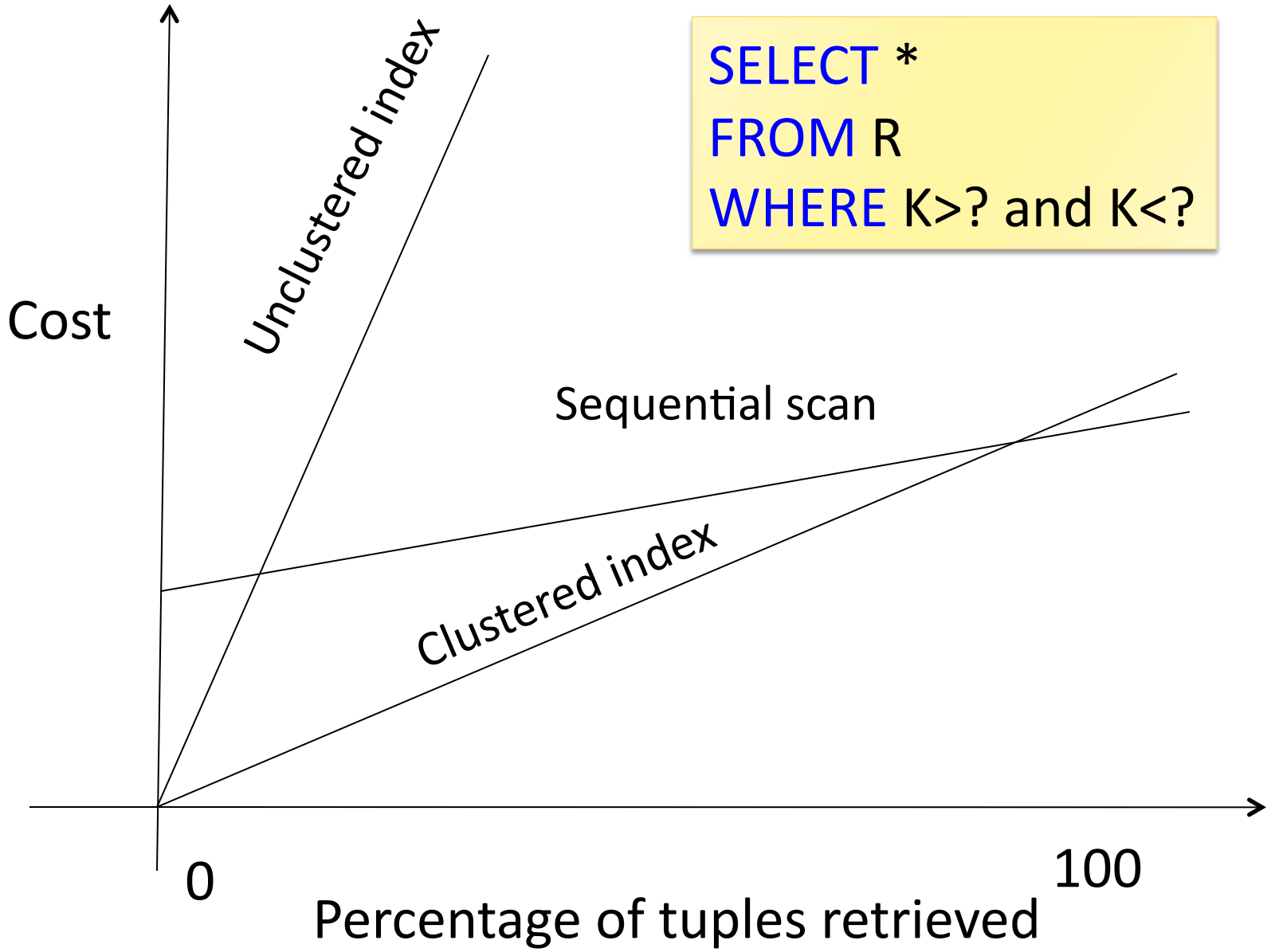
```
SELECT K2
FROM R
WHERE K1=55
```

Can be answered with an index-only plan

To Cluster or Not to Cluster?

- Range queries benefit mostly from clustering

- Covering indexes do *not* need to be clustered ← Why?


SELECT *
FROM R
WHERE K>? and K<?
Cost
Unclustered index
Sequential scan
Clustered index
0
100
Percentage of tuples retrieved

Hash Table v.s. B+ tree

- Rule 1: always use a B+ tree ☺

- Rule 2: use a Hash table on K when:
  - There is a very important selection query on equality (WHERE K=?), and no range queries
  - You know that the optimizer uses a nested loop join where K is the join attribute of the inner relation (you will understand that in a few lectures)

Updates

- Indexes speed up queries
  - SELECT FROM WHERE

- But they usually slow down updates:
  - INSERT, DELETE, UPDATE
  - However some updates benefit from indexes

```
UPDATE R
SET    A = 7
WHERE  K=55
```

Tools for Index Selection

- SQL Server 2000 Index Tuning Wizard
- DB2 Index Advisor

- How they work:
  - They walk through a large number of configurations, compute their costs, and choose the configuration with minimum cost

Horizontal/Vertical Partitioning

- When would we want to do this?

Contracts(cid, supplierID, projectID, deptID, partID, qty, value)

(in BCNF)

Q1: Find the contracts held by supplier S
Q2: Find the contracts held by department D

Tuning the Conceptual Schema

- Index selection
- Horizontal/vertical partitioning
- Denormalization

Denormalization

Product(**pid**, pname, price, cid)
Company(**cid**, cname, city)

A very frequent query:

```
SELECT x.pid, x.pname
FROM Product x, Company y
WHERE x.cid = y.cid and x.price < ? and y.city = ?
```

How can we speed up this query workload ?

Denormalization

Product(**pid**, pname, price, cid)
Company(**cid**, cname, city)

Denormalize:

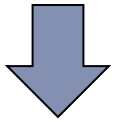
ProductCompany(**pid**, pname, price, cname, city)

```
INSERT INTO ProductCompany
  SELECT x.pid, x.pname, x.price, y.cname, y.city
  FROM Product x, Company y
  WHERE x.cid = y.cid
```

Denormalization

Next, replace the query

```
SELECT x.pid, x.pname
FROM Product x, Company y
WHERE x.cid = y.cid and x.price < ? and y.city = ?
```



```
SELECT pid, pname
FROM ProductCompany
WHERE price < ? and city = ?
```

Issues with Denormalization

- It is no longer in BCNF
  - We have the hidden FD: cid → cname, city
- When Product or Company are updated, we need to propagate updates to ProductCompany
  - Use RULE in PostgreSQL (see PostgreSQL doc.)
  - Or use a trigger on a different RDBMS
- Sometimes cannot modify the query
  - What do we do then ?

Denormalization Using Views

```
INSERT INTO ProductCompany
  SELECT x.pid, x.pname, x.price, y.cid, y.cname, y.city
  FROM Product x, Company y
  WHERE x.cid = y.cid;

DROP Product; DROP Company;

CREATE VIEW Product AS
  SELECT pid, pname, price, cid FROM ProductCompany

CREATE VIEW Company AS
  SELECT DISTINCT cid, cname, city FROM ProductCompany
```