



Hashing

Database System Concepts, 6th Ed.

©Silberschatz, Korth and Sudarshan

See www.db-book.com for conditions on re-use



Static Hashing

- A **bucket** is a unit of storage containing one or more records (a bucket is typically a disk block).
- In a **hash file organization** we obtain the bucket of a record directly from its search-key value using a **hash function**.
- Hash function h is a function from the set of all search-key values K to the set of all bucket addresses B .
- Hash function is used to locate records for access, insertion as well as deletion.
- Records with different search-key values may be mapped to the same bucket; thus entire bucket has to be searched sequentially to locate a record.



Example of Hash File Organization

Hash file organization of *instructor* file, using *dept_name* as key
(See figure in next slide.)

- There are 10 buckets,
- The binary representation of the i th character is assumed to be the integer i .
- The hash function returns the sum of the binary representations of the characters modulo 10
 - E.g. $h(\text{Music}) = 1$ $h(\text{History}) = 2$
 $h(\text{Physics}) = 3$ $h(\text{Elec. Eng.}) = 3$



Example of Hash File Organization

bucket 0

bucket 1

15151	Mozart	Music	40000

bucket 2

32343	El Said	History	80000
58583	Califieri	History	60000

bucket 3

22222	Einstein	Physics	95000
33456	Gold	Physics	87000
98345	Kim	Elec. Eng.	80000

bucket 4

12121	Wu	Finance	90000
76543	Singh	Finance	80000

bucket 5

76766	Crick	Biology	72000

bucket 6

10101	Srinivasan	Comp. Sci.	65000
45565	Katz	Comp. Sci.	75000
83821	Brandt	Comp. Sci.	92000

bucket 7

Hash file organization of *instructor* file, using *dept_name* as key (see previous slide for details).



Hash Functions

- Worst hash function maps all search-key values to the same bucket; this makes access time proportional to the number of search-key values in the file.
- An ideal hash function is **uniform**, i.e., each bucket is assigned the same number of search-key values from the set of *all* possible values.
- Ideal hash function is **random**, so each bucket will have the same number of records assigned to it irrespective of the *actual distribution* of search-key values in the file.
- Typical hash functions perform computation on the internal binary representation of the search-key.
 - For example, for a string search-key, the binary representations of all the characters in the string could be added and the sum modulo the number of buckets could be returned. .



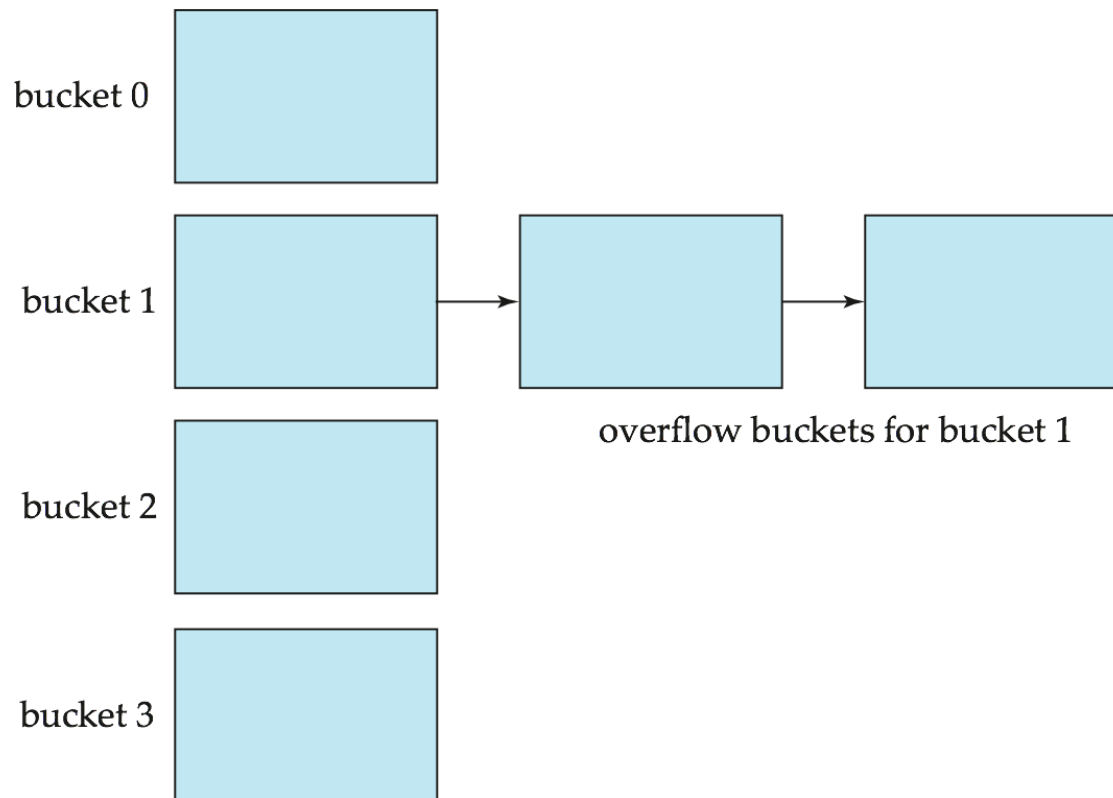
Handling of Bucket Overflows

- Bucket overflow can occur because of
 - Insufficient buckets
 - Skew in distribution of records. This can occur due to two reasons:
 - ▶ multiple records have same search-key value
 - ▶ chosen hash function produces non-uniform distribution of key values
- Although the probability of bucket overflow can be reduced, it cannot be eliminated; it is handled by using *overflow buckets*.



Handling of Bucket Overflows (Cont.)

- **Overflow chaining** – the overflow buckets of a given bucket are chained together in a linked list.
- Above scheme is called **closed hashing**.
 - An alternative, called **open hashing**, which does not use overflow buckets, is not suitable for database applications.





Hash Indices

- Hashing can be used not only for file organization, but also for index-structure creation.
- A **hash index** organizes the search keys, with their associated record pointers, into a hash file structure.
- Strictly speaking, hash indices are always secondary indices
 - if the file itself is organized using hashing, a separate primary hash index on it using the same search-key is unnecessary.
 - However, we use the term hash index to refer to both secondary index structures and hash organized files.



Example of Hash Index

bucket 0

76766	

bucket 1

45565	
76543	

bucket 2

22222	

bucket 3

10101	

bucket 4

bucket 5

15151	
33456	

bucket 6

83821	

bucket 7

12121	
32343	

76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
45565	Katz	Comp. Sci.	75000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000
12121	Wu	Finance	90000
76543	Singh	Finance	80000
32343	El Said	History	60000
58583	Califieri	History	62000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
33465	Gold	Physics	87000

hash index on *instructor*, on attribute *ID*



Deficiencies of Static Hashing

- In static hashing, function h maps search-key values to a fixed set of B of bucket addresses. Databases grow or shrink with time.
 - If initial number of buckets is too small, and file grows, performance will degrade due to too much overflows.
 - If space is allocated for anticipated growth, a significant amount of space will be wasted initially (and buckets will be underfull).
 - If database shrinks, again space will be wasted.
- One solution: periodic re-organization of the file with a new hash function
 - Expensive, disrupts normal operations
- Better solution: allow the number of buckets to be modified dynamically.

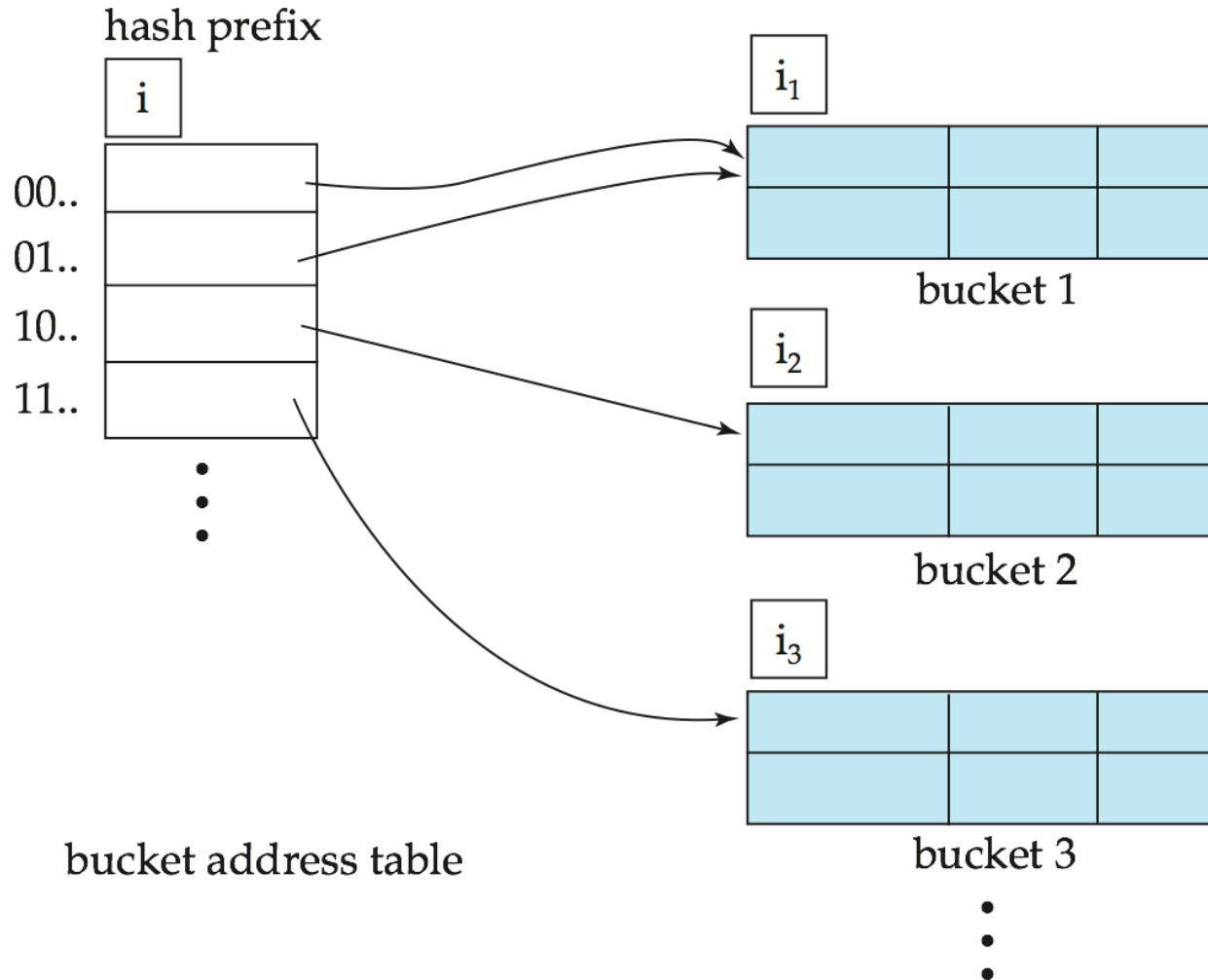


Dynamic Hashing

- Good for database that grows and shrinks in size
- Allows the hash function to be modified dynamically
- **Extendable hashing** – one form of dynamic hashing
 - Hash function generates values over a large range — typically b -bit integers, with $b = 32$.
 - At any time use only a prefix of the hash function to index into a table of bucket addresses.
 - Let the length of the prefix be i bits, $0 \leq i \leq 32$.
 - ▶ Bucket address table size = 2^i . Initially $i = 0$
 - ▶ Value of i grows and shrinks as the size of the database grows and shrinks.
 - Multiple entries in the bucket address table may point to a bucket (why?)
 - Thus, actual number of buckets is $< 2^i$
 - ▶ The number of buckets also changes dynamically due to coalescing and splitting of buckets.



General Extendable Hash Structure



In this structure, $i_2 = i_3 = i$, whereas $i_1 = i - 1$ (see next slide for details)



Bitmap Indices

- Bitmap indices are a special type of index designed for efficient querying on multiple keys
- Records in a relation are assumed to be numbered sequentially from, say, 0
 - Given a number n it must be easy to retrieve record n
 - ▶ Particularly easy if records are of fixed size
- Applicable on attributes that take on a relatively small number of distinct values
 - E.g. gender, country, state, ...
 - E.g. income-level (income broken up into a small number of levels such as 0-9999, 10000-19999, 20000-50000, 50000- infinity)
- A bitmap is simply an array of bits



Bitmap Indices (Cont.)

- In its simplest form a bitmap index on an attribute has a bitmap for each value of the attribute
 - Bitmap has as many bits as records
 - In a bitmap for value v , the bit for a record is 1 if the record has the value v for the attribute, and is 0 otherwise

record number	<i>ID</i>	<i>gender</i>	<i>income_level</i>
0	76766	m	L1
1	22222	f	L2
2	12121	f	L1
3	15151	m	L4
4	58583	f	L3

Bitmaps for *gender*

m	10010
f	01101

Bitmaps for *income_level*

L1	10100
L2	01000
L3	00001
L4	00010
L5	00000



Bitmap Indices (Cont.)

- Bitmap indices are useful for queries on multiple attributes
 - not particularly useful for single attribute queries
- Queries are answered using bitmap operations
 - Intersection (and)
 - Union (or)
 - Complementation (not)
- Each operation takes two bitmaps of the same size and applies the operation on corresponding bits to get the result bitmap
 - E.g. $100110 \text{ AND } 110011 = 100010$
 $100110 \text{ OR } 110011 = 110111$
 $\text{NOT } 100110 = 011001$
 - Males with income level L1: $10010 \text{ AND } 10100 = 10000$
 - ▶ Can then retrieve required tuples.
 - ▶ Counting number of matching tuples is even faster



Index Definition in SQL

- Create an index

create index <index-name> **on** <relation-name>
(<attribute-list>)

E.g.: **create index** *dept_index* **on** *instructor* (*dept_name*)

- Use **create unique index** to indirectly specify and enforce the condition that the search key is a candidate key is a candidate key.
 - Not really required if SQL **unique** integrity constraint is supported
- To drop an index

drop index <index-name>

- Most database systems allow specification of type of index, and clustering.