CS460: Intro to Database Systems

Class 13: Hash Indexing

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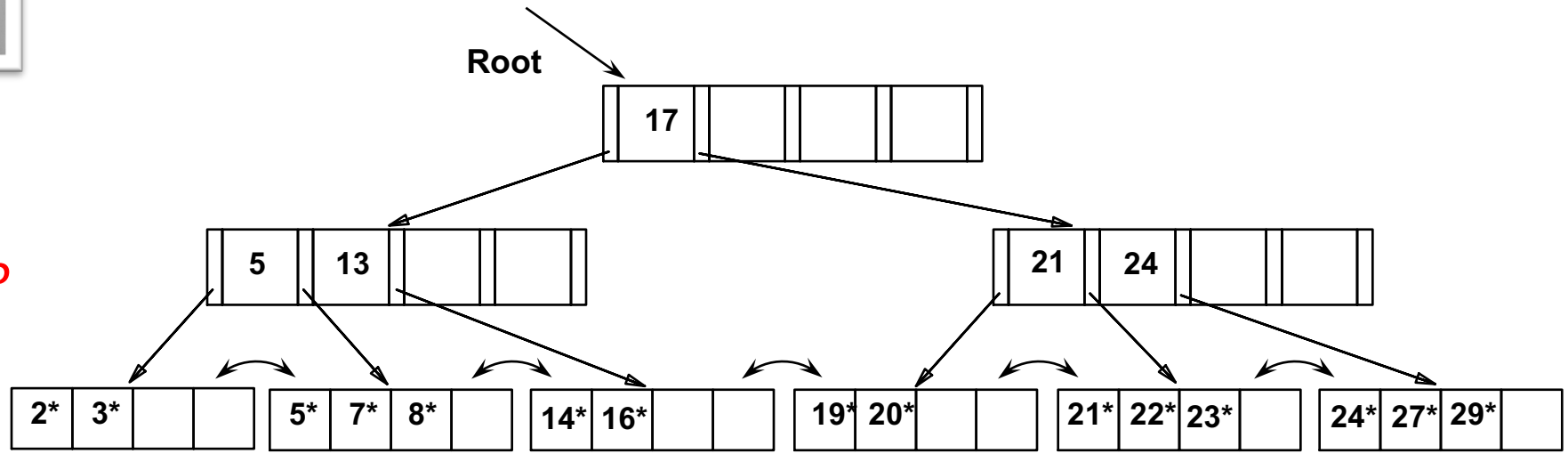
https://bu-disc.github.io/CS460/

Last time: B+ Trees

"It could be said that the world's information is at our fingertips because of B-trees"

Other forms of indexing?



Hash Indexing

Static Hashing

Extendible Hashing

Linear Hashing

Reminder: Alternatives of Data Entries

1. <**k**, entire data record>
2. <**k**, rid of exactly-one-at-a-time matching data record>
3. <**k**, list of rids of matching data records>

Choice is orthogonal to the indexing technique

Hash-based indexes → *equality selections*
Cannot support range searches

Static and dynamic hashing techniques exist

Hash function

a **function** that **maps** a **search key** to an **index** between **[0 .. M-1]**

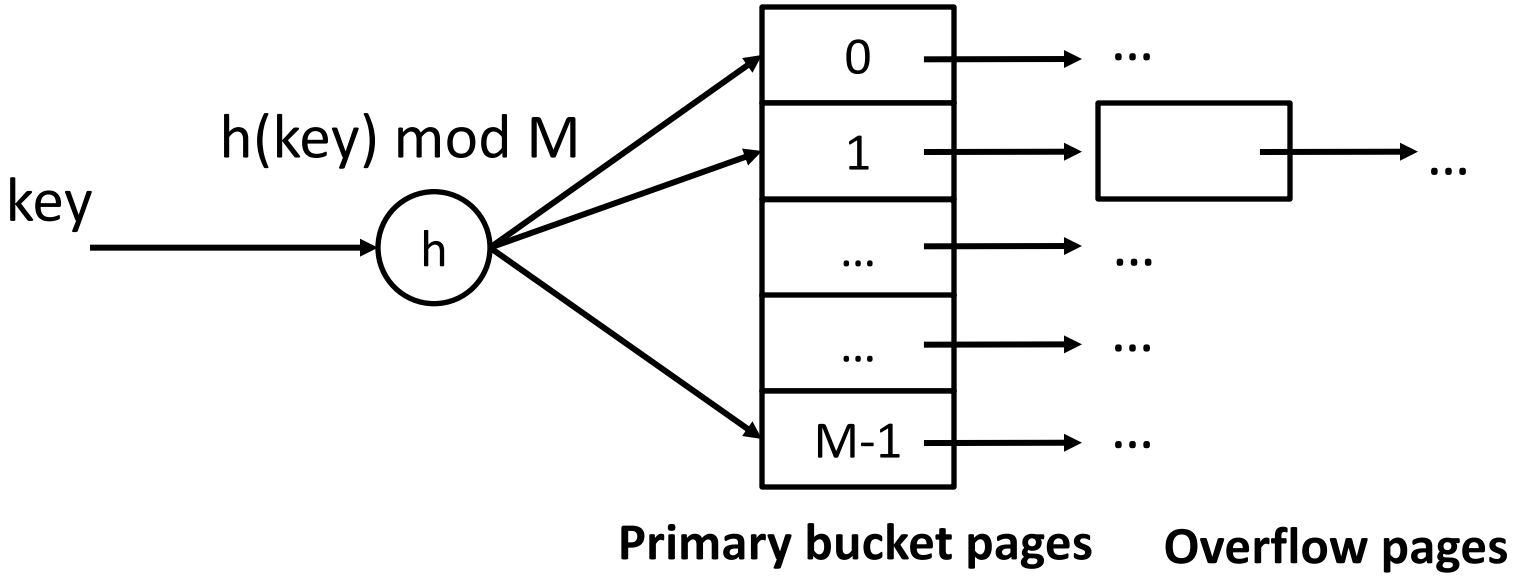
where M is the number of **buckets** (pages) available to our index

- ideally a hash function maps the search keys uniformly in [0, …, M-1]
- in practice simple hash functions are used (fast to compute)
- different keys might be mapped to the same bucket

Static Hashing

#primary bucket pages fixed, allocated sequentially, never de-allocated; overflow pages if needed

h(k) mod M = bucket to insert data entry with key *k* (M: #buckets)



Static Hashing (Contd.)

Buckets contain data entries

Remember, data entries:
<k, record>
<k, rid>
<k, rid-list>

Hash function on *search key* field of record *r*

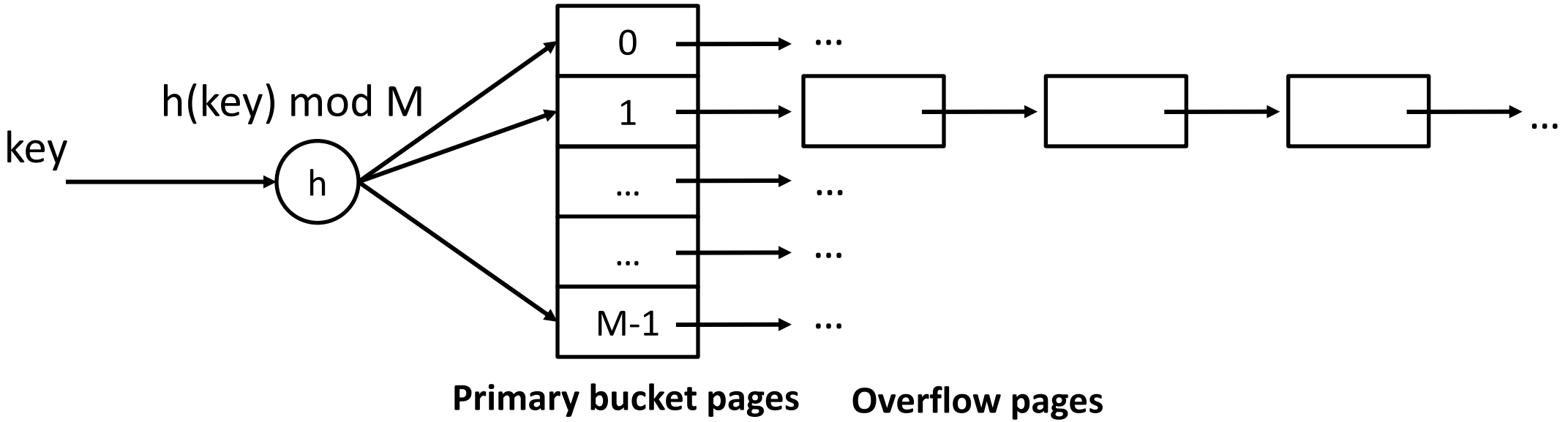
Must distribute values over range 0 ... M-1

What is a good hash function?

h(*key*) = (a * *key* + b) usually works well

a and b are constants; lots known about how to tune **h**

Static Hashing – Problems?



What does that do to performance?

Instead of O(1) we may go as bad as O(N)

Static Hashing – Solutions

Long overflow chains can develop and degrade performance

Ways to solve?

– Reorganization (re-hashing) is expensive and may block queries

– *Extendible* and *Linear Hashing*: Dynamic techniques to fix this problem

Hash Indexing

Static Hashing

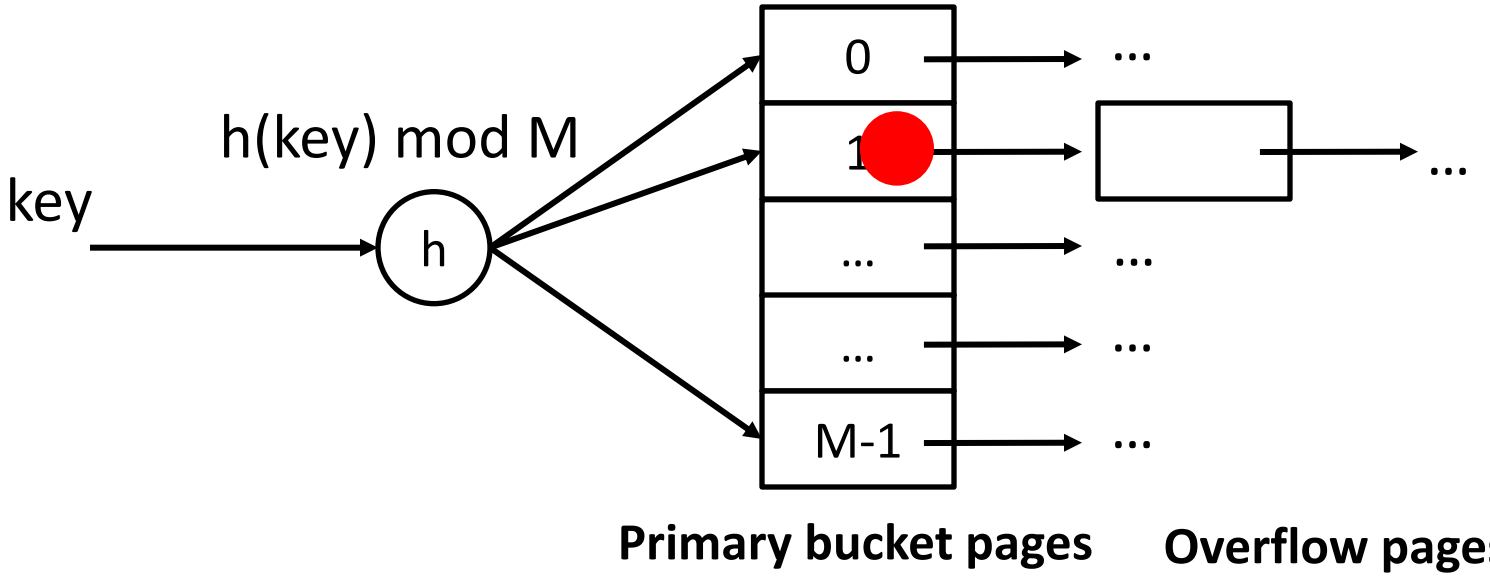
Extendible Hashing

Linear Hashing

Let's start from Static Hashing

What else we can do instead of adding an overflow page?

h(k) mod M = bucket to insert data entry with key *k* (M: #buckets)



Extendible Hashing

Why not **double** the **number** of buckets?

Note that reading and writing all pages is expensive!

Idea:

Use **directory of pointers** to buckets

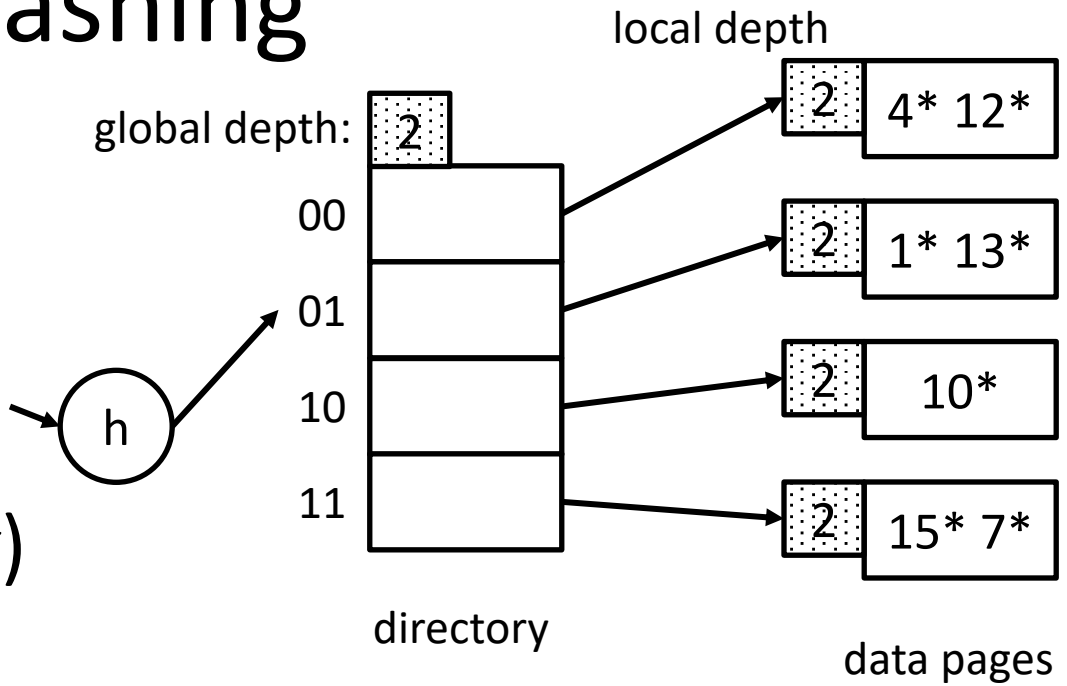
On overflow, **double only the directory** (not the # of buckets)

Why does this help?

- Directory is much smaller than the entire index file
- Only one page of data entries is split
- *No overflow page! (caveat: duplicates w.r.t. the hash function)*

Trick lies in how the hash function is adjusted!

Extendible Hashing



Directory: an array

Search for k:

– Apply hash function h(k)

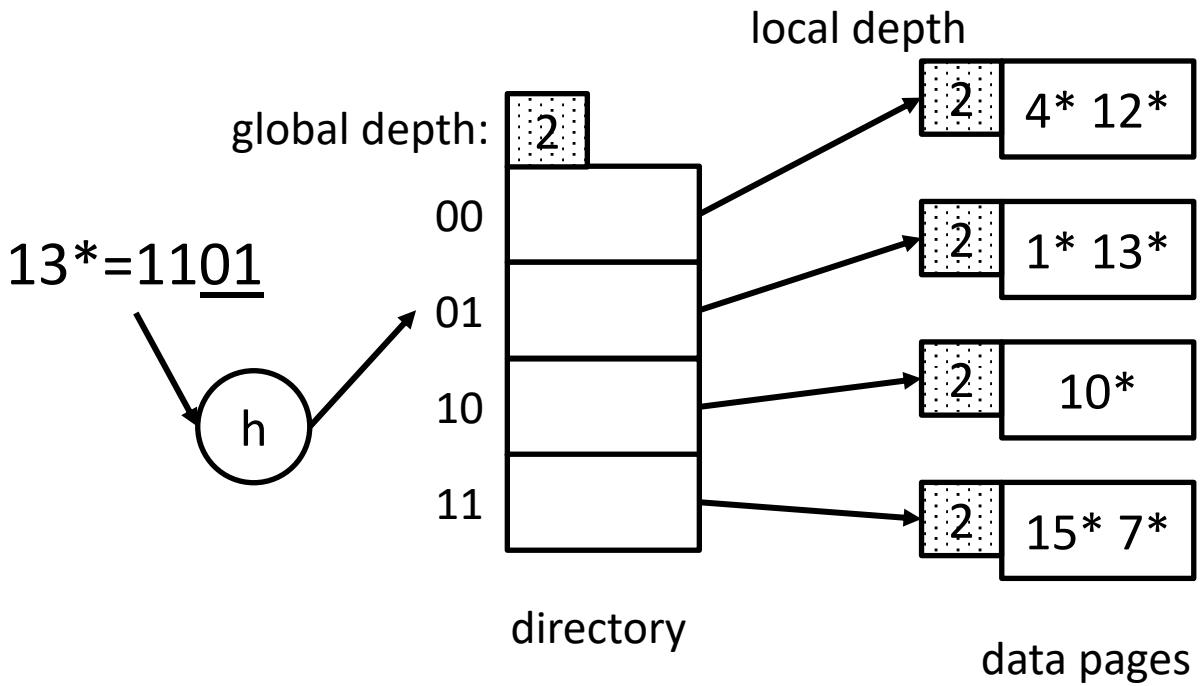
– Take last **global depth** # bits of **h**(*k*)

Insert:

– If the bucket has space, insert, done

– If the bucket if full, **split** it, re-distribute – If necessary, double the directory

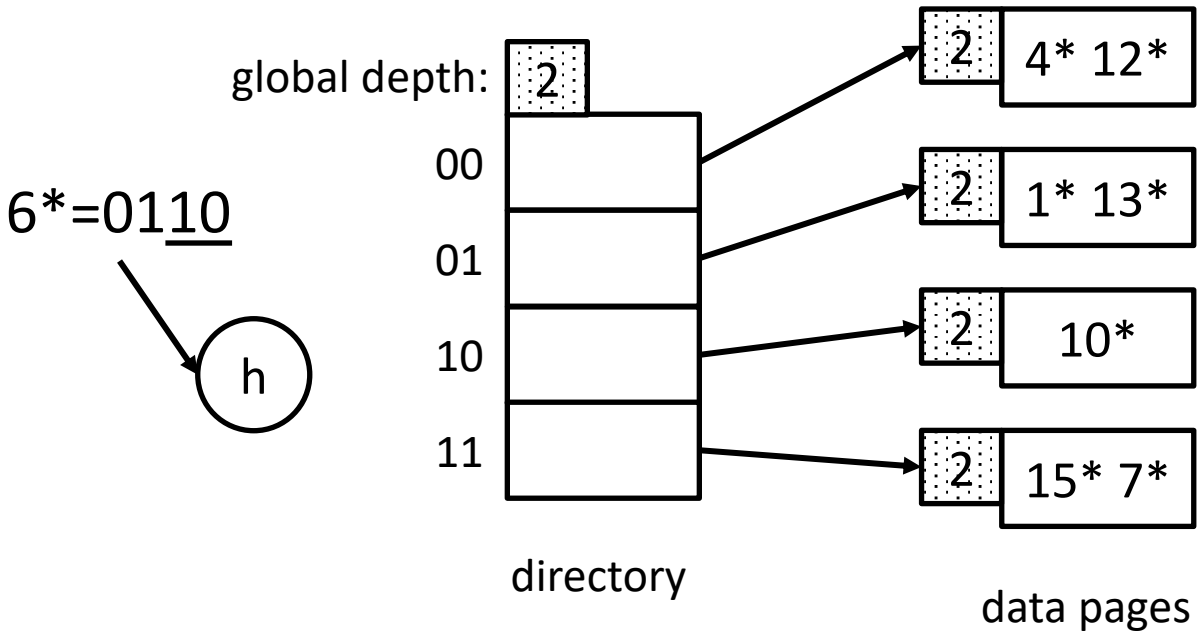
Example



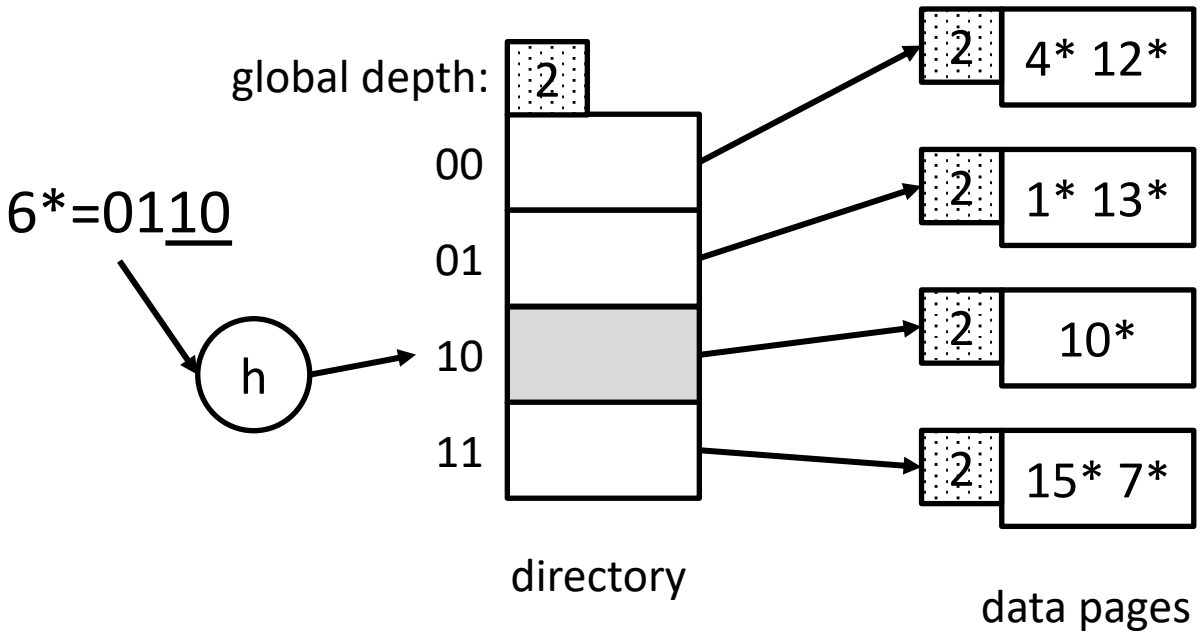
what is the hash function?

the last two bits! so: *k mod 4*

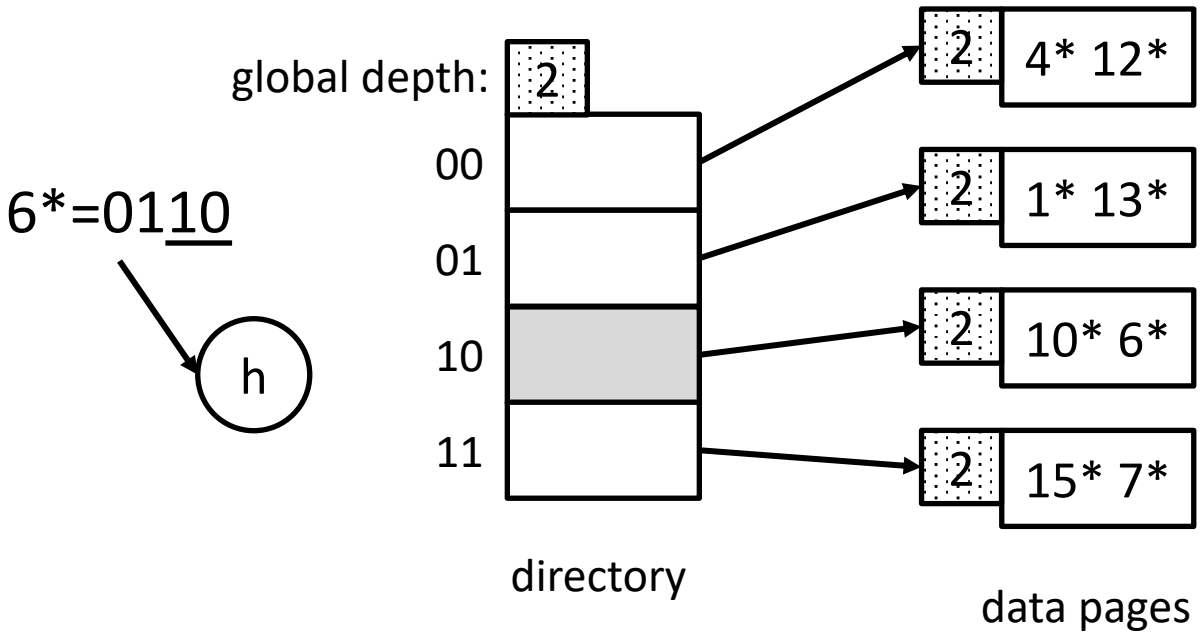
Example: Insert 6



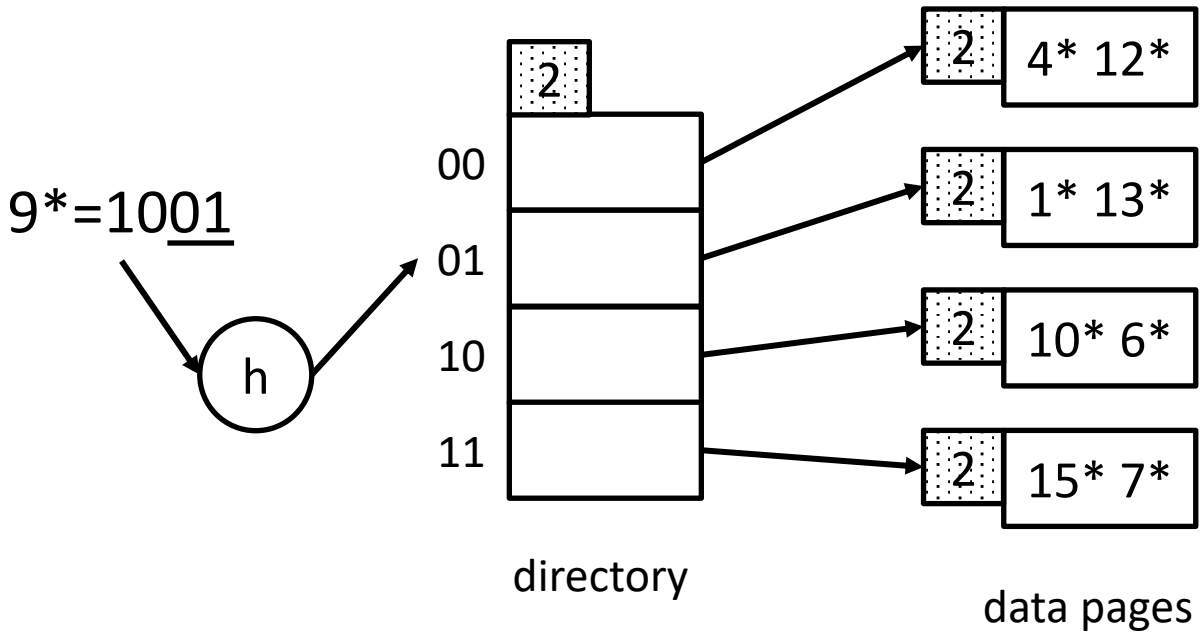
Example: Insert 6



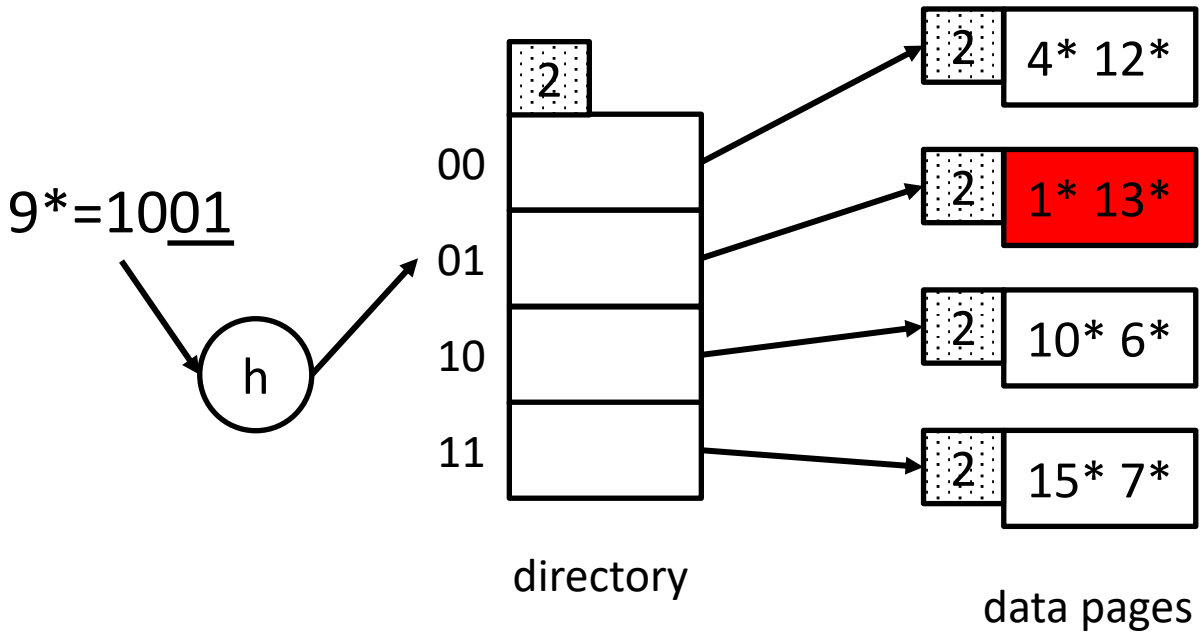
Example: Insert 6



Example 2: Insert 9

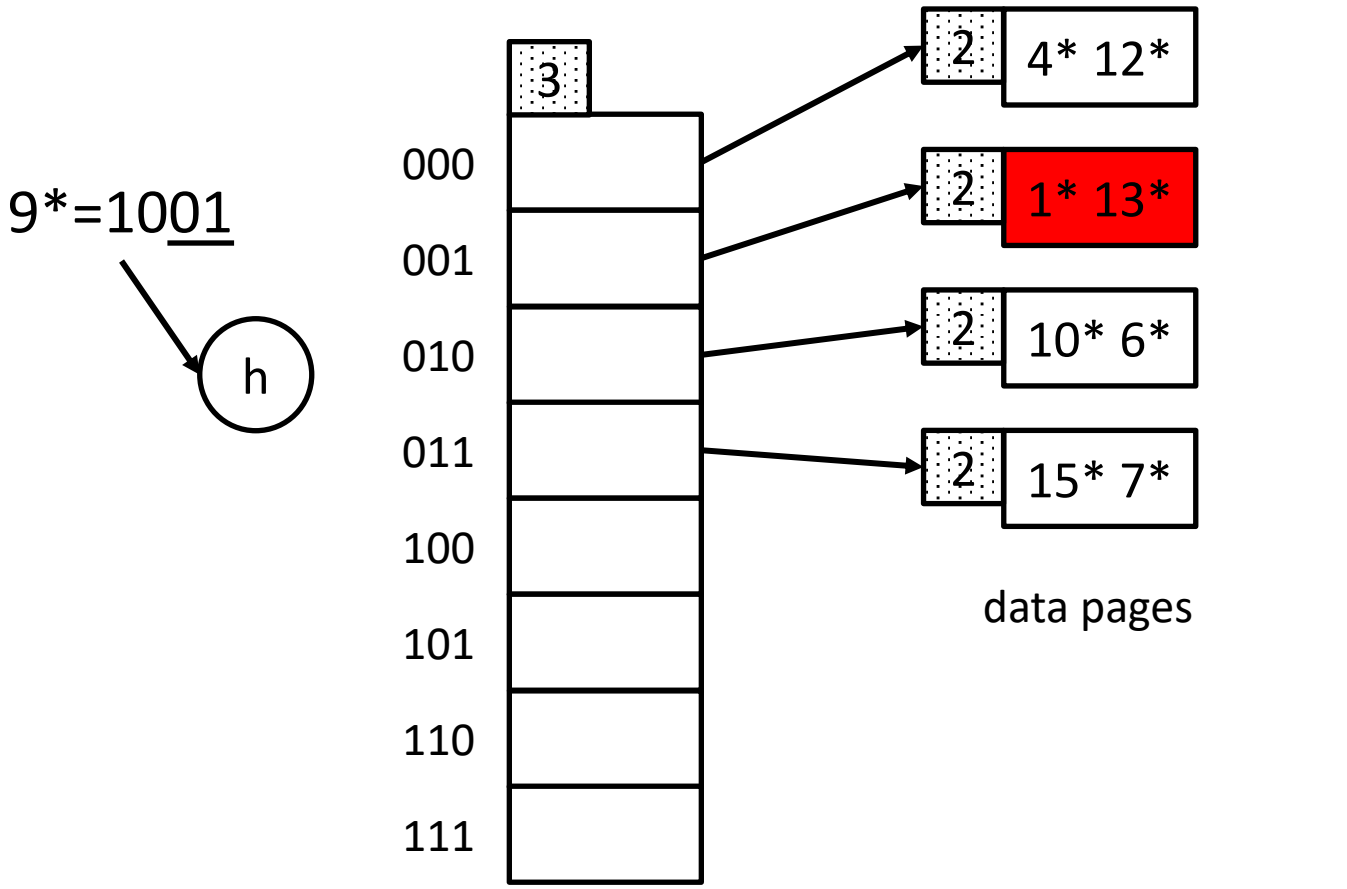


Example 2: Insert 9



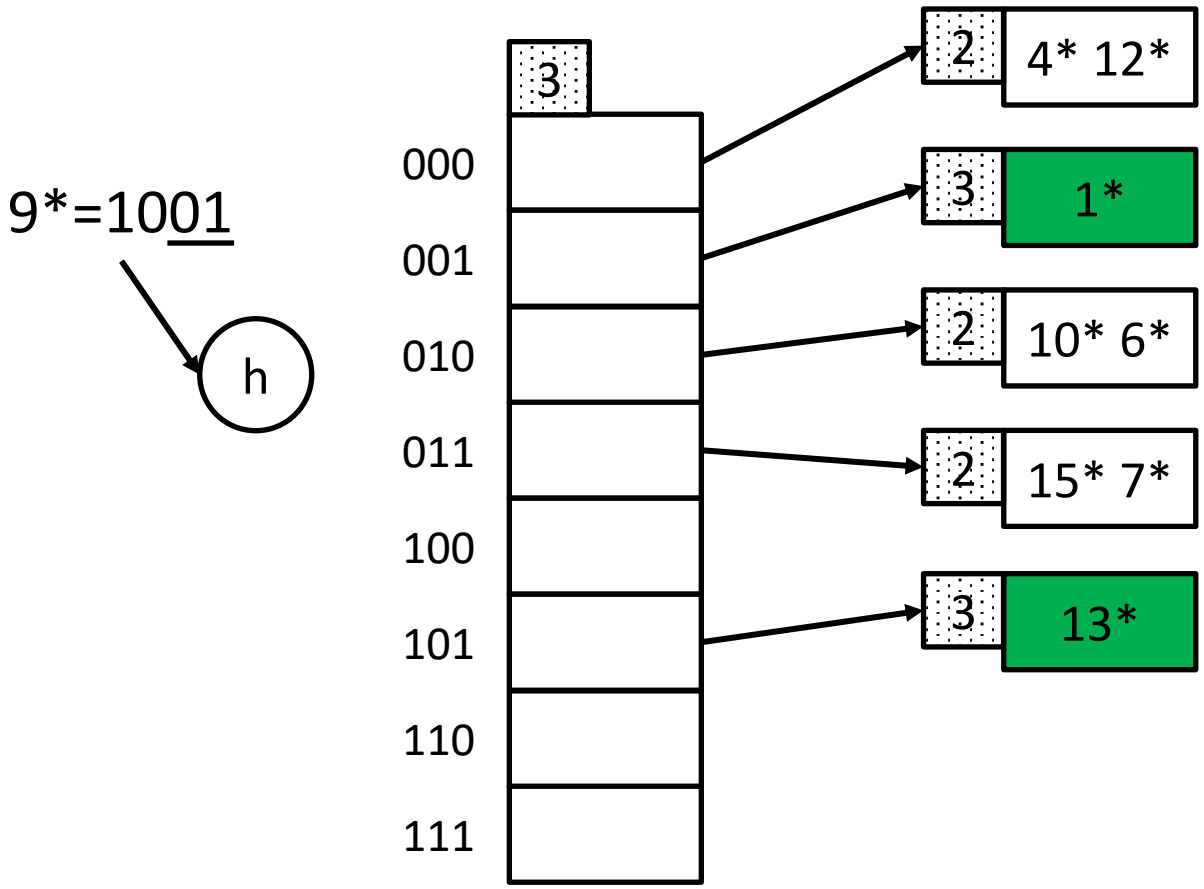
now what??

Example 2: Insert 9



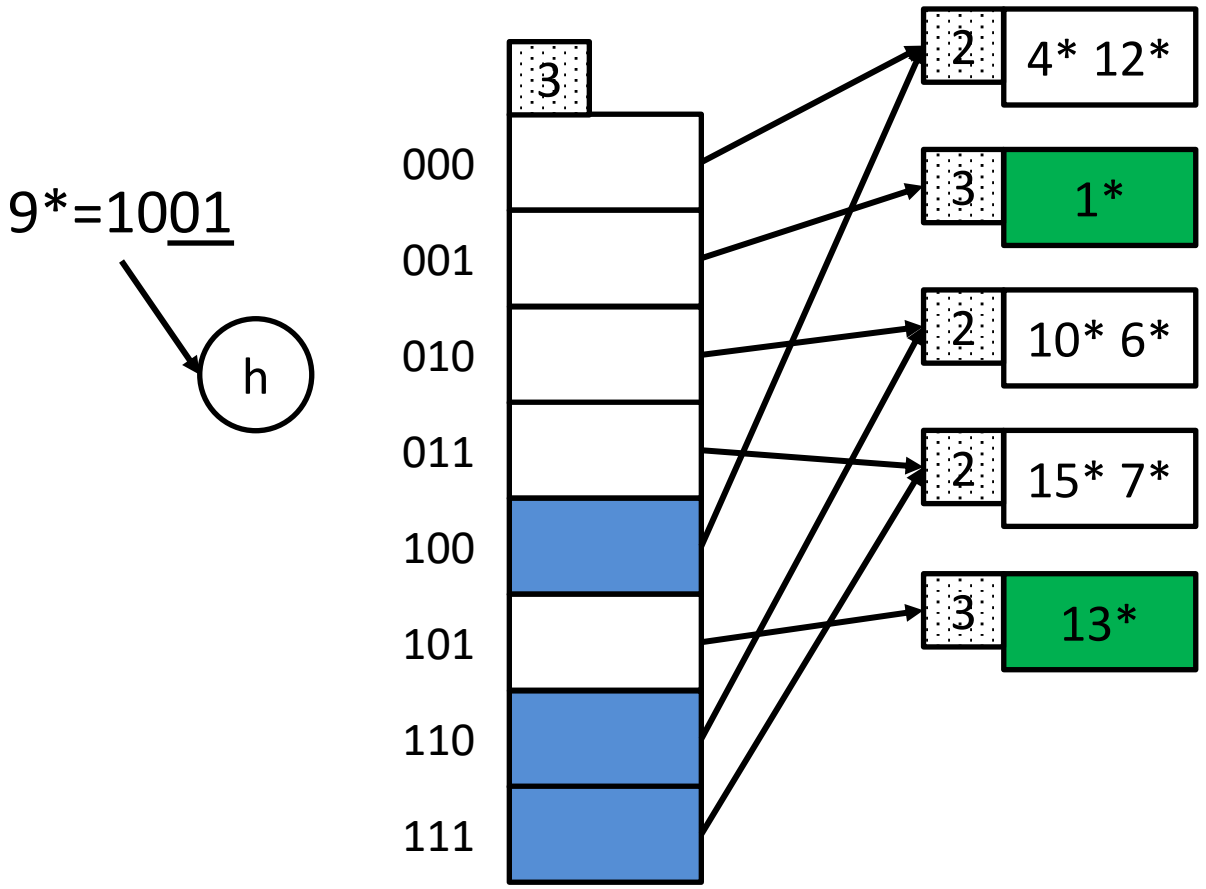
(1) double the directory

Example 2: Insert 9



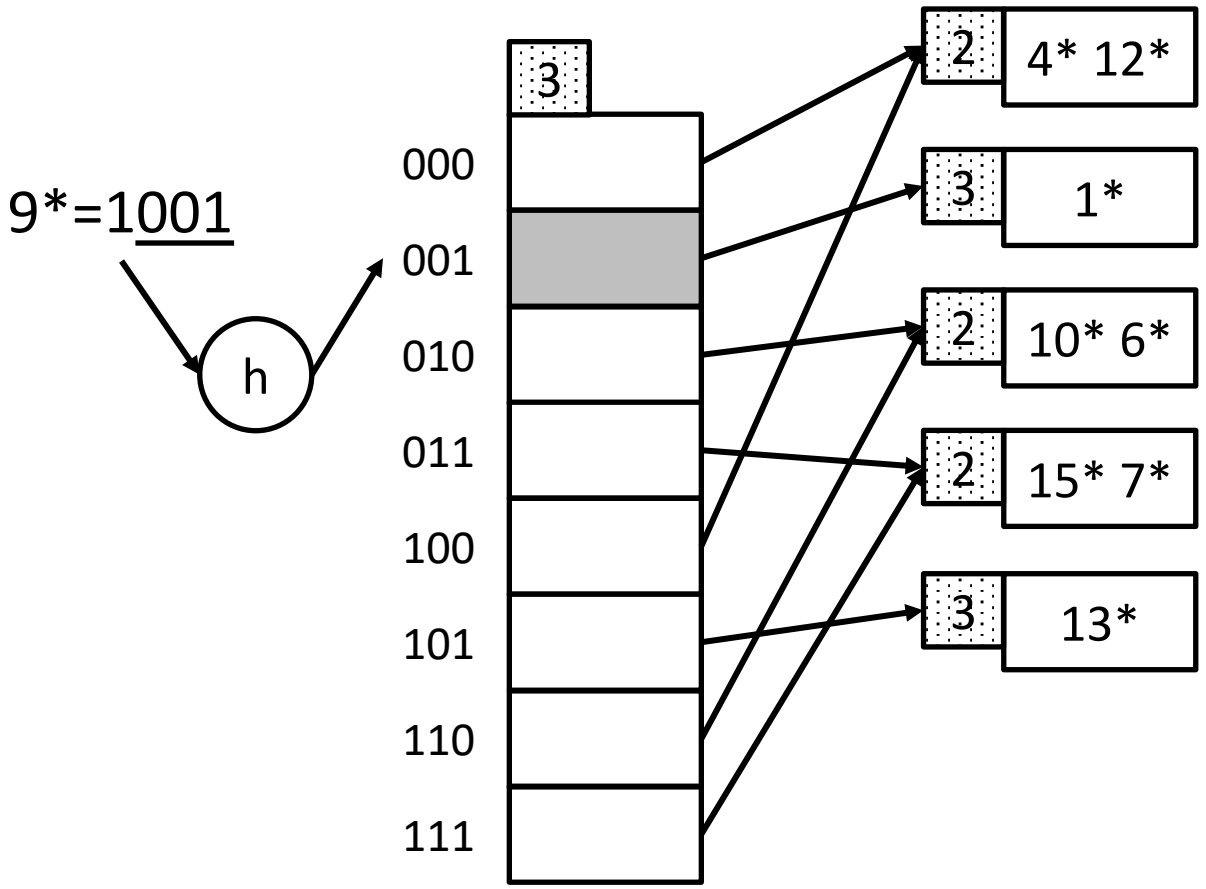
(1) double the directory
(2) re-distribute the split bucket

Example 2: Insert 9

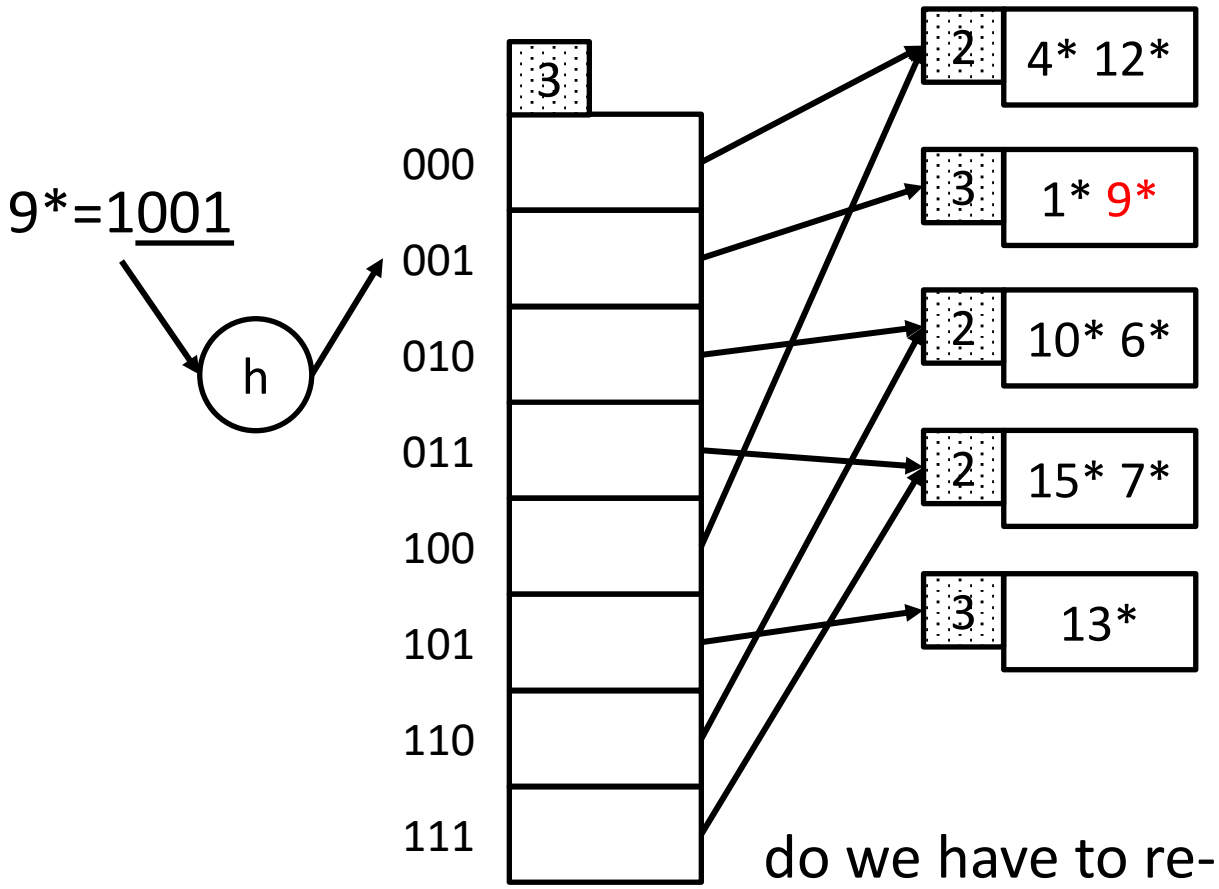


(1) double the directory
(2) re-distribute the split bucket
(3) connect corresponding buckets

Example 2: Insert 9

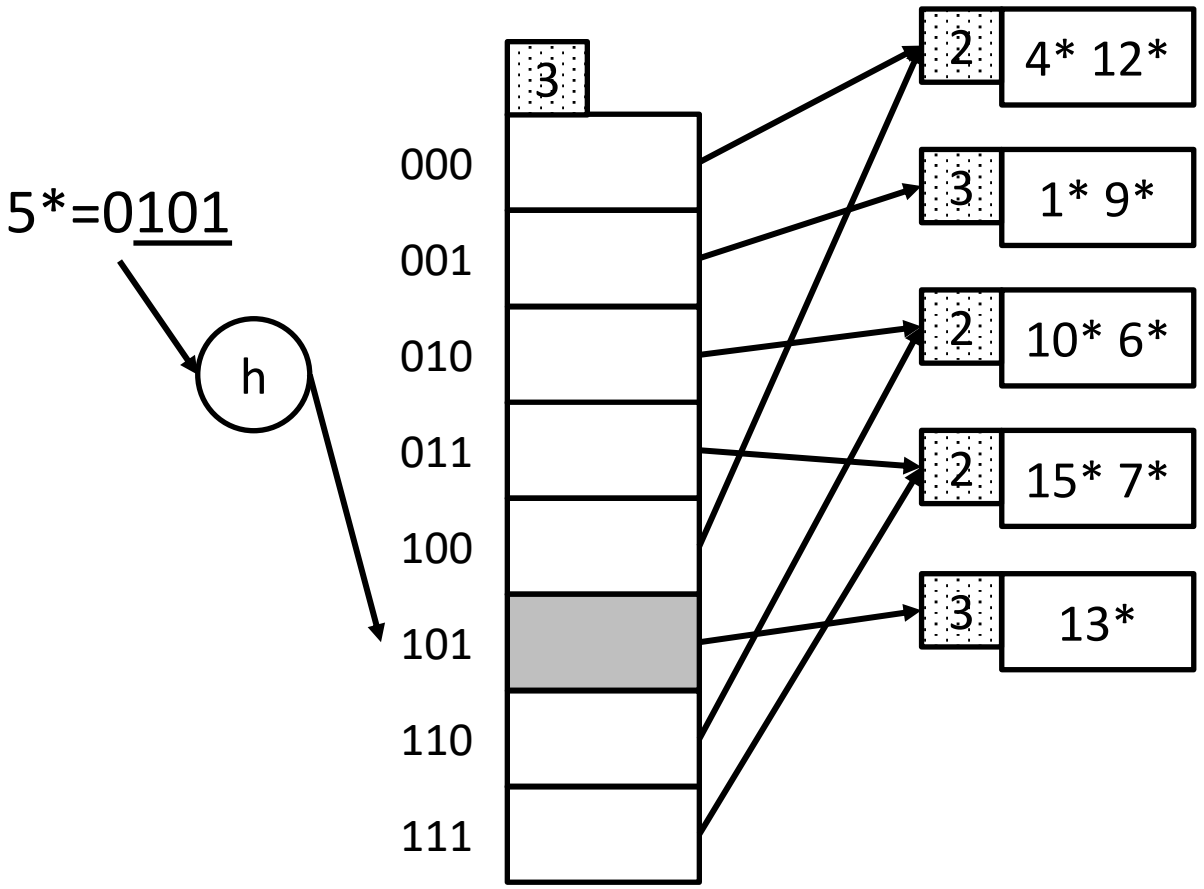


Example 2: Insert 9

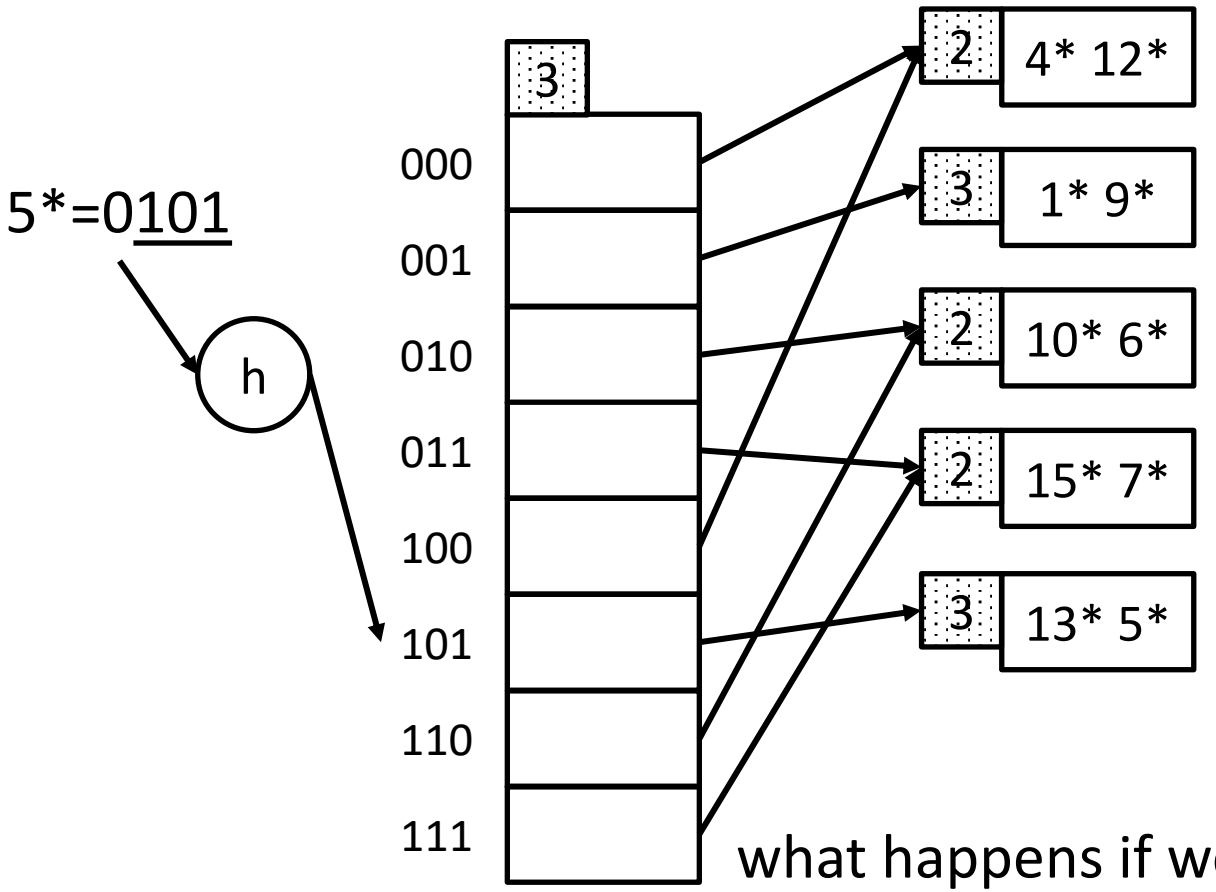


do we have to re-distribute all?

Example 3: Insert 5



Example 3: Insert 5

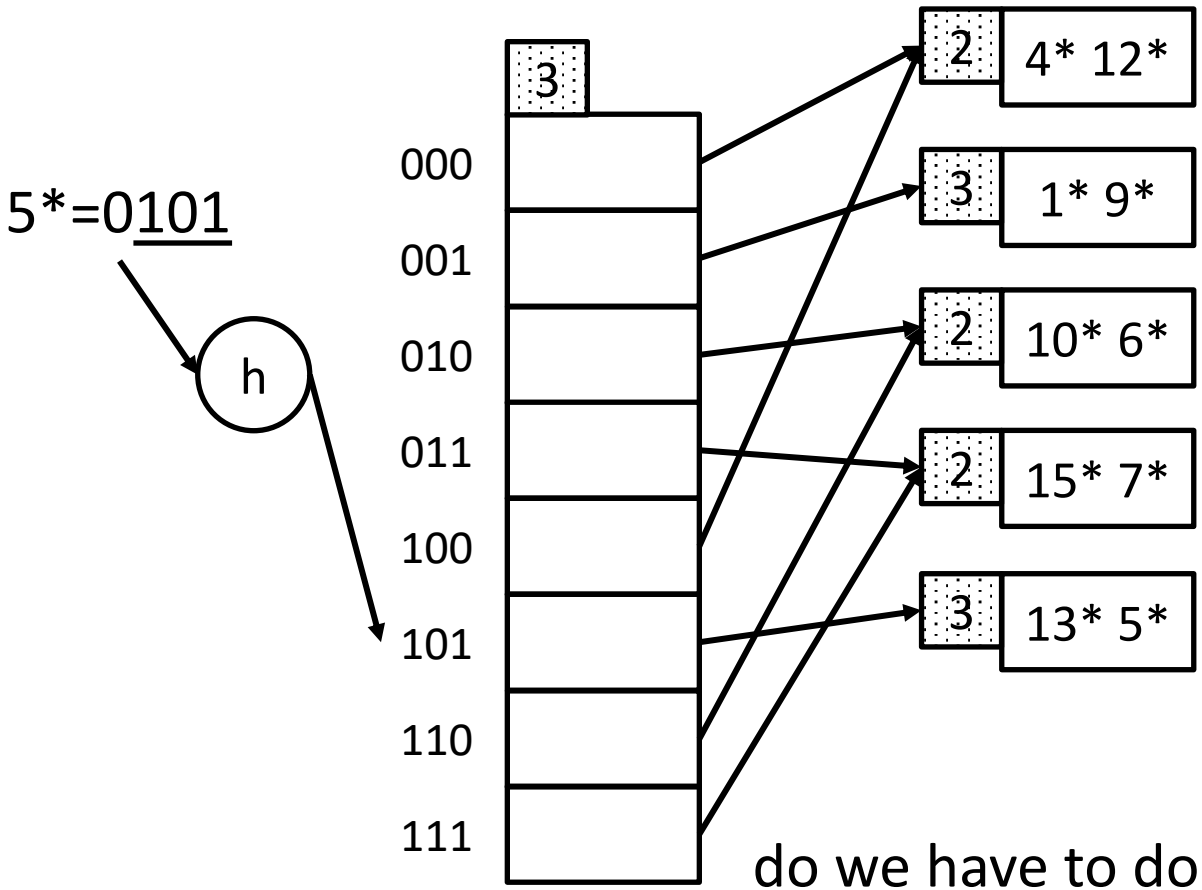


what happens if we want to insert 17?

do we have to re-distribute all?

[17→10001] so, double the dir again!

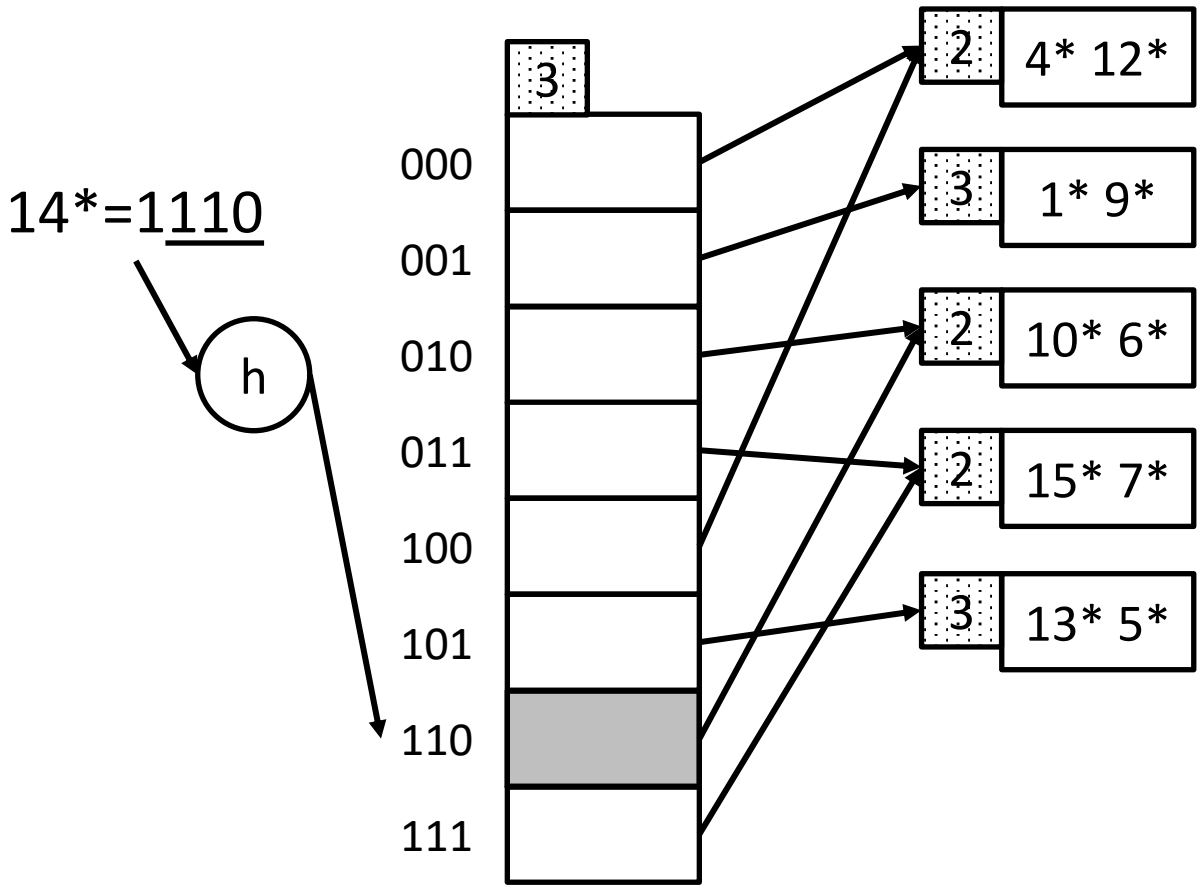
Example 3: Insert 5



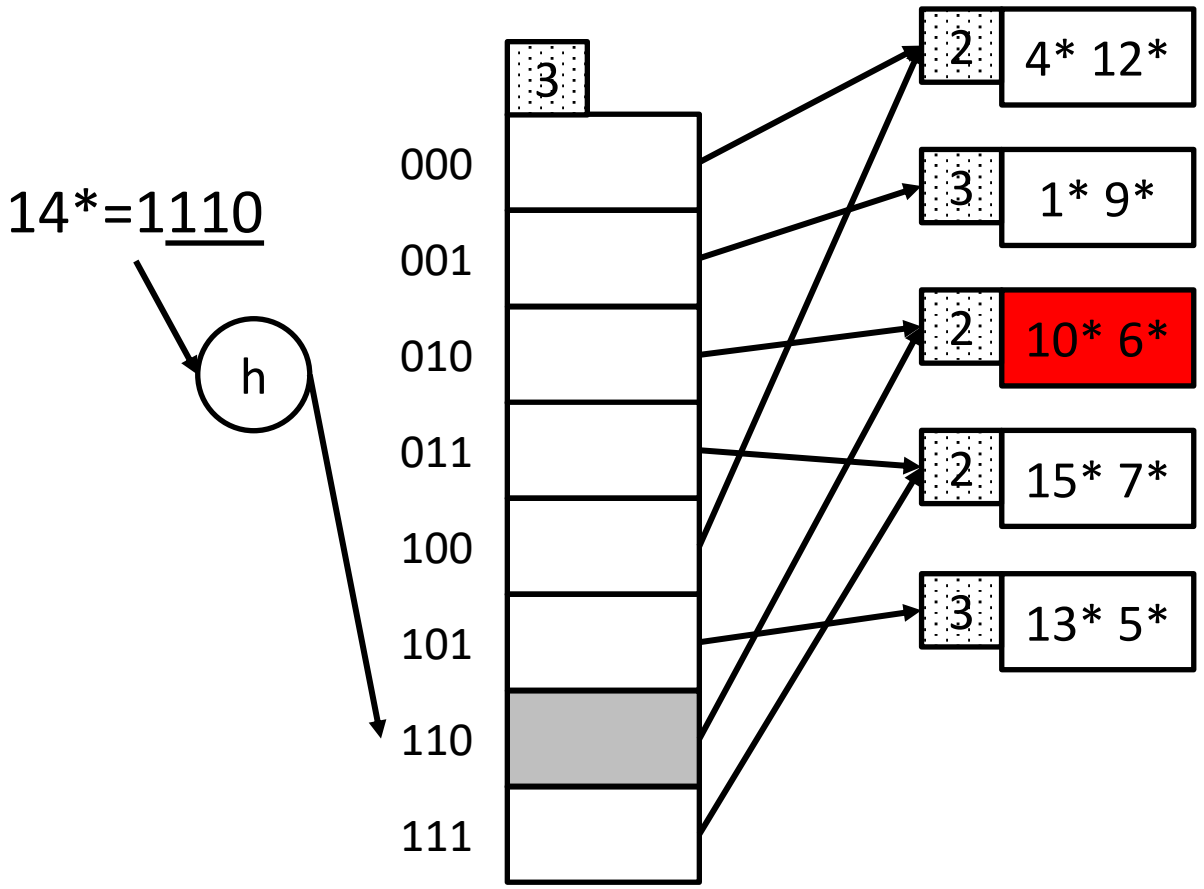
do we have to double the directory every time we split a bucket?

when?

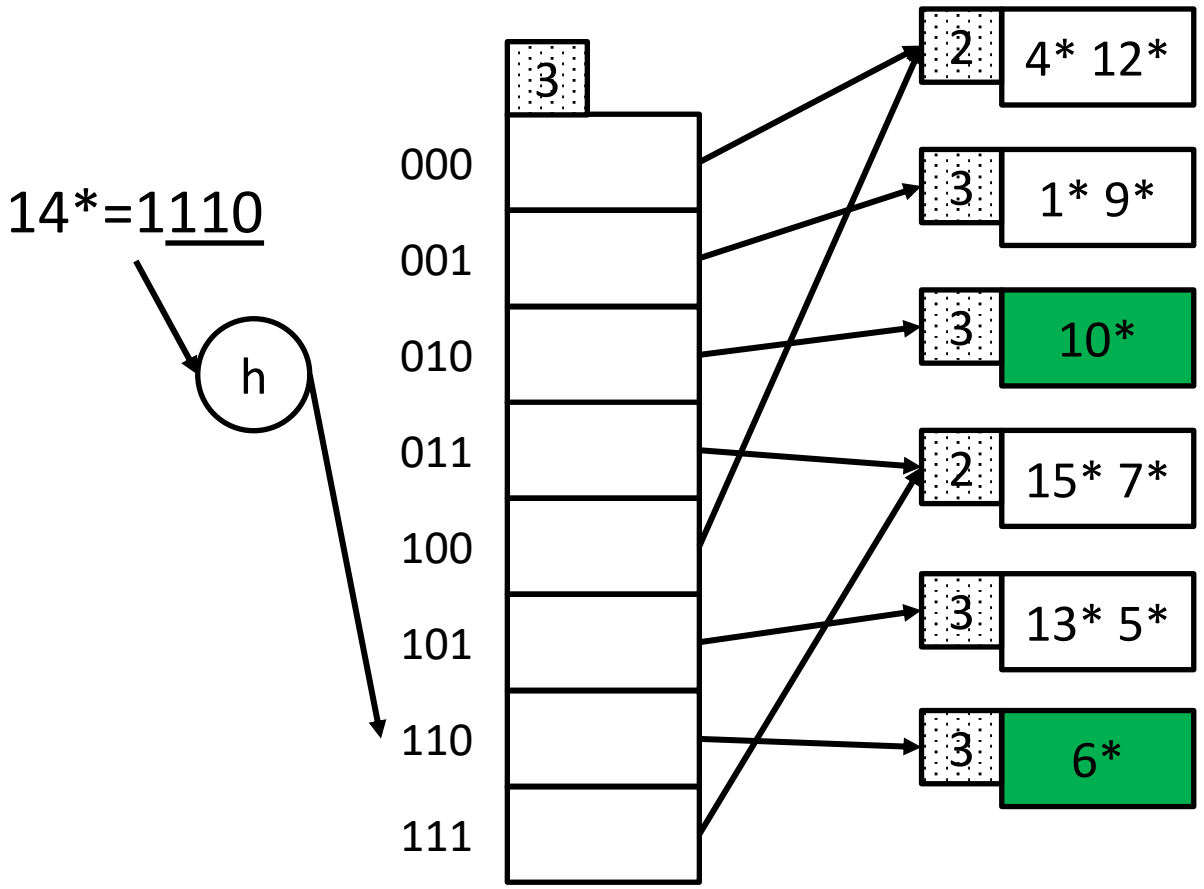
Example 3: Insert 14



Example 3: Insert 14



Example 3: Insert 14



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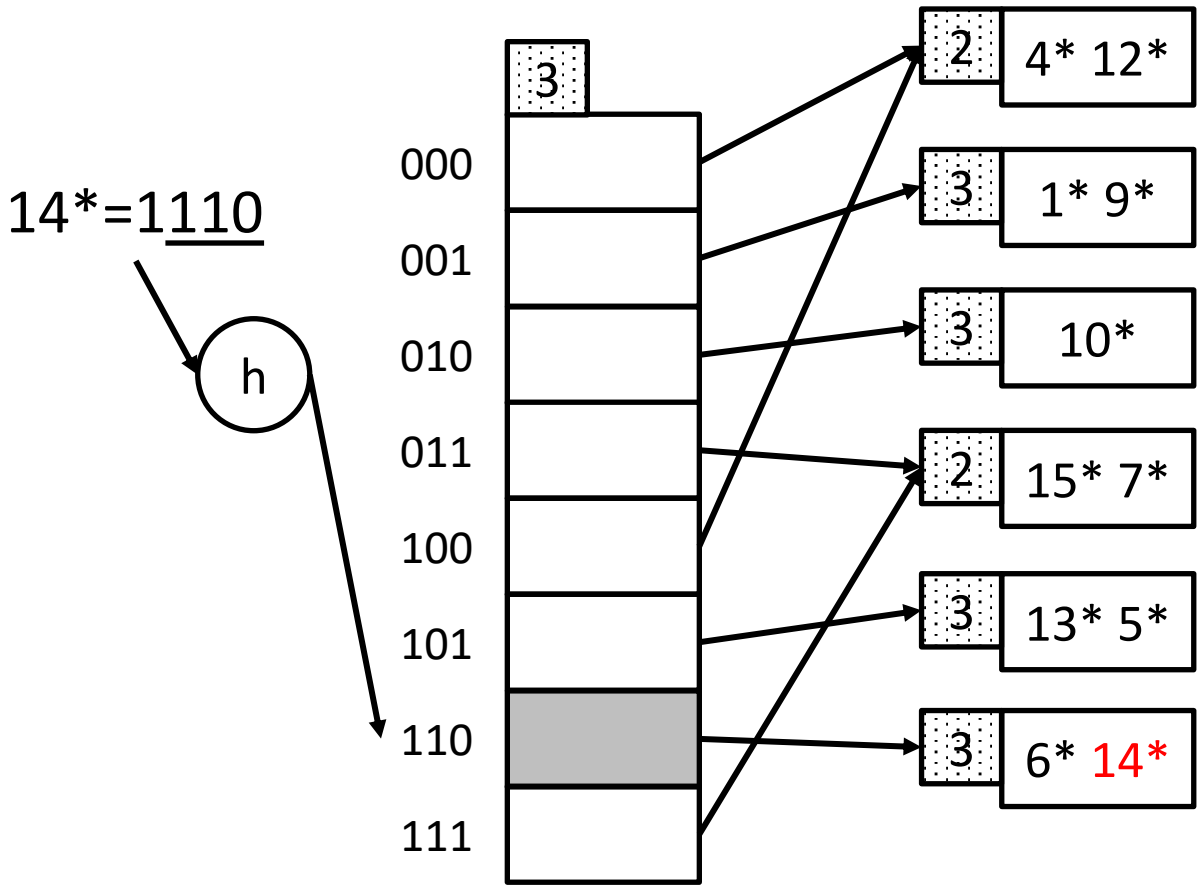


Notes on Extendible Hashing

How many disk accesses for equality search?

- One if directory fits in memory, else two

Directory grows in spurts, and, if the distribution *of hash values* is skewed, can grow large

Notes on Extendible Hashing

Do we ever need overflow pages?

- Multiple entries with same hash value cause problems!

Delete: Reverse of inserts

- Can merge with split image
- Can shrink the directory by half. When?

  Each directory element points to same bucket as its split image
- Is shrinking/merging a good idea?

Hash Indexing

Static Hashing

Extendible Hashing

Linear Hashing

Linear Hashing

another dynamic hashing scheme

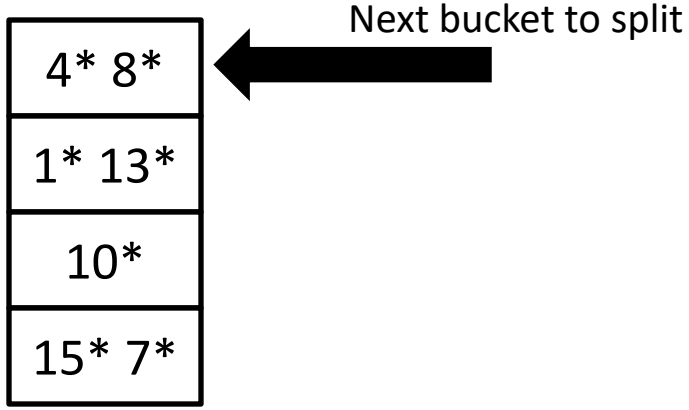
LH handles overflow chains without a directory

Idea: Use overflow pages, and split pages in a round-robin fashion

Example

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11



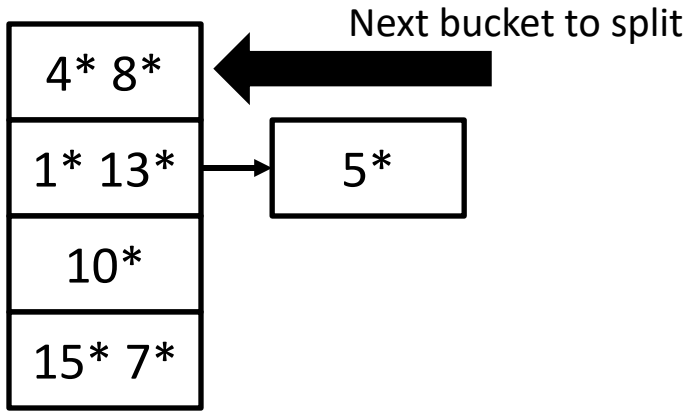
what happens when we insert 5?

$h_0(5) =$ 01

Example

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11



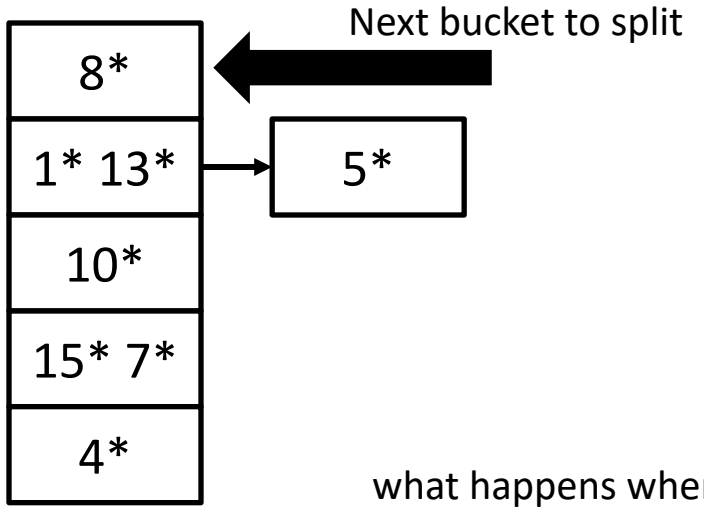
what happens when we insert 5?

(1) 5 goes to an overflow page

Example

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11
100	



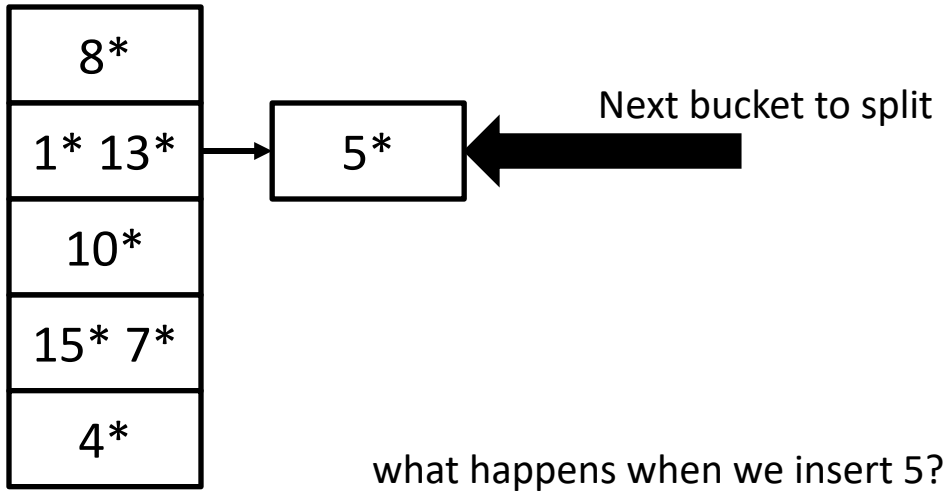
what happens when we insert 5?

(1) 5 goes to an overflow page
(2) we split the ”next” page

Example

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11
100	

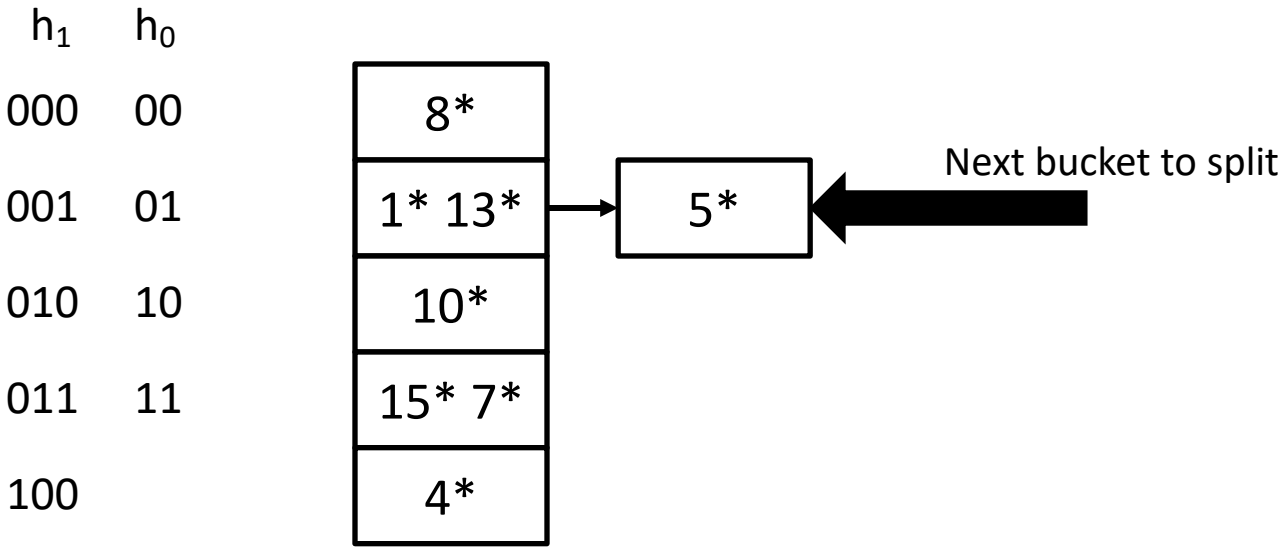


what happens when we insert 5?

(1) 5 goes to an overflow page
(2) we split the ”next” page
(3) we move the ”next” pointer

Example: Insert 2

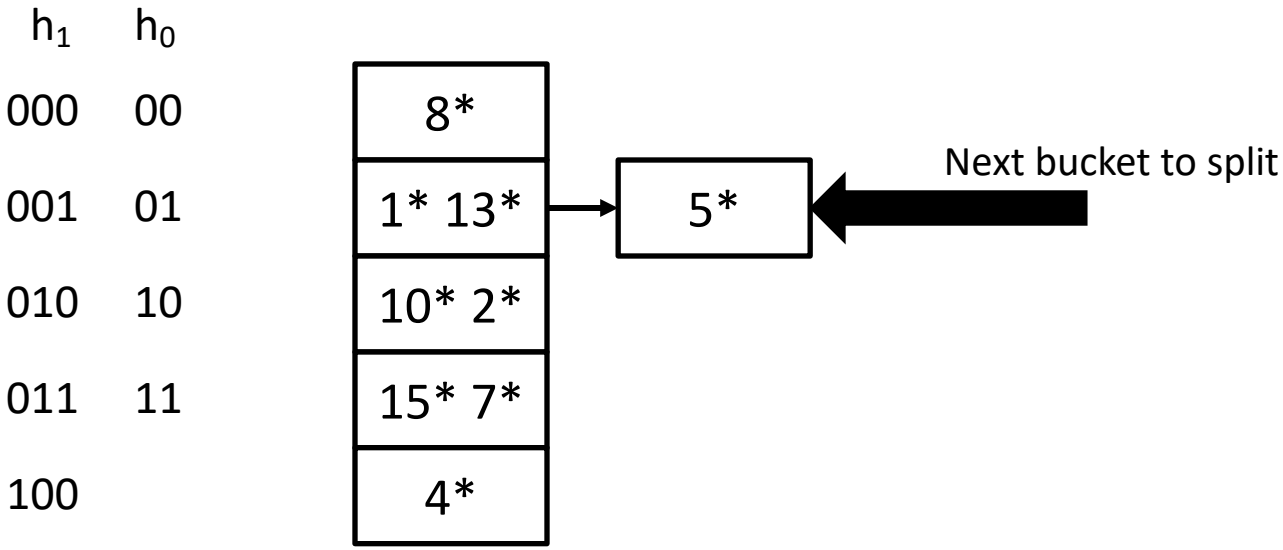
this for information reasons!
it is not really kept.



$h_0(2) = 10$

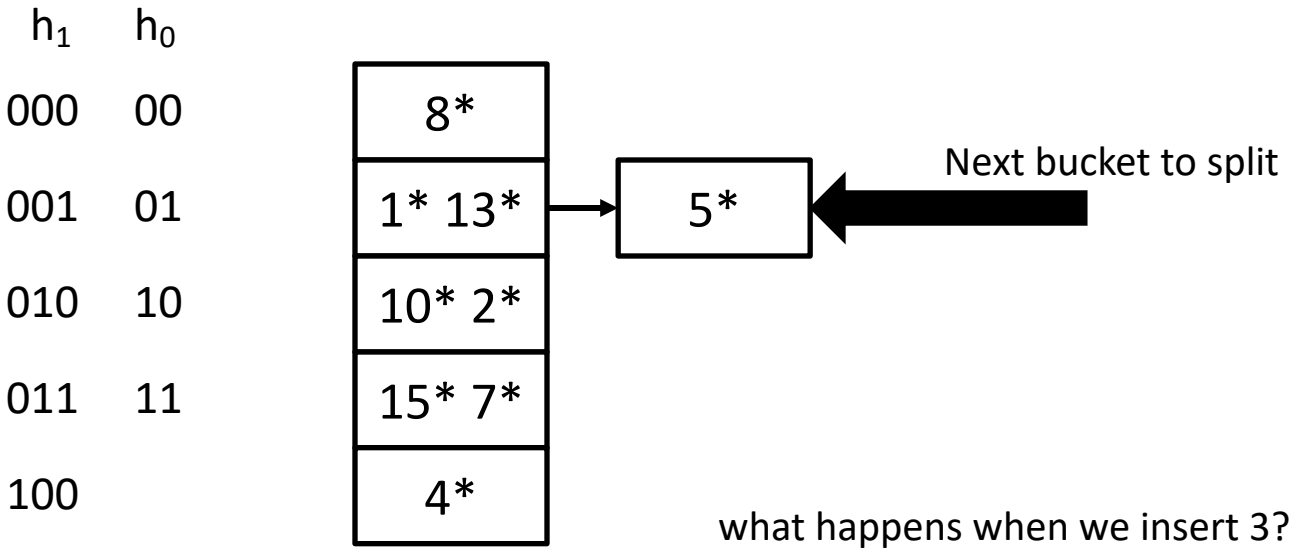
Example: Insert 2

this for information reasons!
it is not really kept.



Example: Insert 3

this for information reasons!
it is not really kept.

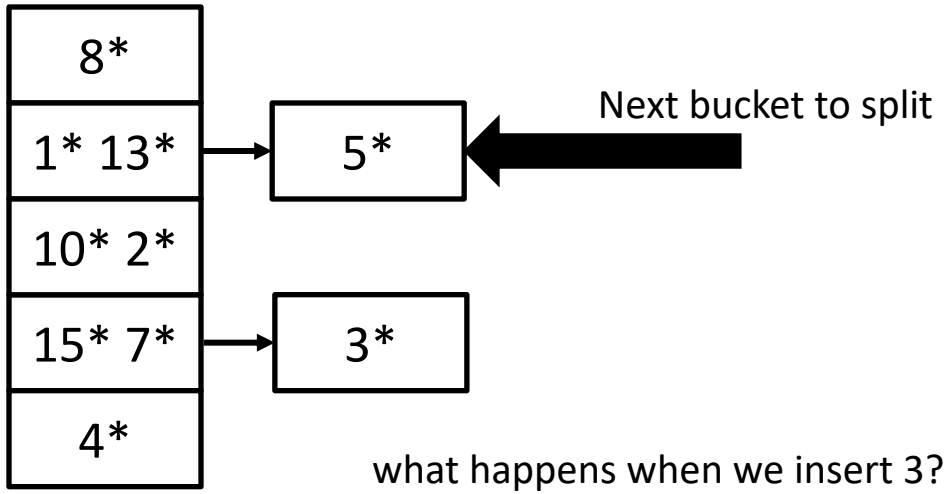


what happens when we insert 3? $h_0(3) = 11$

Example: Insert 3

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11
100	



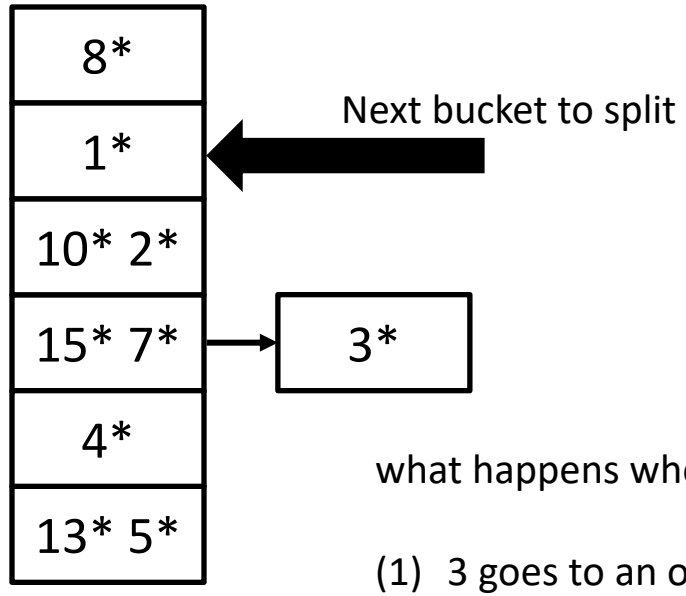
what happens when we insert 3?

(1) 3 goes to an overflow page

Example: Insert 3

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11
100	
101	



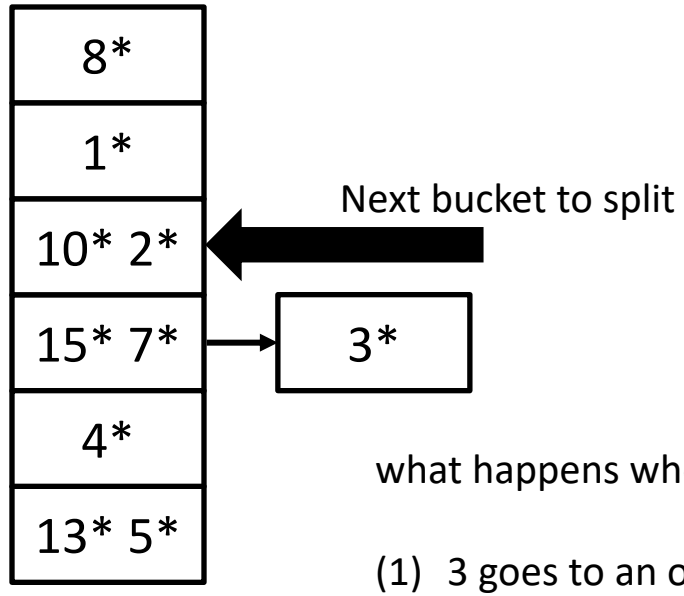
what happens when we insert 3?

(1) 3 goes to an overflow page
(2) we split the ”next” page

Example: Insert 3

this for information reasons!
it is not really kept.

h_1	h_0
000	00
001	01
010	10
011	11
100	
101	



what happens when we insert 3?

(1) 3 goes to an overflow page
(2) we split the ”next” page
(3) we move the ”next” pointer

Linear Hashing

h_0, h_1 ,h_2 … can be more general hash functions

when h_0 hits on a split buffer we employ h_1 and we have to look in both buffers

if the second is also split we use h_2 and so on

Benefit: buckets are split round-robin

→ no long chains

Hash Indexing

Hash indexes: best for **equality** searches

Static Hashing can lead to long **overflow chains**

Extendible Hashing

avoids overflow pages by splitting a bucket when full
directory to keep track of buckets
BUT dir. can get too large (>memory) when data is skewed

Linear Hashing

avoids directory by splitting buckets round-robin
uses overflow pages
overflow pages not likely to be long