ICS 421 Spring 2010
Indexing (2)

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Hash Indexes

- *As for any index, 3 alternatives for data entries* **k***:
  - Data record with key value **k**
  - <**k**, rid of data record with search key value **k**>
  - <**k**, list of rids of data records with search key **k**>
  - Choice orthogonal to the *indexing technique*
- *Hash-based* indexes are best for *equality selections*. ***Cannot*** support range searches.
- Static and dynamic hashing techniques exist; trade-offs similar to ISAM vs. B+ trees.

The Hashing Idea (i)

key | data

DOW Number	DOW String
1	Monday
2	Tuesday
3	Wednesday
4	Thursday
5	Friday
6	Saturday
7	Sunday

How do we get the day of the week (DOW) string from the DOW number ?

```
String DOWstring[8] = {   "invalid",
                          "Monday",
                          "Tuesday",
                          "Wednesday",
                          "Thursday",
                          "Friday",
                          "Saturday",
                          "Sunday" };
```

```
Print ( "Day 4 of the week is " + DOWstring[4] );
```

- What if we want to use an array of 7 slots ?
- Essential idea: get an array index/address directly from the key field

The Hashing Idea (ii)

data | Key

DOW Number	DOW String
1	Monday
2	Tuesday
3	Wednesday
4	Thursday
5	Friday
6	Saturday
7	Sunday

How do we get the numeric day of the week (DOW) from the DOW string ?

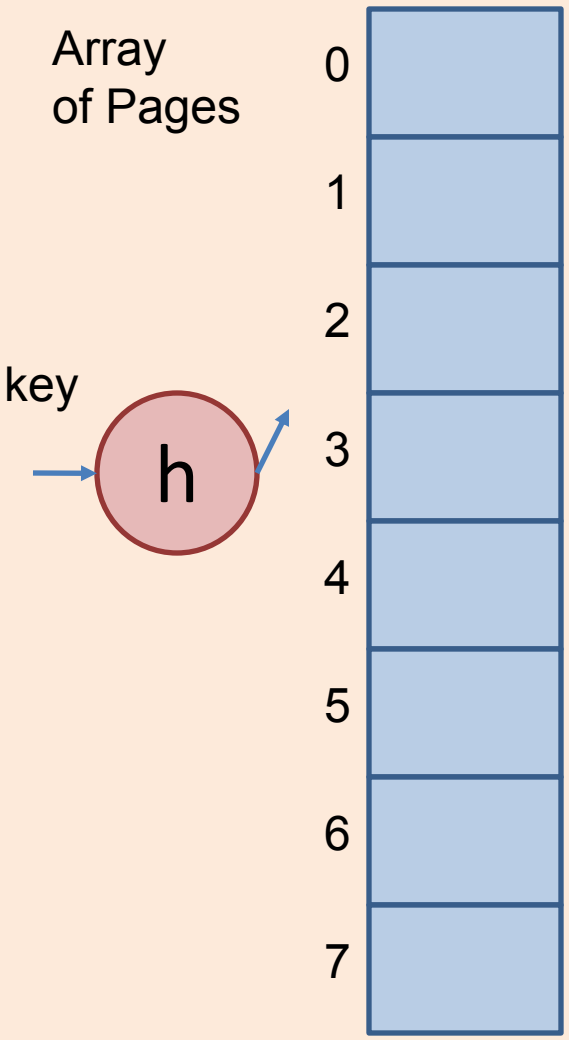
```
Int hashfn(string day) {
    foreach i do sum += day[i]
    return sum % 7;      }

String DOWnum[7];

DOWnum[hashfn("Monday")] = 1;
DOWnum[hashfn("Tuesday")] = 2;
…
Print ( "Monday is day " +
DOWnum[hashfn("Monday")] + " of the week );
```

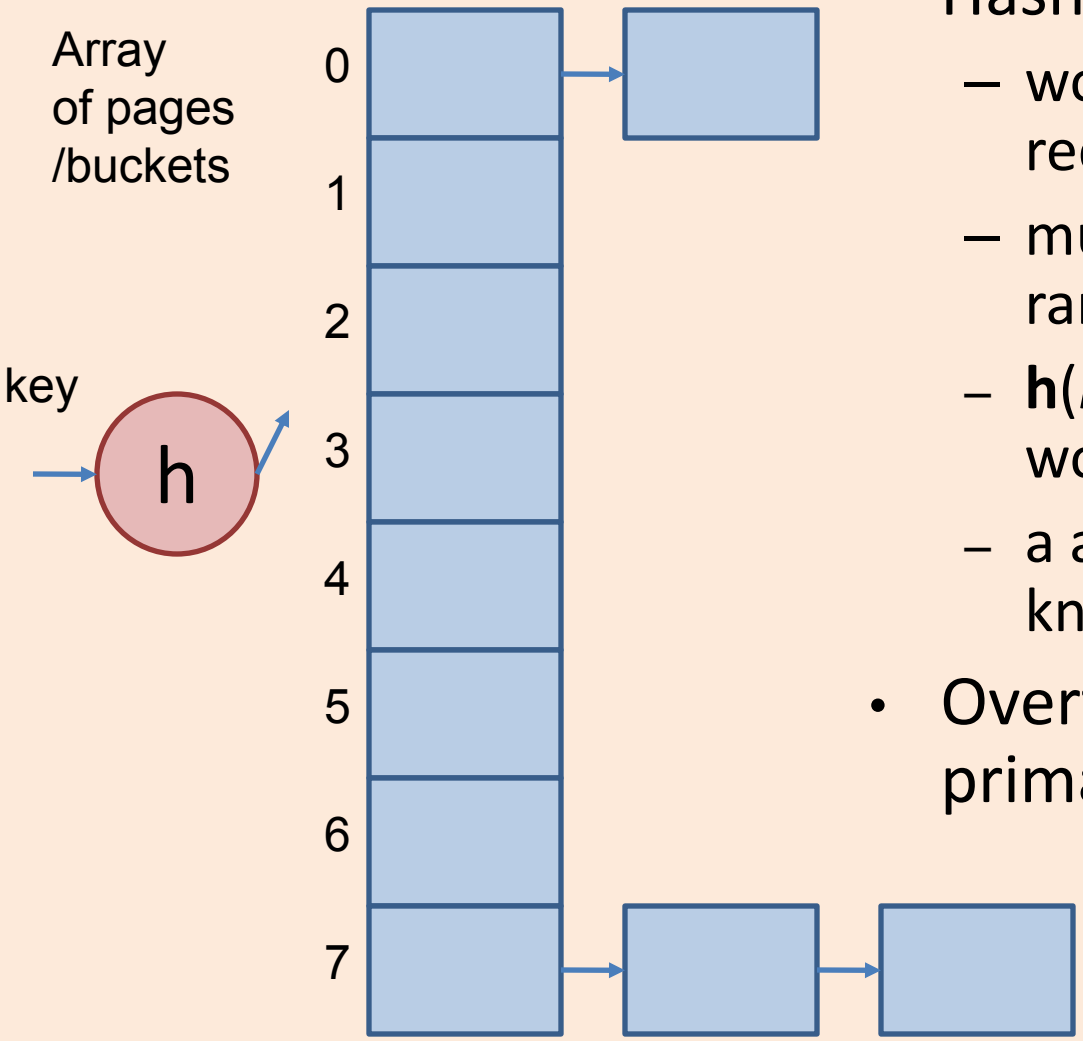
- What do we do if two strings map to the same hash value ?

Hash Indexes in Databases



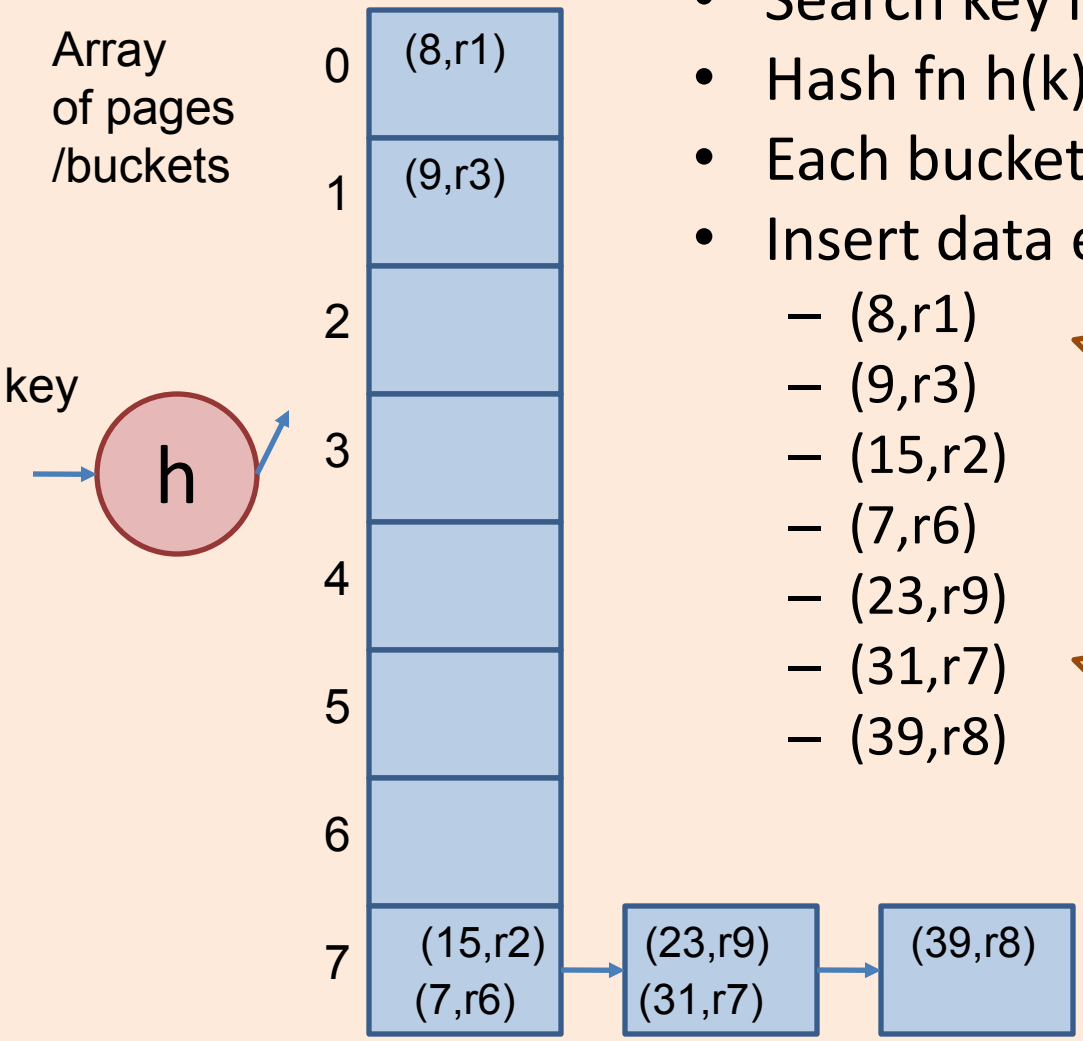
- Conceptually an array of pages or buckets
- h(k) mod M = bucket ID for key k
- M is the number of buckets in array
- *Data entries* **k***:
  - Data record with key value **k**
  - <**k**, rid of data record with search key value **k**>
  - <**k**, list of rids of data records with search key **k**>
  - Choice orthogonal to the *indexing technique*
- *Hash-based* indexes are best for *equality selections*. ***Cannot*** support range searches.

Static Hashing



- Hash fn
  - works on *search key* field of record *r.*
  - must distribute values over range 0 ... M-1.
  - **h**(*key*) = (a * *key* + b) usually works well.
  - a and b are constants; lots known about how to tune **h**.
- Overflow buckets used when primary buckets are full

Example : Static Hashing



- Search key is Sailors.age
- Hash fn h(k) = k mod 8
- Each bucket/page can hold 2 entries
- Insert data entries
  - (8,r1)
  - (9,r3)
  - (15,r2)
  - (7,r6)
  - (23,r9)
  - (31,r7)
  - (39,r8)

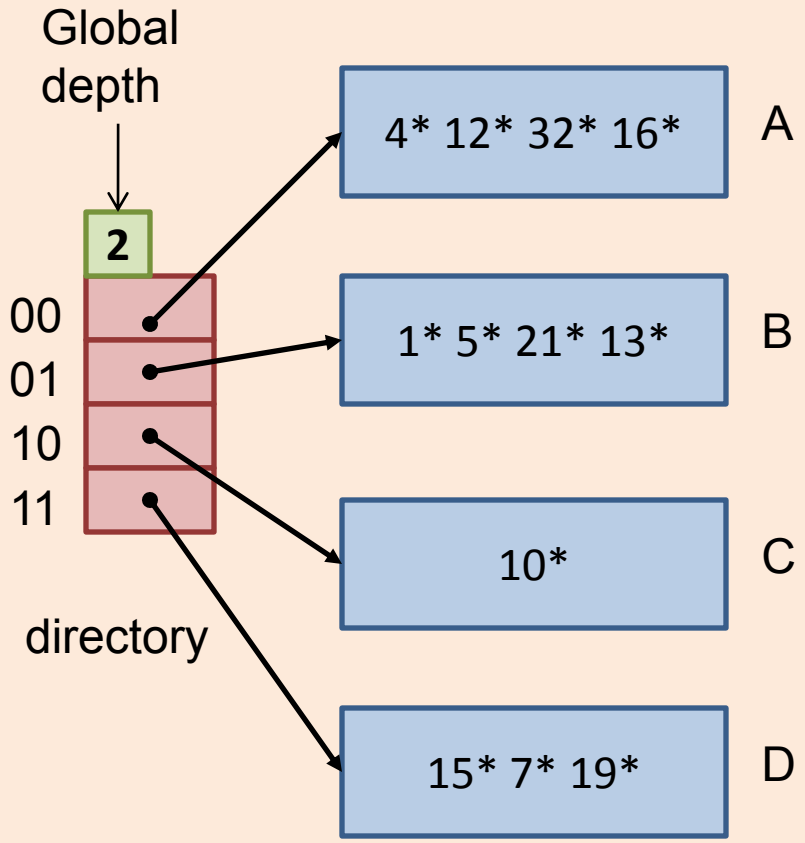
How many page IOs do i need to find RIDs of sailors aged 8?

How many page IOs do i need to find RIDs of sailors aged 31?

Extendible Hashing

- Situation: Bucket (primary page) becomes full. Why not re-organize file by *doubling* # of buckets?
  - Reading and writing all pages is expensive!
  - *Idea*: Use *directory of pointers to buckets,* double # of buckets by *doubling the directory,* splitting just the bucket that overflowed!
  - Directory much smaller than file, so doubling it is much cheaper. Only one page of data entries is split. *No overflow page*!
  - Trick lies in how hash function is adjusted!

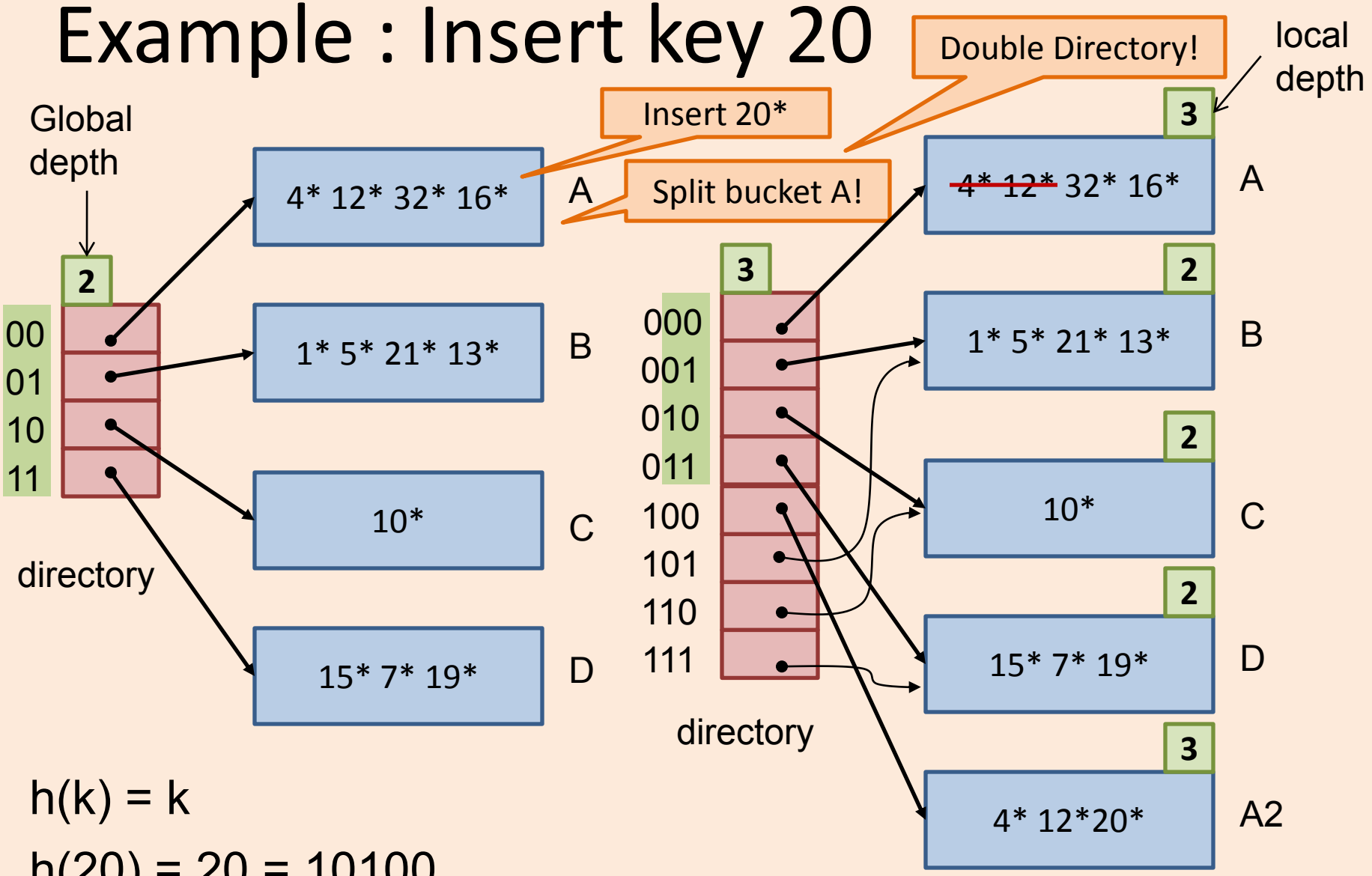
Example : Extendible Hashing



h(k) = k

- Directory is array of size 4.
- Each bucket holds 4 entries.
- To find bucket for *r*, take last `*global depth*' # bits of **h**(*r*); we denote *r* by **h**(*r*).
  - If **h**(*r*) = 5 = binary 101, it is in bucket pointed to by 01.
- **Insert**: If bucket is full, *split* it (*allocate new page, re-distribute*).
- If necessary, double the directory.

Example : Insert key 20



h(k) = k

h(20) = 20 = 10100

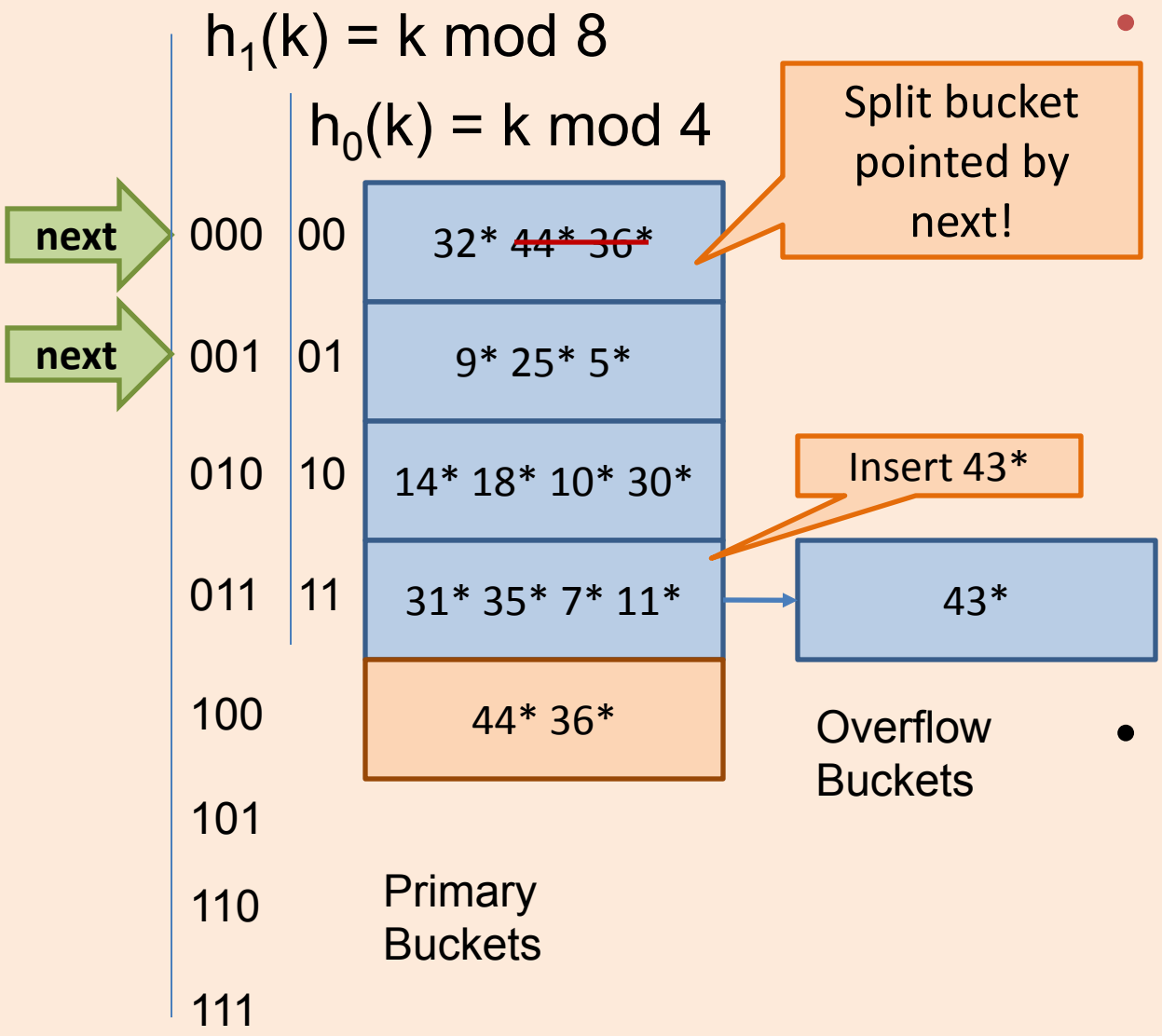
Points to Note

- 20 = binary 10100. Last **2** bits (00) tell us *r* belongs in A or A2. Last **3** bits needed to tell which.
  - *Global depth of directory*: Max # of bits needed to tell which bucket an entry belongs to.
  - *Local depth of a bucket*: # of bits used to determine if an entry belongs to this bucket.
- When does bucket split cause directory doubling?
  - Before insert, *local depth* of bucket = *global depth*. Insert causes *local depth* to become > *global depth*; directory is doubled by *copying it over* and `fixing' pointer to split image page. (Use of least significant bits enables efficient doubling via copying of directory!)
- If directory fits in memory, equality search answered with one disk access; else two.

Linear Hashing

- This is another dynamic hashing scheme, an alternative to Extendible Hashing.
- LH handles the problem of long overflow chains without using a directory, and handles duplicates.
- *Idea*: Use a family of hash functions $\mathbf{h}_0$, $\mathbf{h}_1$, $\mathbf{h}_2$, ...
  - $\mathbf{h}_i(key) = \mathbf{h}(key) \bmod (2^i N)$; N = initial # buckets
  - **h** is some hash function (range is *not* 0 to N-1)
  - If $N = 2^{d0}$, for some *d0*, $\mathbf{h}_i$ consists of applying **h** and looking at the last *di* bits, where *di* = *d0* + *i*.
  - $\mathbf{h}_{i+1}$ doubles the range of $\mathbf{h}_i$ (similar to directory doubling)

Example: Linear Hashing



- **Insert**: Find bucket by applying $\mathbf{h}_{Level}$ / $\mathbf{h}_{Level+1}$:
  - If bucket to insert into is full:
  - Add overflow page and insert data entry.
  - (*Maybe*) Split *Next* bucket and increment *Next*.
- Since buckets are split round-robin, long overflow chains don't develop!

Summary

- Hash-based indexes: best for equality searches, cannot support range searches.
- Static Hashing can lead to long overflow chains.
- Extendible Hashing avoids overflow pages by splitting a full bucket when a new data entry is to be added to it. (*Duplicates may require overflow pages.*)
  - Directory to keep track of buckets, doubles periodically.
  - Can get large with skewed data; additional I/O if this does not fit in main memory.

Summary (Cont.)

- Linear Hashing avoids directory by splitting buckets round-robin, and using overflow pages.
  - Overflow pages not likely to be long.
  - Duplicates handled easily.
  - Space utilization could be lower than Extendible Hashing, since splits not concentrated on `dense' data areas.
    - Can tune criterion for triggering splits to trade-off slightly longer chains for better space utilization.
- For hash-based indexes, a *skewed* data distribution is one in which the *hash values* of data entries are not uniformly distributed!