If we want to eliminate the lost update problem and also not execute the transactions in strict modem, we can simply overwrite all older before images on commit. On the basis of ACA, the before image of a variable is only updated when a transaction which writes to this variable is committed. During the transaction, for every write that occurs, a list of changed values and their locations can be saved, and upon commit, these values can be taken to overwrite all other instances of the before images.

If we have transactions T1 and T2 with the following history

initial before images: x = 1, y = 0

T1 T2 before image

w1(x, 2); x = 1, y = 0

w2(x, 8);

w2(y, 9);

c2; x = 8, y = 9

w1(y, 3);

a1 x = 8, y = 9

Thus, when T1 aborts, x and y are recovered using the before images, T2’s updates are not lost. Also, T2 is permitted to overwrite the uncommitted data by T1, thus this execution is not in strict mode.

2a.

h0(x) = x mod 4, h1(x) = x mod 8

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bucket # | 0 | 1 (B\_split) | 2 | 3 | 4 (B\_last) |
|  | 4 |  | 2 | 3 |  |
|  |  |  | 6 | 7 |  |
|  |  |  | 14 |  |  |

Overflow: 18

h0(x) = x mod 4, h1(x) = x mod 8

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Bucket # | 0 | 1 | 2 (B\_split) | 3 | 4 | 5 (B\_last) |
|  | 4 | 9 | 2 | 3 |  |  |
|  |  |  | 6 | 7 |  |  |
|  |  |  | 14 | 19 |  |  |

Overflow: 18 11

2b.

table after splits under no overflow buckets:

**s = 4, h0(x) = x mod 4, h1(x) = x mod 8**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bucket # | 0 | 1 (B\_split) | 2 | 3 | 4 (B\_last) |
|  |  |  | 2 | 3 | 4 |
|  |  |  | 6 | 7 |  |
|  |  |  | 14 |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Bucket # | 0 | 1 | 2 (B\_split) | 3 | 4 | 5 (B\_last) |
|  |  |  | 2 | 3 | 4 |  |
|  |  |  | 6 | 7 |  |  |
|  |  |  | 14 |  |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bucket # | 0 | 1 | 2 | 3 (B\_split) | 4 | 5 | 6 (B\_last) |
|  |  |  | 2 | 3 | 4 |  | 6 |
|  |  |  | 18 | 7 |  |  | 14 |
|  |  |  |  |  |  |  |  |

**s = 8, h0(x) = x mod 8, h1(x) = x mod 16**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bucket # | 0 (B\_split) | 1 | 2 | 3 | 4 | 5 | 6 | 7 (B\_last) |
|  |  | 9 | 2 | 3 | 4 |  | 6 | 7 |
|  |  |  | 18 | 19 |  |  | 14 |  |
|  |  |  |  | 11 |  |  |  |  |

In terms of **insertion** with no collisions, linear bucket with overflow buckets has an amortized efficiency of O(1). This is the same with linear hashing without overflow bucket, since no duplicate hash values occur and the split pointer is not moved.

During insertions with collisions, if the overflow bucket is far ahead from the split point, overflow bucket will delay the split, thus insertion is still O(1). A few split operations will trigger the freeing of an overflow bucket, causing an O(k) operation of rehashing where k is the size of the overflow bucket.

If not using overflow buckets, many insertions might cause an O(S) split time, where S is the hash key value. Split time is O(S) since the filled bucket has to constantly wait for the split pointer to reach its index, especially when multiples of a value are inserted over and over. Thus, the amortized insertion efficiency with overflow buckets is definitely superior to the that without overflow buckets.

While **Searching,** linear hashing without overflow bucket has a superior runtime since every queried data is guaranteed to be one of the records in some bucket. If we consider the number of records as a constant number, then this operation is O(1). Linear hashing with overflow buckets on the other hand, might cause a probing operation through the overflow buckets list. This might result in a linear runtime on average if significant data are stored in overflow buckets.

delete with/without compaction

The **split frequency** of linear hashing without overflow buckets is higher than linear hashing with buckets. If without overflow buckets, split pointer will have to keep moving until it reaches the index where the collision happens. If overflow buckets are used, then it is guaranteed that only one split operation will be performed upon a collision. Thus, more splits happen for linear hashing without overflow buckets than with overflow buckets.

The i**nternal fragmentation** of linear hashing without overflow buckets is more than with overflow buckets. As discussed in previous paragraphs, some collisions cause the split pointer to move to their indices. During this process, the split pointer skips over a lot of buckets, leading to a long expansion of the bucket list which has many empty buckets. If overflow buckets are used, only one split will happen per collision so not too many empty buckets will be created.

The **number of pointers** in linear hashing without overflow buckets is less than that with overflow buckets since overflow buckets of each bucket is a linked-list of buckets. Every newly overflow bucket will increase the number of pointer by 1.

3.

0110

1110

10010

01111

10011

1011

00

0001

1001

0100

11

10

01

2

4.

5. With spinning disks, slotted pages with S-P pages works well because the head can pick up the whole record as the disk with the record spins by. For SSDs, we have random access with automatic caching via cache lines. Therefore, slotted pages with PAX pages will work better, since we can pick up one field for multiple records into the cache with one read. This means that searching for a key will be faster as well, thanks to the spacial locality.

6. Head starts on track 12. Without loss of generality, assume that the head starts on sector 0. That is, the sector numbers declared in the following order can trivially be incremented by 4 modulo 64, but it is easier to reason with 0, 31, and 63 than it is to reason with 4, 35, and 3. Assume instant reading and writing as long as head is above target sector.

(a) 6ms to read half of track into the buffer.

(b) 1.5 x 2 = 3ms to move the head to track 14, concurrent with spinning the disk another 6ms to get back to sector 0.

(c) 6ms to write the buffer from sector 0 to sector 31. Head is now at sector 31.

(d) 3ms to move the head back to track 12, concurrent with spinning the disk 12ms to get back to sector 31.

(e) 6ms to read half of the track into the buffer. Head is now at sector 0.

(f) 3ms to move the head to track 14, concurrent with spinning the disk 6ms to get back to sector 32.

(g) 6ms to write the buffer from sector 32 to sector 63.

Total: 48ms