Level 5

Hashing

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TUTORIAL

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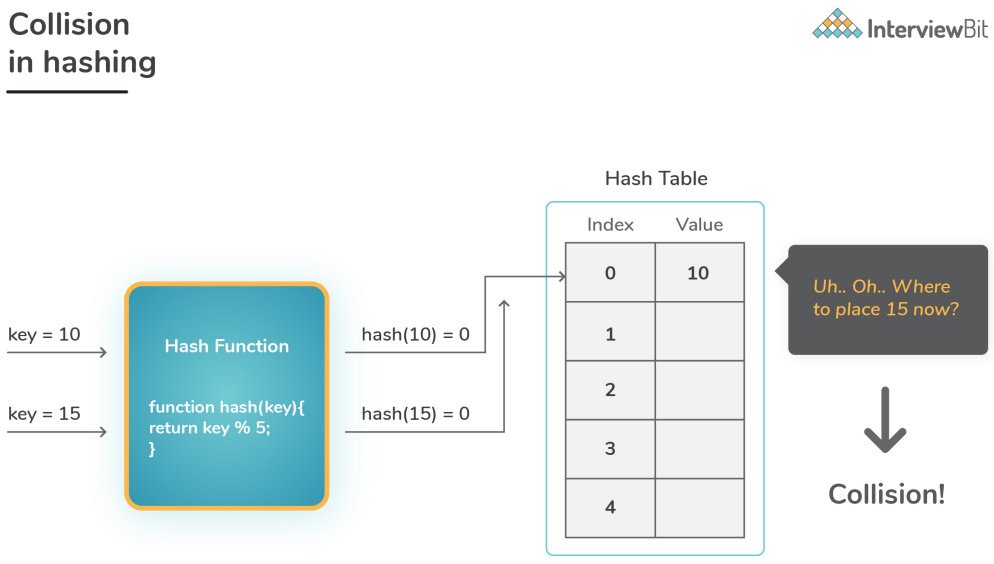
Hashing Techniques

Collisions are bound to occur no matter how good a hash function is. Hence, to maintain the performance of a hash table, it is important to minimise collisions through various collision resolution techniques.

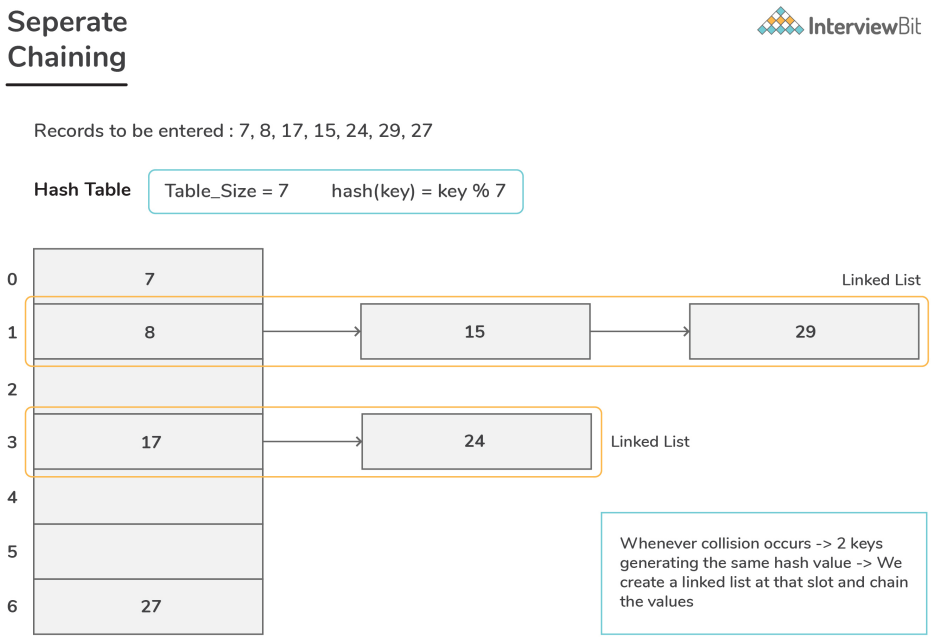


There are majorly 2 methods for handling collisions:

- Separate Chaining
- Open Addressing

Seperate Chaining

- Here the main idea is to make each slot of hash table point to a linked list of records that have the same hash value.



- **Performance Analysis:**
  - Hashing performance can be evaluated under the assumption that each key is equally likely and uniformly hashed to any slot of hash table.
  - Consider `table_size` as number of slots in hash table and `n` as number of keys to be saved in the table. Then:

```
We have Load factor α = n/table_size
Time complexity to search/delete = O(1 + α)
Time complexity for insert = O(1)

Hence, overall time complexity of search, insert and delete operatio
n will be O(1) if α is O(1)
```

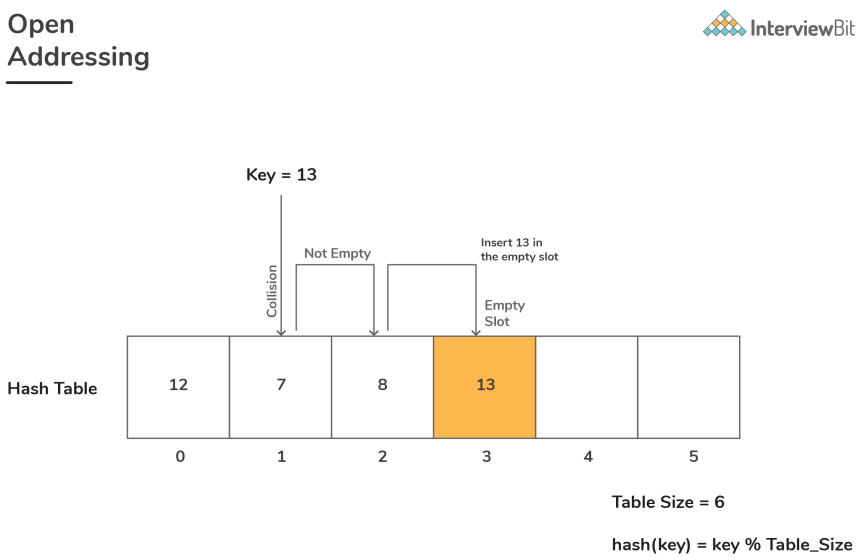
- **Advantages of Separate Chaining:**
  - This technique is very simple in terms of implementation.
  - We can guarantee that the insert operation always occurs in `O(1)` time complexity as linked lists allows insertion in constant time.
  - We need not worry about hash table getting filled up. We can always add any number elements to the chain whenever needed.
  - This method is less sensitive or not very much dependent on the hash function or the load factors.
  - Generally this method is used when we do not know exactly how many and how frequently the keys would be inserted or deleted.
- **Disadvantages of Separate Chaining:**
  - Chaining uses extra memory space for creating and maintaining links.
  - It might happen that some parts of hash table will never be used. This technically contributes to wastage of space.
  - In the worst case scenario, it might happen that all the keys to be inserted belong to a single bucket. This would result in a linked list structure and the

search time would be `O(n)`.

- Chaining cache performance is not that great since we are storing keys in the form of linked list. Open addressing techniques has better cache performance as all the keys are guaranteed to be stored in the same table. We will explore open addressing techniques in the next section.

Open Adressing

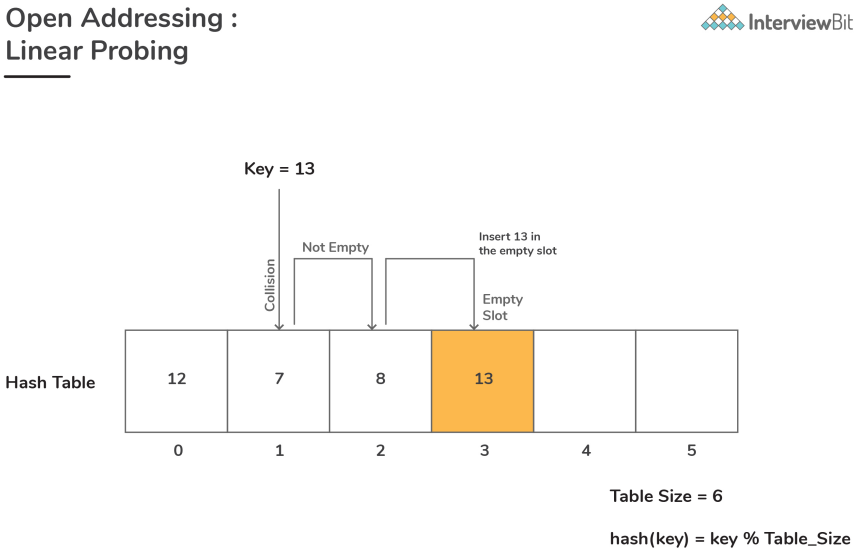
- In this technique, we ensure that all records are stored in the hash table itself. The size of the table must be greater than or equal to the total number of keys available. In case the array gets filled up, we increase the size of table by copying old data whenever needed. How do we handle the following operations in this techniques? Let's see below:
  - **Insert(key):** When we try to insert a key to the bucket which is already occupied, we keep probing the hash table until an empty slot is found. Once we find the empty slot, we insert `key` into that slot.



  - **Search(key):** While searching for `key` in the hash table, we keep probing until slot's value doesn't become equal to `key` or until an empty slot is found.
  - **Delete(key):** While performing delete operation, when we try to simply delete `key`, then the search operation for that key might fail. Hence, deleted key's slots are marked as "**deleted**" so that we get the status of the key when searched.
- The term "open addressing" tells us that the address or location of the key to be placed is not determined by its hash value.
- Following are the techniques for following open addressing:
  - **Linear Probing:**
    - In this, we linearly probe for the next free slot in the hash table. Generally, gap between two probes is taken as 1.
    - Consider `hash(key)` be the slot index computed using hash function and `table_size` represent the hash table size.
      Suppose `hash(key)` index has a value occupied already, then:

```
 We check if (hash(key) + 1) % table_size is free
If ((hash(key) + 1) % table_size) is also not free, then we ch
eck for ((hash(key) + 2) % table_size)
If ((hash(key) + 2) % table_size) is again not free, then we t
ry ((hash(key) + 3) % table_size),
:
:
:
and so on until we find the next available free slot
```

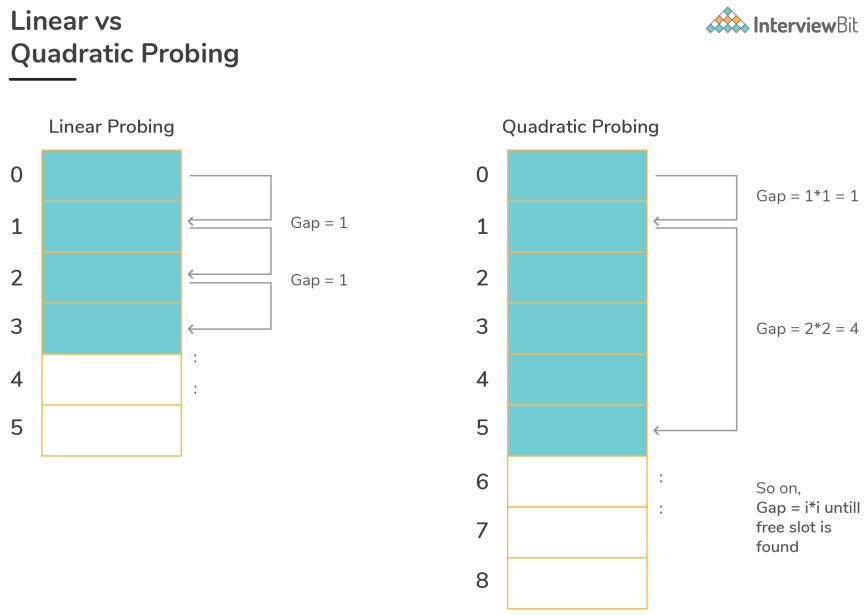
- When performing search operation, the array is scanned linearly in the same sequence until we find the target element or an empty slot is found. Empty slot indicates that there is no such key present in the table.



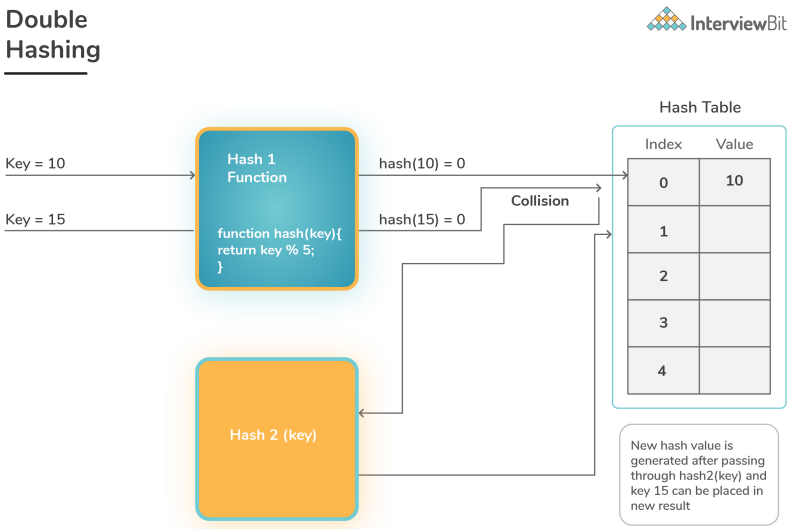
- **Disadvantage:** There would be cases where many consecutive elements form groups and the time complexity to find the available slot or to search an element would increase greatly thereby reducing the efficiency. This phenomenon is called as **clustering**.

- **Quadratic Probing:**
  - In this approach, we look for i^2-th slot in i-th iteration.
  - Consider `hash(key)` be the slot index required to place key computed using hash function and `table_size` is the size of hash table available, then:

```
 If slot (hash(key) % table_size) is not free, then we check for ava
ilability of ((hash(key) + 1*1) % table_size)
If ((hash(key) + 1*1) % table_size) is again full, then we check for
((hash(key) + 2*2) % table_size)
If ((hash(key) + 2*2) % table_size) is not empty, then we check for
the status of ((hash(key) + 3*3) % table_size)
:
:
:
and so on until we find the next available empty slot.
```



- **Double Hashing:**
  - In this method: we follow the idea of applying a second hash function on the key whenever a collision occurs.



  - It can be done as follows:

```
(hash1(key) + c * hash2(key)) % Table_Size , where c keeps inc
remented by 1 upon every collision to find the next free slot.
```

    - Here `hash1()` is the first hash function and `hash2()` is the second hash function applied in case of collision and `Table_Size` is the size of hash table.
    - First hash function can be defined as `hash1(key) = key % Table_Size` . Second hash function is popularly like `hash2(key) = prime_no - (key % PRIME)` where `prime_no` is a prime number smaller than `Table_Size` .
- **Analysis of Open Addressing:**

- The performance of hashing technique can be evaluated under the assumption that each key is equally likely and uniformly hashed to any slot of the hash table.
- Consider `table_size` as total number of slots in the hash table, `n` as number of keys to be inserted into the table, then:

```
 * Load factor, α = n/table_size ( α < 1 )
* Expected time taken to search/insert/delete operation < (1/(1 - α))
* Hence, search/insert/delete operations take at max (1/(1 - α)) time
```