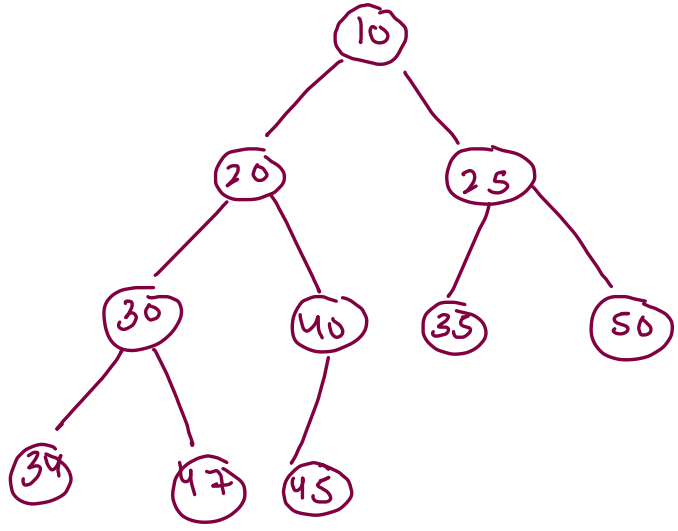
DS -> heap

add -> log n

remove -> log n

peek -> O(1)



Smaller value has higher priority

(i) heap order property.

priority (parent) > priority (lc, rc)

(ii) complete binary tree property.

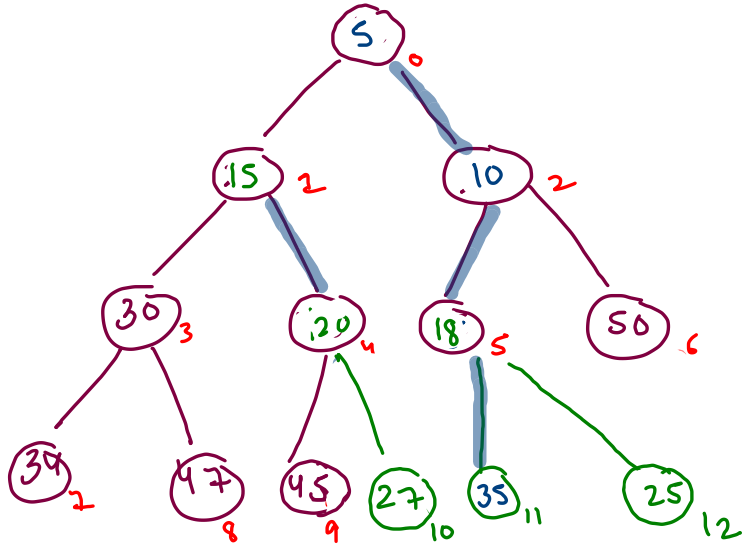
0 to h-1 levels are completely filled and last level is filled from left to right.

10 (0) 15 (1) 25 (2) 30 (3) 15 20 (4) 35 (5) 50 (6) 39 (7) 47 (8) 45 (9) 27 (10) 5 (11) 18 (12)

add -> log n

remove -> log n

peek -> O(1)



Parent to child

lci = 2pi + 1

rci = 2pi + 2

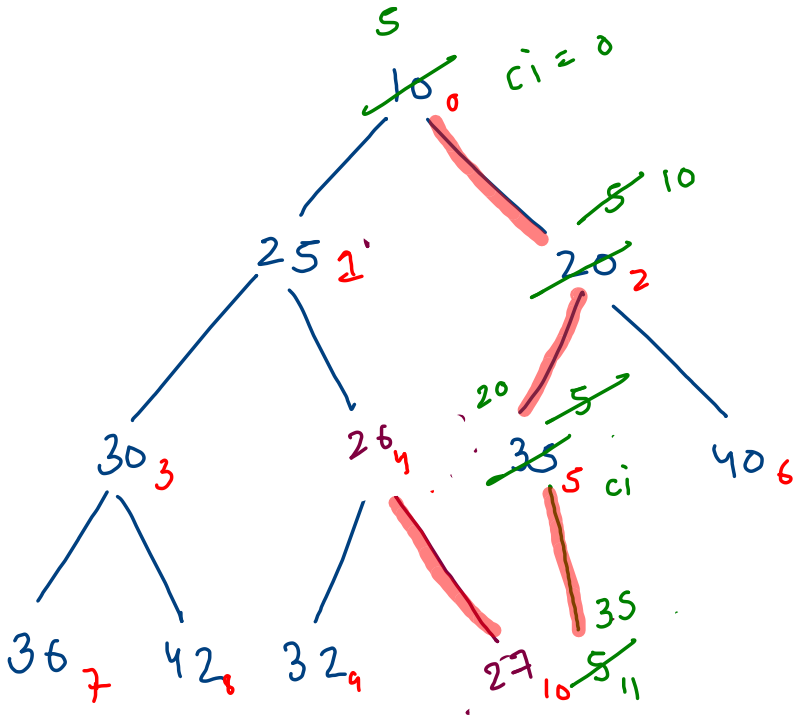
child to parent

pi = (ci - 1) / 2

Cost -> pi to ci -> log n

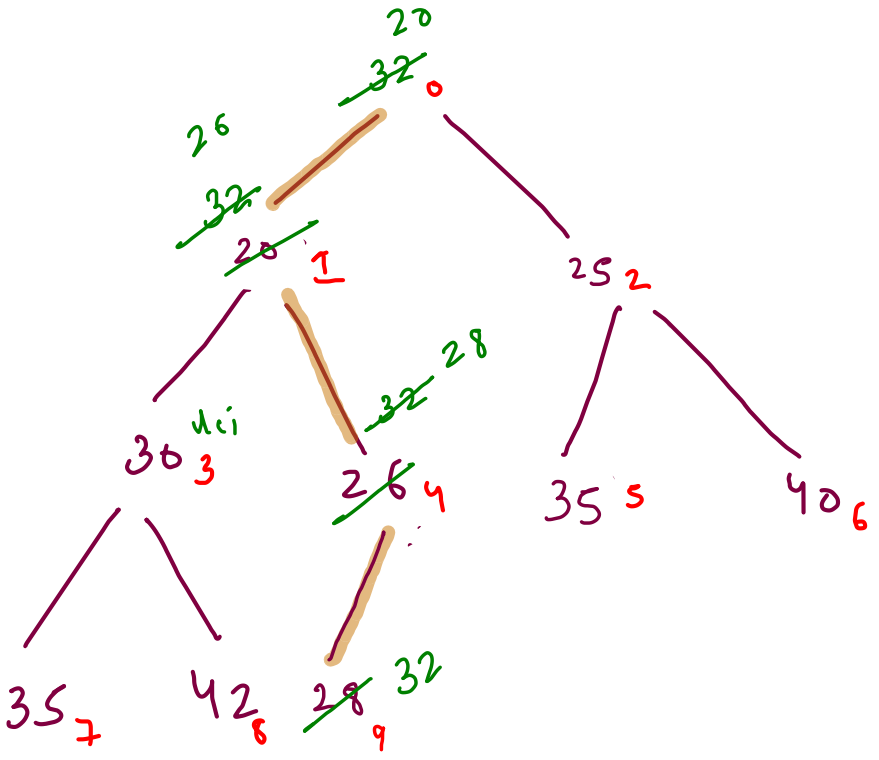
ci to pi

```java
public void add(int val) {
    data.add(val); //may be hop is not honoured
    upheapify(data.size()-1); //to honour hop
}

private void upheapify(int ci) {
    if(ci == 0) {
        return;
    }

    int pi = (ci - 1) / 2;

    if(list.get(ci) < list.get(pi) {
        swap(ci,pi);
        upheapify(pi);
    }
}
```



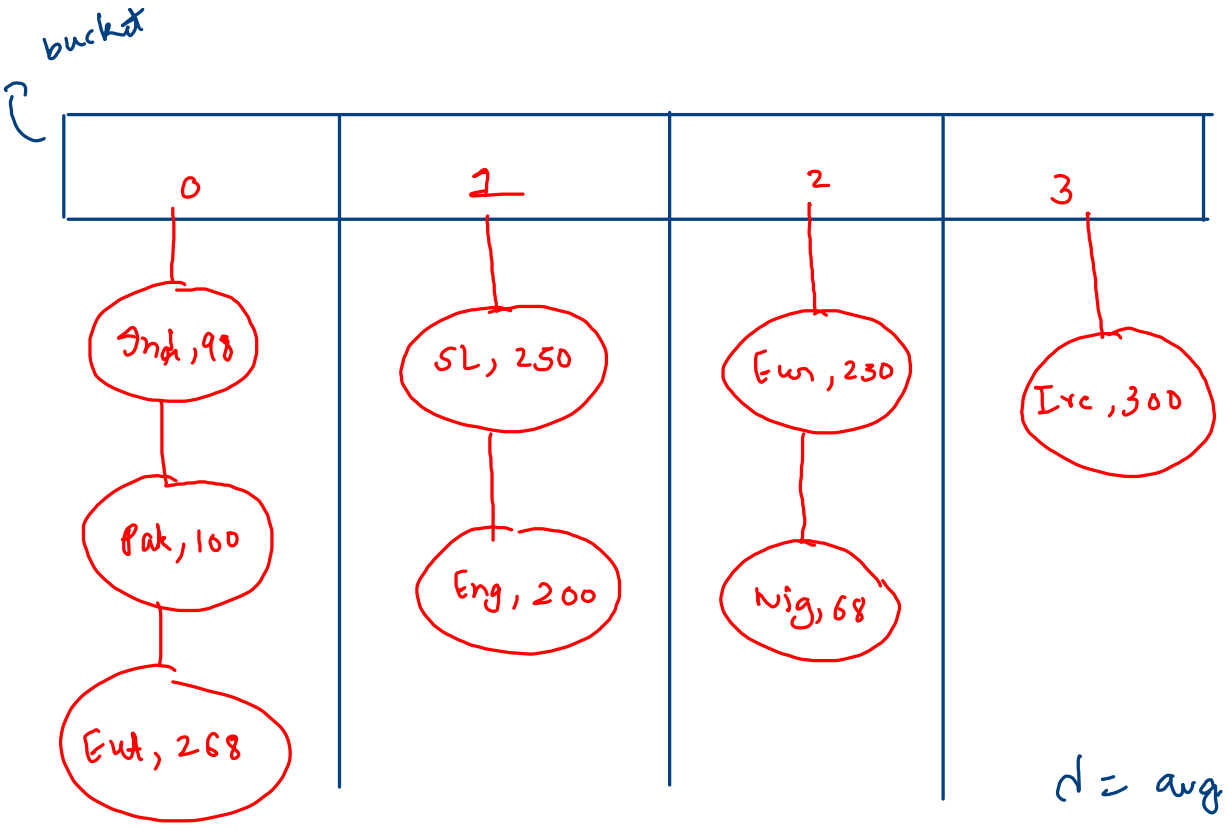
add(26)

add(5)

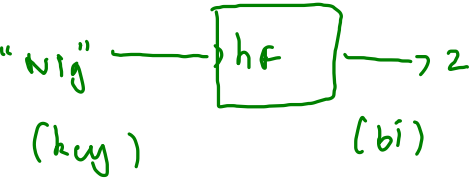



```java
public int remove() {
    if(data.size() == 0) {
        System.out.println("Underflow");
        return -1;
    }
    else {
        int peek =  data.get(0);
        swap(0,data.size()-1); //swap first and last element
        data.remove(data.size()-1);

        downheapify(0);
        return peek;
    }
}
```

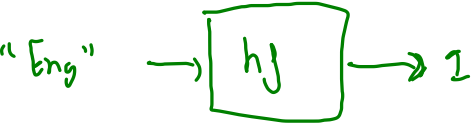
```java
private void downheapify(int pi) {
    int min_idx = pi; //min idx
    int lci  = 2*pi + 1;
    int rci = 2*pi + 2;

    if(lci < data.size() && data.get(lci) < data.get(min_idx)) {
        min_idx = lci;
    }

    if(rci < data.size() && data.get(rci) < data.get(min_idx)) {
        min_idx = rci;
    }


    if(min_idx != pi) {
        swap(min_idx,pi);
        downheapify(min_idx);
    }
}
```



① hm.put("Nig", 68)



② hm.put("Eng", 200)



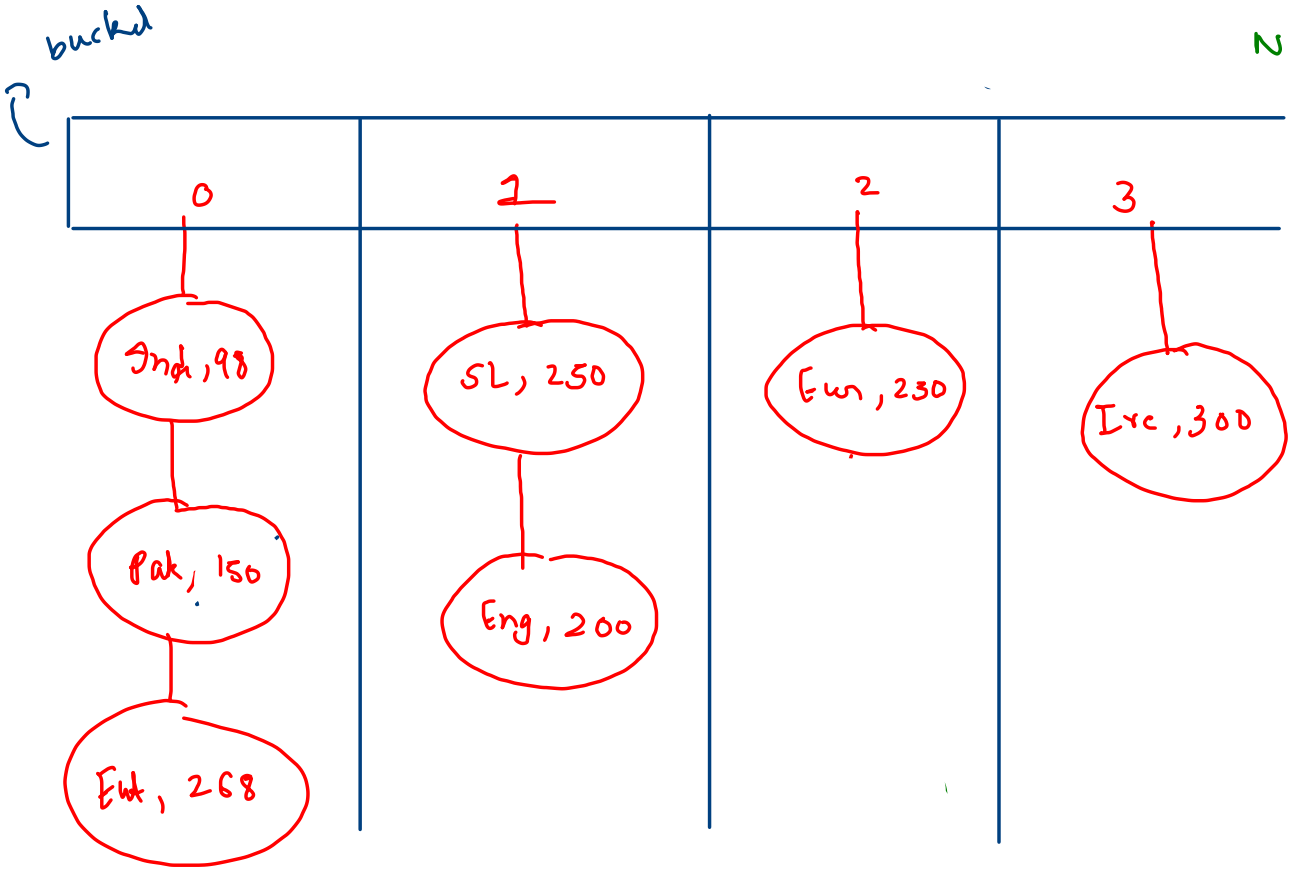
N -> 4

n -> 7

d = avg number of nodes in a bucket

$d = \frac{n}{N}$

O(d)



n = total nodes

N = buckets.length

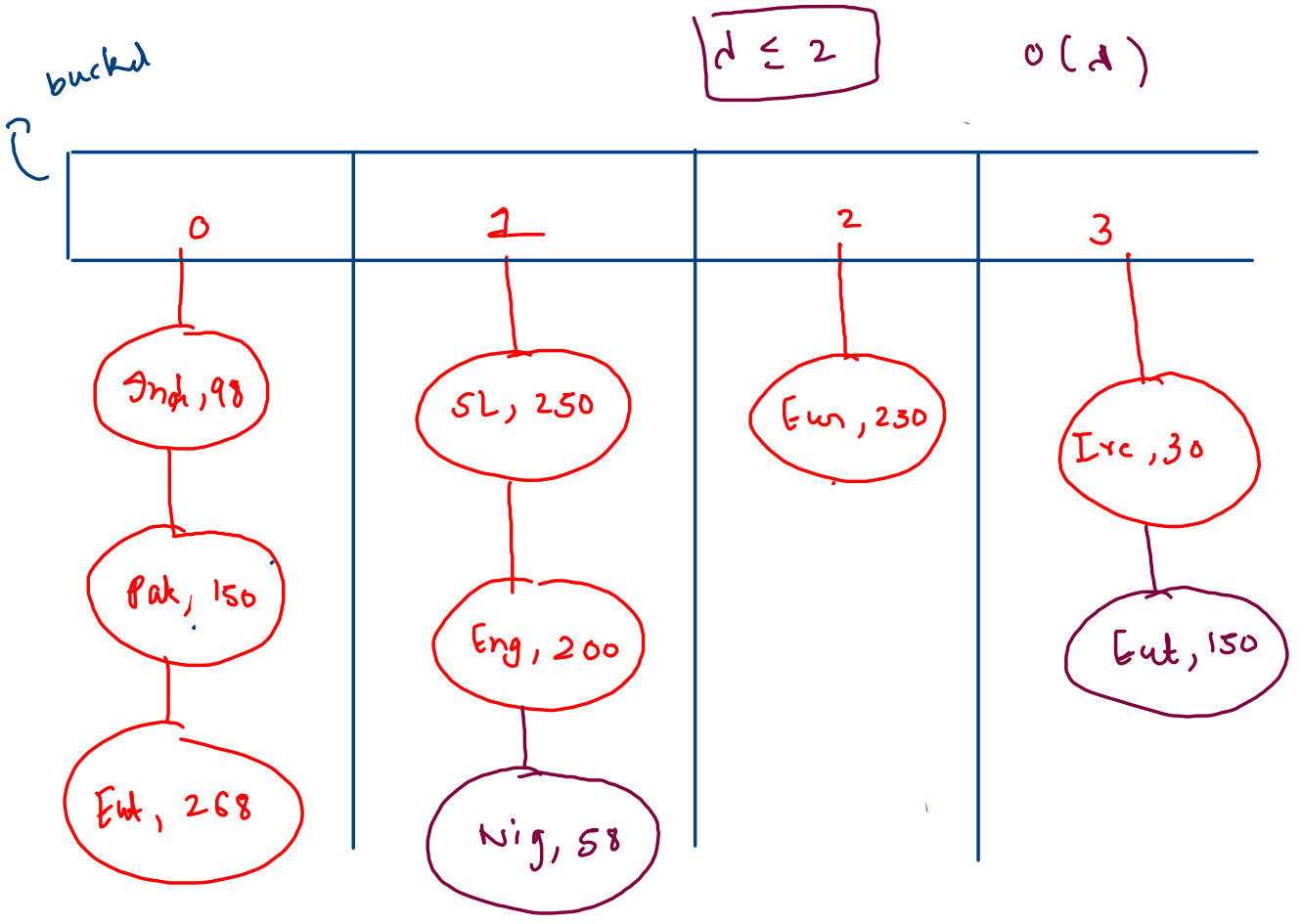
d = avg. no. of nodes per bucket.

$$d = \frac{n}{N} = \frac{7}{4} = 1.75$$

$d \leq 2$

$O(d)$

$n \uparrow, d \uparrow$



$\alpha = \frac{n}{N}$

$\alpha = \frac{9}{4} = 2.25$

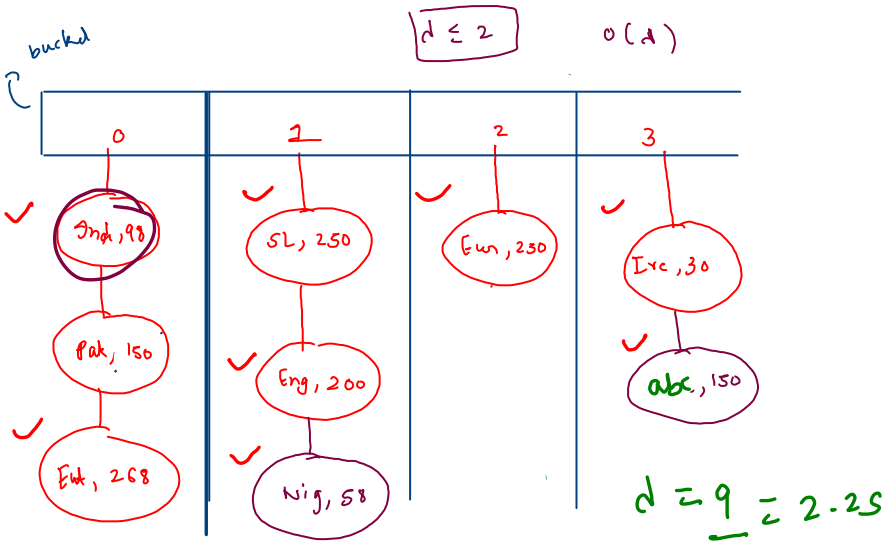
Ind $\xrightarrow{hc}$ 44 $\xrightarrow{bi}$ 0

SL $\xrightarrow{hc}$ 57 $\xrightarrow{bi}$ 1

Eng $\xrightarrow{hc}$ 61 $\xrightarrow{bi}$ 1

Nig $\xrightarrow{hc}$ 65 $\xrightarrow{bi}$ 1

Aut $\xrightarrow{hc}$ 83 $\xrightarrow{bi}$ 3



$d = \frac{9}{4} = 2.25$

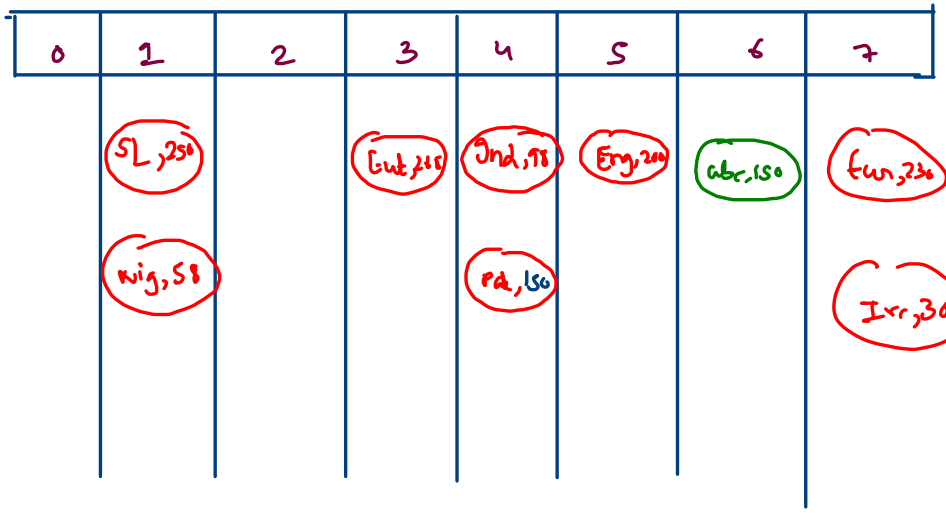
Ind $\xrightarrow{hc}$ 44 $\xrightarrow{bi}$ 0 (44 % 4 = 0)

SL $\xrightarrow{hc}$ 57 $\xrightarrow{bi}$ 1

Eng $\xrightarrow{hc}$ 61 $\xrightarrow{bi}$ 1

Nig $\xrightarrow{hc}$ 65 $\xrightarrow{bi}$ 1

Ent $\xrightarrow{hc}$ 83 $\xrightarrow{bi}$ 3



Ind $\xrightarrow{hc}$ 44 $\xrightarrow{bi}$ 44 % 8 = 4

SL $\xrightarrow{hc}$ 57 $\xrightarrow{bi}$ 57 % 8 = 1

Eng $\xrightarrow{hc}$ 61 $\xrightarrow{bi}$ 61 % 8 = 5

Nig $\xrightarrow{hc}$ 65 $\xrightarrow{bi}$ 65 % 8 = 1

Ent $\longrightarrow$ bi $\longrightarrow$ 3

$d = \frac{9}{8} = 1.125$