Segment Trees

Q Given an array, & given Q queries.

1) i, val → make a[i] = val

2) l, r → Find minimum in index range [l:r]

0	1	2	3	4	5	6	7
10	2	-7	-3	5	8	1	15

2)	L=1	R=4	-3
2)	L=4	R=6	1
1)	i=2	val= -7	
2)	L=0	R= 5	-7

Brute force :

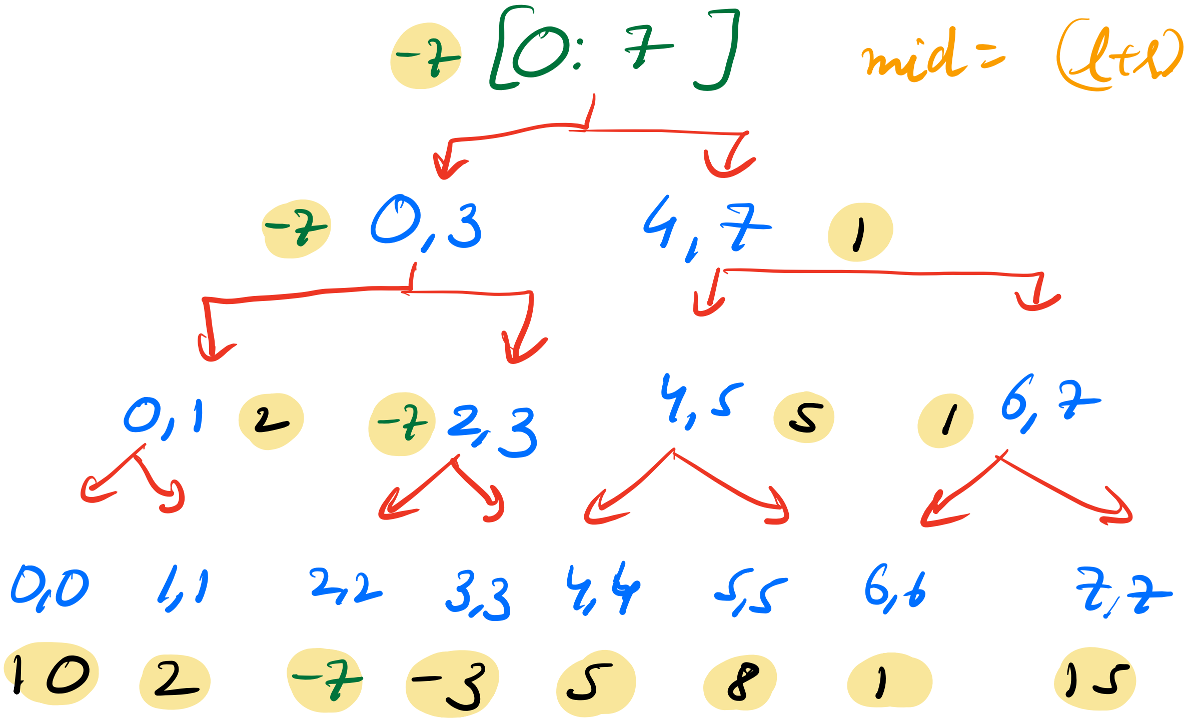
1) Make a[i] = val

2) Iterate on [l:r].

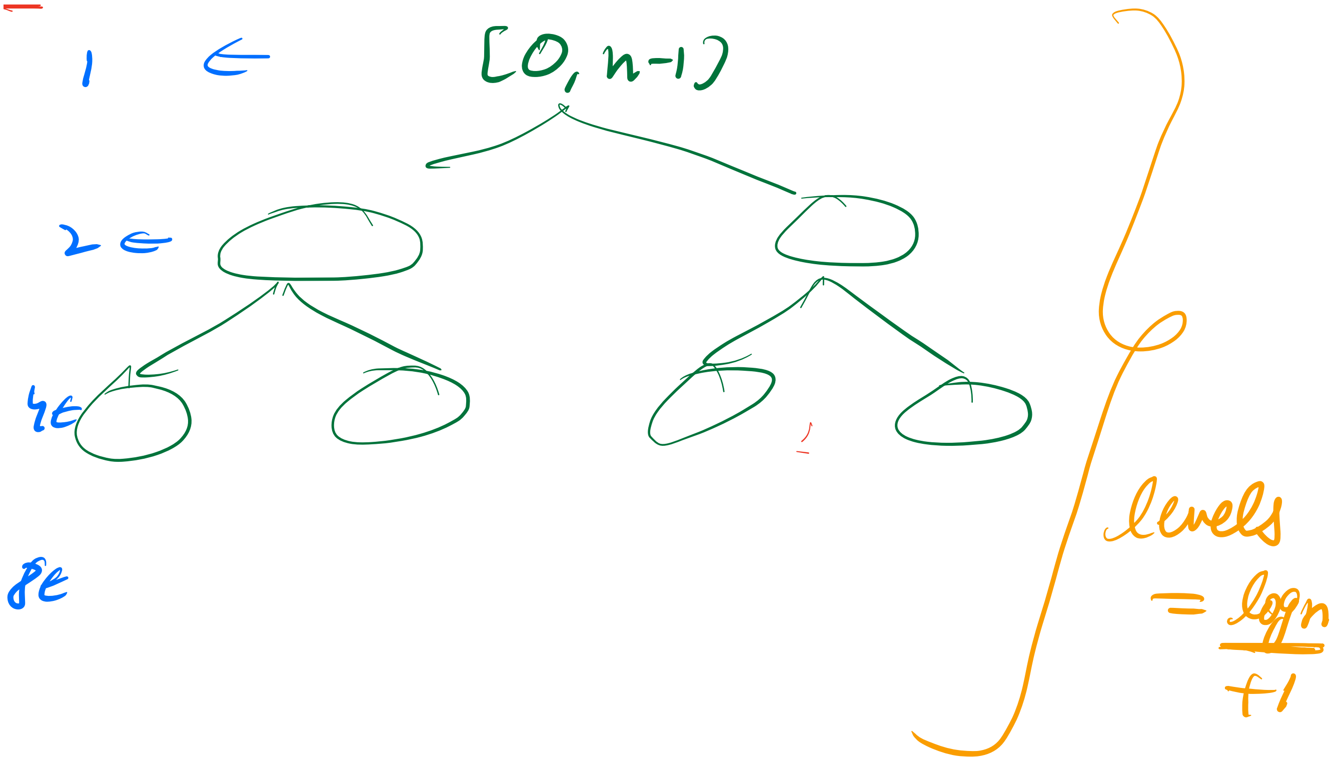
TC: O(Q*N)

Segment tree ⇒ Maintain answers for different blocks.

$mid = (l+r)/2$



Range [2,6]



level i ⇒ 2^i nodes

Total ⇒ Level 0 + level 1 + level2

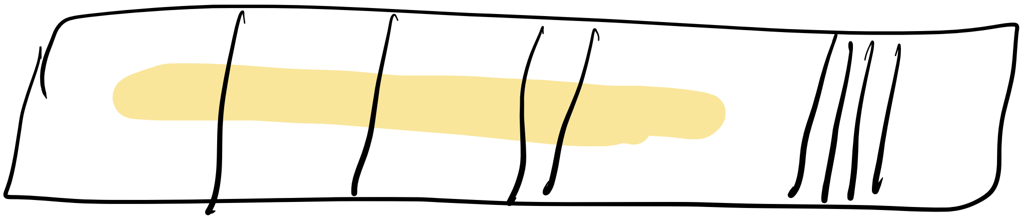
$2^0 + 2^1 + 2^2 + \cdots\cdots 2^{\log n + 1}$

4N − 1

- TC of query 1 : $O(\log n)$
- TC of query 2 : $O(\log n)$

Max overlap at any particular level = 2

WHY ?



- TC of building that tree

= total no of nodes

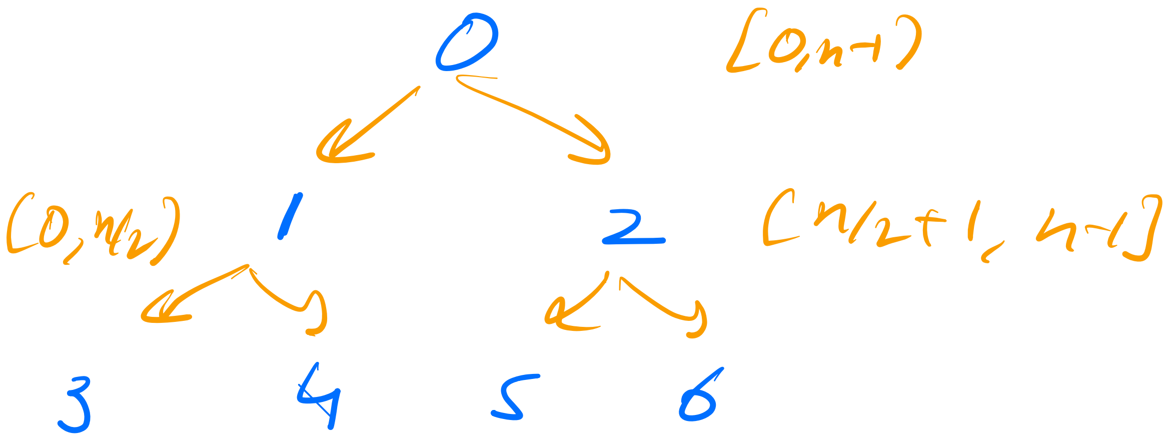
= 4N ⇒ $O(N)$

Implementation using arrays

1) tree [4N]

root → 0, n-1 → 0

i →
- left child $2i+1$
- right child $2i+2$
- parent $(i-1)/2$



```
void build ( idx , start, end ) {
    if (start == end) {
        tree [ idx ] = A[ start]
        return
    }
    else {
        mid = (start + end )/2
        lc = 2idx +1      rc = 2idx +2
        build (lc , start, mid)
        build (rc, mid+1 , end)
        tree [idx] = min (tree[lc],
                          tree [rc])
    }
}
```

```
                                     current range
                                       in consideration
int query(int idx, int x, int y,
                        int l, int r){
                        query range

    if(x≥l && y≤r)
        return tree[idx]
    if(x>r || y<l)
        return INT_MAX
    mid = (x+y)/2
    return min(query(2idx+1, x, mid, l, r),
               query(2idx+2, mid+1, y, l, r))
}
```

```
void update( int idx, int i, int val,
                      int l, int r ){
                      query range

  if ( l==r) {
      a[i] = val
      tree[idx] = val
  }
  else {
     mid= (l+r)/2
     lc = 2idx+1     rc= 2idx+2
     if( x≤ i     && ( i ≤ mid)
       update( lc, i, val, x, mid)
     else
       update( rc, i, val, mid+1, y)
  tree[idx] = min(tree[lc],
                      tree[rc])
}
```

{done}