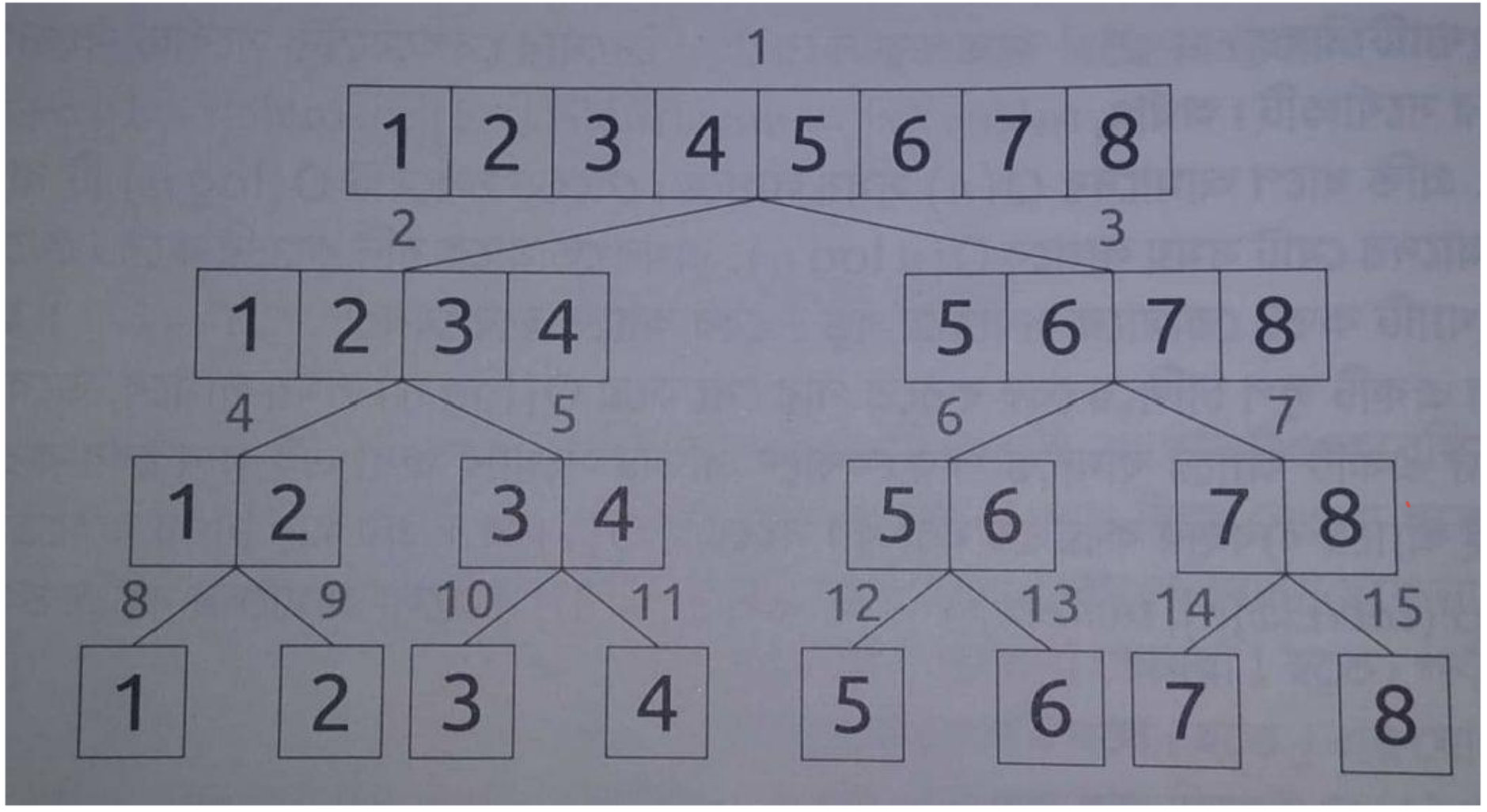
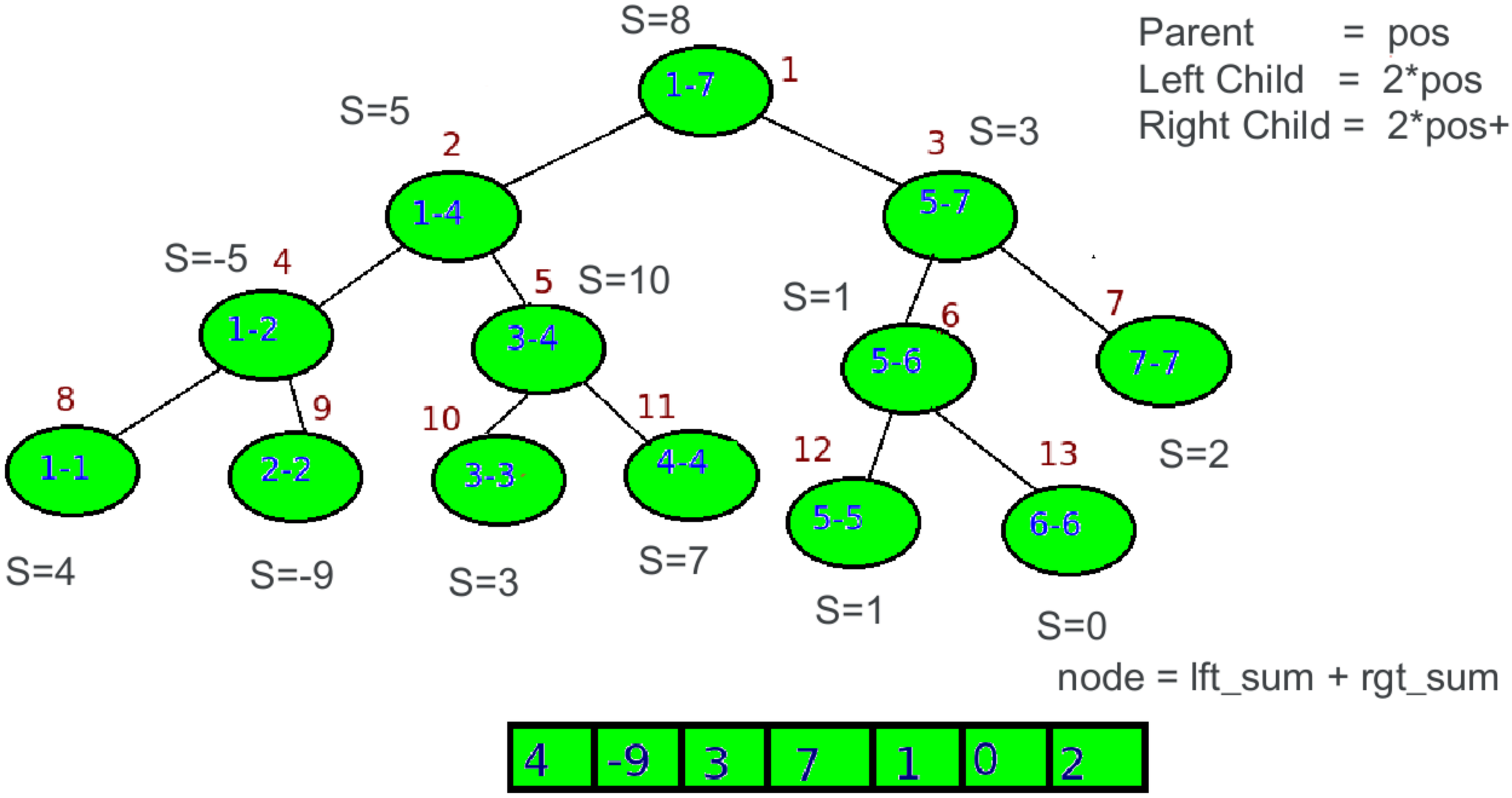
Segment Tree

Given an array of n integers, your task is to process q queries of the following types:
1. update the value at position k to u
2. what is the sum of values in range [a,b]?

CSES-1648


1
1 2 3 4 5 6 7 8
2
3
1 2 3 4
5 6 7 8
4
5
6
7
1 2
3 4
5 6
7 8
8
9
10
11
12
13
14
15
1
2
3
4
5
6
7
8



Parent = pos
Left Child = 2*pos
Right Child = 2*pos+1

node = lft_sum + rgt_sum

4	-9	3	7	1	0	2

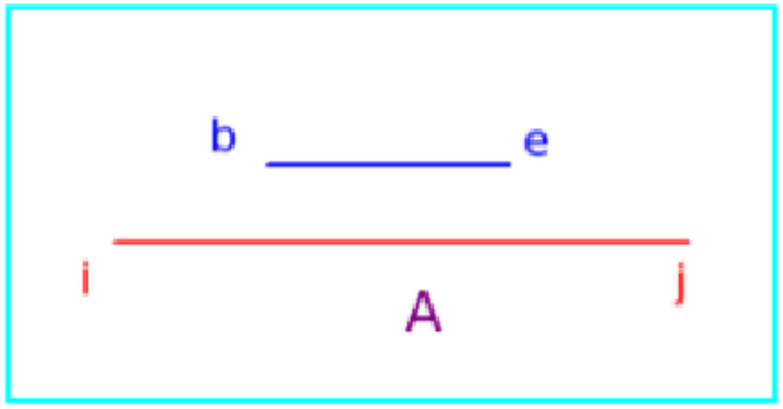
Building Segment Tree :

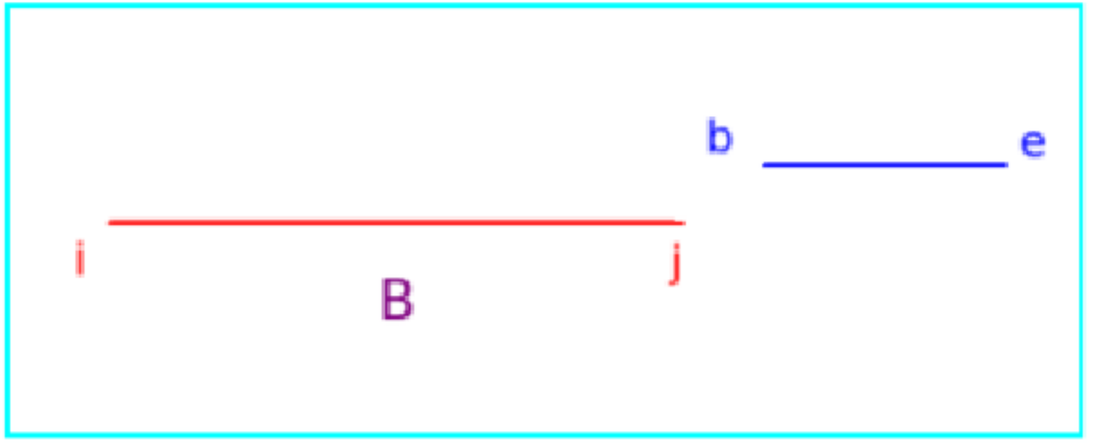
```
int arr[mx];
int tree[mx * 3];
void init(int node, int b, int e)
{
    if (b == e) {
        tree[node] = arr[b];
        return;
    }
    int Left = node * 2;
    int Right = node * 2 + 1;
    int mid = (b + e) / 2;
    init(Left, b, mid);
    init(Right, mid + 1, e);
    tree[node] = tree[Left] + tree[Right];
}
```

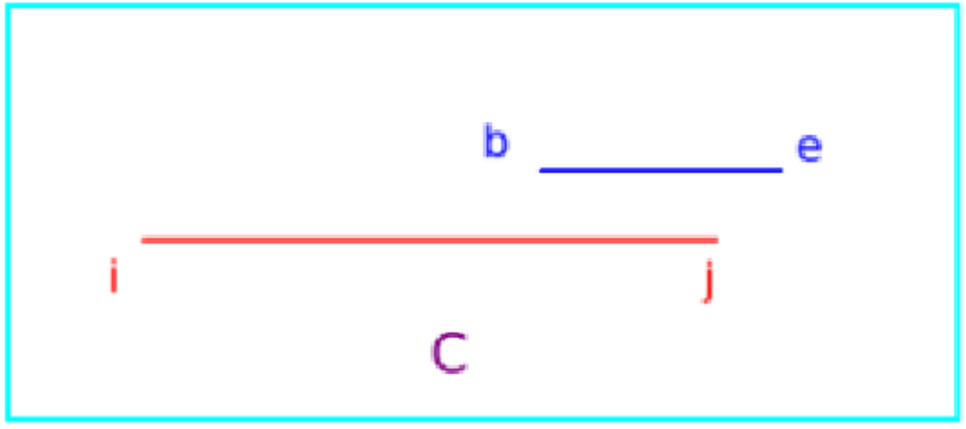
$$
\begin{aligned}
&\textit{Height of the tree} = \lceil (\log(N)) \rceil. \\
&\textit{No. of nodes in } 0^{th} \textit{ level} = 1. \\
&\textit{No. of nodes in } 1^{st} \textit{ level} = 2. \\
&\textit{No. of nodes in } r^{th} \textit{ level} = 2^r. \\
&\textit{No. of nodes in last level} = 2^{\lceil (\log(N)) \rceil} \\
&\textit{So, total number of nodes} = 1 + 2 + ... + 2^r + ... + 2^{\lceil \log(N) \rceil}.
\end{aligned}
$$

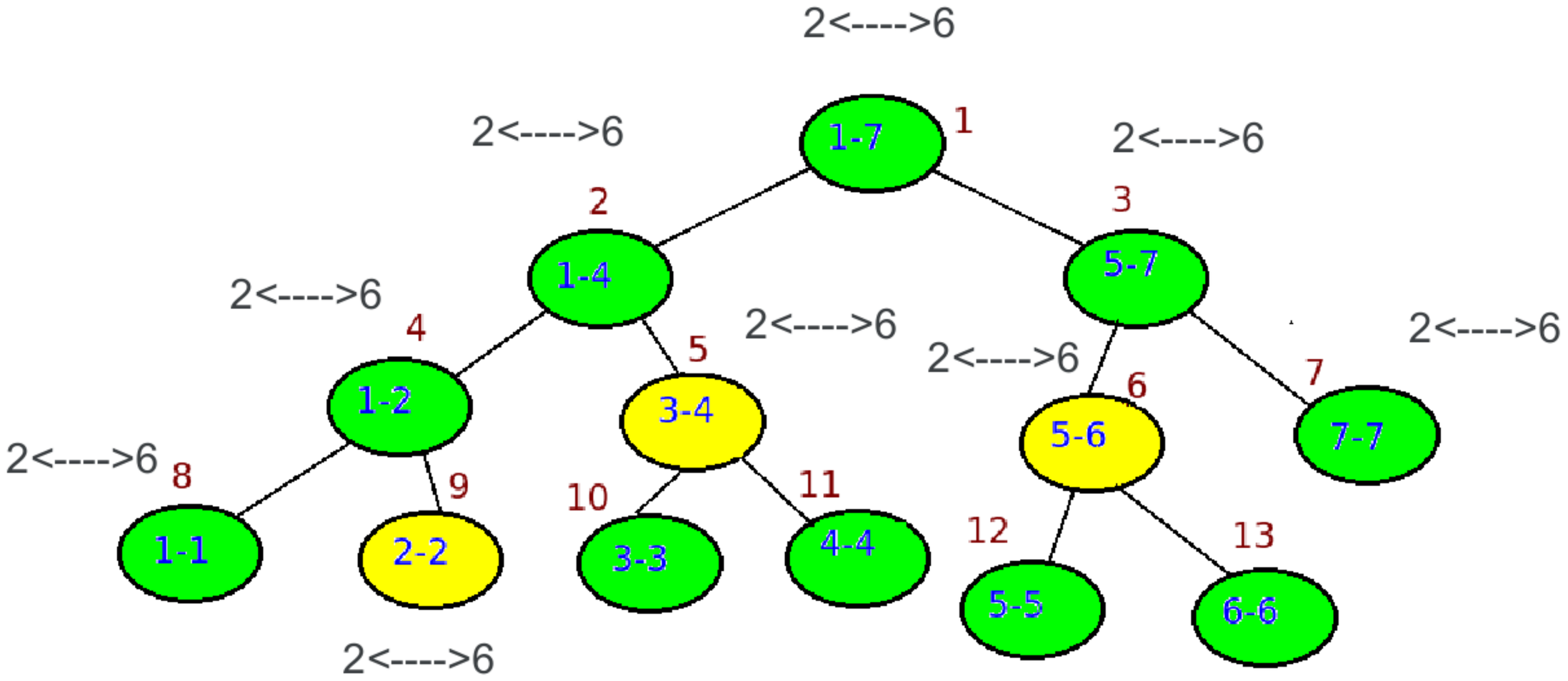
$$
= \frac{1 * \left(2^{\lceil \log(N) \rceil + 1} - 1\right)}{2 - 1}
$$

$$
= \left(2^{\lceil \log(N) \rceil + 1} - 1\right) < 4 * N.
$$


b
e
i
j
A


b
e
i
j
B

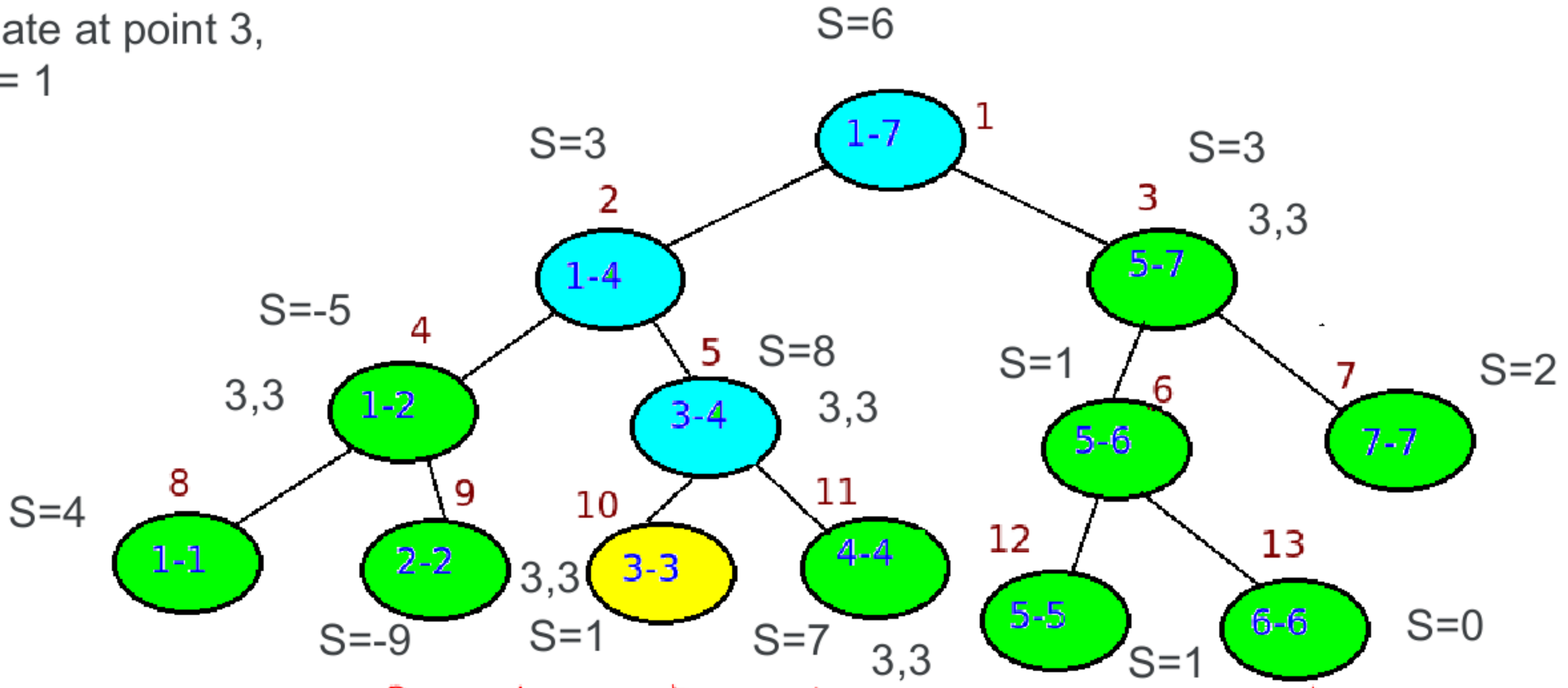

b
e
i
j
C



২ থেকে ৬ ইনডেক্সের যোগফল বের করতে হলুদ নোডগুলোর যোগফল বের করাই যথেষ্ট

```
1  int query(int node, int b, int e, int i, int j)
2  {
3      if (i > e || j < b)
4          return 0; //বাইরে চলে গিয়েছে
5      if (b >= i && e <= j)
6          return tree[node]; //রিলেভেন্ট সেগমেন্ট
7      int Left = node * 2; //আরো ভাঙতে হবে
8      int Right = node * 2 + 1;
9      int mid = (b + e) / 2;
10     int p1 = query(Left, b, mid, i, j);
11     int p2 = query(Right, mid + 1, e, i, j);
12     return p1 + p2; //বাম এবং ডান পাশের যোগফল
13 }
```

Update at point 3,
a[3]= 1



যে নোডটি আপডেট করবো সেই নোডে পৌছানোর পথের সবগুলো নোড আপডেট হয়ে যাবে

4	-9	3	7	1	0	2

```
1  void update(int node, int b, int e, int i, int newvalue)
2  {
3      if (i > e || i < b)
4          return; //বাইরে চলে গিয়েছে
5      if (b >= i && e <= i) { //রিলেভেন্ট সেগমেন্ট
6          tree[node] = newvalue; //নতুন মান বসিয়ে দিলাম
7          return;
8      }
9      int Left = node * 2; //আরো ভাঙতে হবে
10     int Right = node * 2 + 1;
11     int mid = (b + e) / 2;
12     update(Left, b, mid, i, newvalue);
13     update(Right, mid + 1, e, i, newvalue);
14     tree[node] = tree[Left] + tree[Right];
15 }
```