arr[1] + corr[4] = 0 + 2 = 2

Binary lifting

There is a tree of size N, rooted at 0, answer Q queries: given v & K, find K-th ancestor of v.

Brutforce (q * N)

each query in Brute force => O(N)

we want

O(logn)

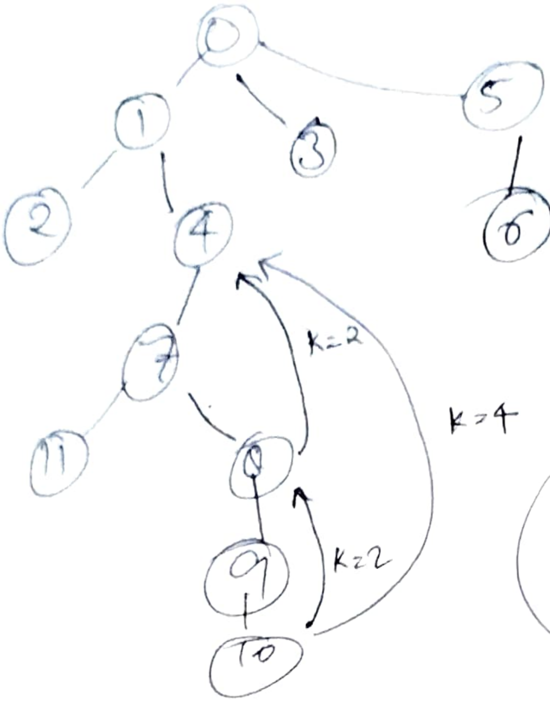
How to improve from O(N) to O(log(N)) ?

divide by 2

- BS
- D&C

Power of 2

- segment tree
- binary lifting
- sparse tables.



int up[N][log];

up[V][J] ⇒ 2^J-th ancestor of V

for v=0 ...... N-1
up[V][0] = ~~up~~ parent[V]
~~for J=1~~
up[V][1] = up[up[V][0]][0]
up[V][2] = up[up[V][1]][1]
up[V][3] = up[up[V][2]][2]
. . . .

for V = 0 -- N-1.
up[V][0] = par[V]
for J=1 ... logN -1:
up[V][J] = up[up[V][J-1]][J-1]

T.C. & S.C ⇒ O(N log(N))

If Parent[i] < i ; then above code is true
else do as: ① run dfs.
② written below:

int up[N][log]:
up[V][J] ---- 2^J - th ancestor of V

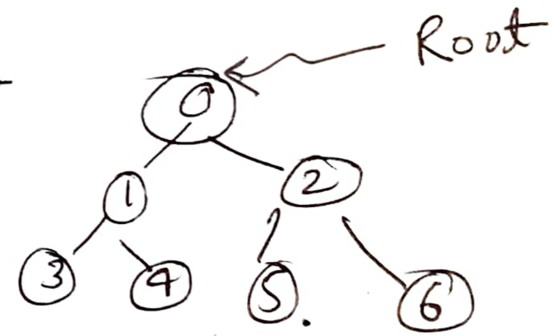
for v = 0 ---- N-1:
up[V][0] = Parent[V]
for J = 1 ...... LogG -1:
for V = 0 ..... N-1:
up[V][J] = up[up[V][J-1]][J-1]

Ex ⇒ 4 ⇒ 19 = 16+2+1 ⇒ x = up[4][0]
x = up[x][1]
x = up[x][4]

How to avoid extra (over) binary lifting :- 8

Ex ⇒ Suppose the root of binary in given tree has the following binary lifting procedure.

Root = 0 ; assume Parent[root] = -1



up[0][0] = Parent[0]

now if we apply same logic as in binary lifting code then there will be a problem.

Problem ⇒ There is no ancestor for the root.

Solution ⇒ $\boxed{\text{Parent [root] = 0;}}$; // Magical Line

Intution ⇒ for above ex; root = 0

up[0][0] = Parent[0] = 0

up[0][1] = up[up[0][1-1]][1-1] = up[0][0] = 0

up[0][2] = up[up[0][2-1]][2-1] = up[0][1] = 0

⋮

up[0][J-1] = up[up[0][J-2]][J-2] = up[0][J-2] = 0

up[0][J] = up[up[0][J-1]][J-1] = up[0][J-1] = 0

⋮

up[0][log] = up[up[0][log-1]][log-1] = up[0][log-1] =

Conclusion ⇒ Similarly, for all the nodes which have no possibili of binary lifting Same logic will be applied.