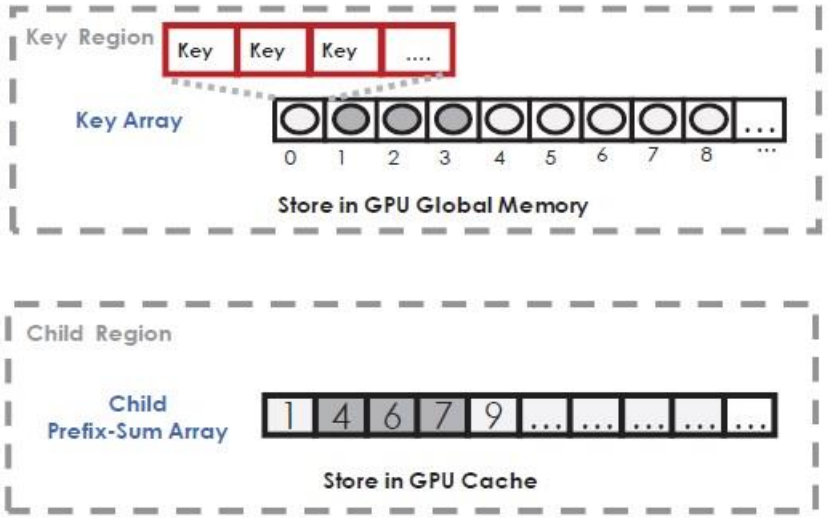
Structure of Harmonia

- Structure of Harmonia consist of precisely two things.

1. vector <struct Node> key_region
2. vector <int> child_prefix_sum

- Apart from this two there one additional global variable used to initialize the child_prefix_sum

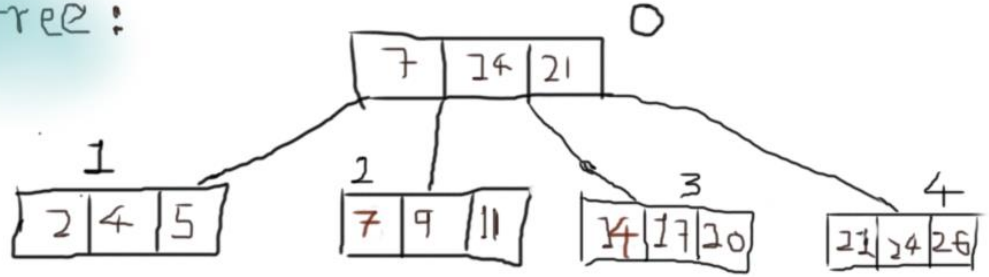
1. psum



(b) Harmonia tree structure

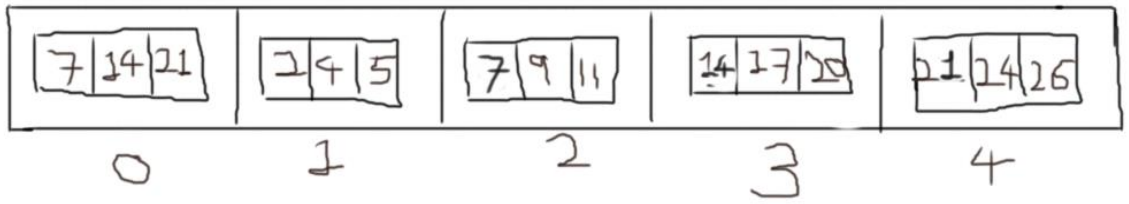
Example

B+tree:

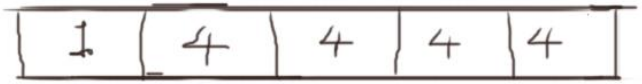


fanout = 4

KeyRegion:



childPrefixSum:



Algorithm createHarmonia(Blocks , column_size)

Create a new vector of blocks called newBlocks

for each block inside Blocks do

store block address of current Block node in curBlock named block pointer

create temporary Node t and add keycount , all keys and all records in to it from the curBlock

push the temporary Node t into the key_region vector

push all the child of the curBlock into the newBlocks vector and increment psum for each child being pushed

if it is first child of the curBlock then

push psum to the child_prefix_sum vector

for end

If size of newBlocks vector is empty then

clear Blocks vector and we are done.

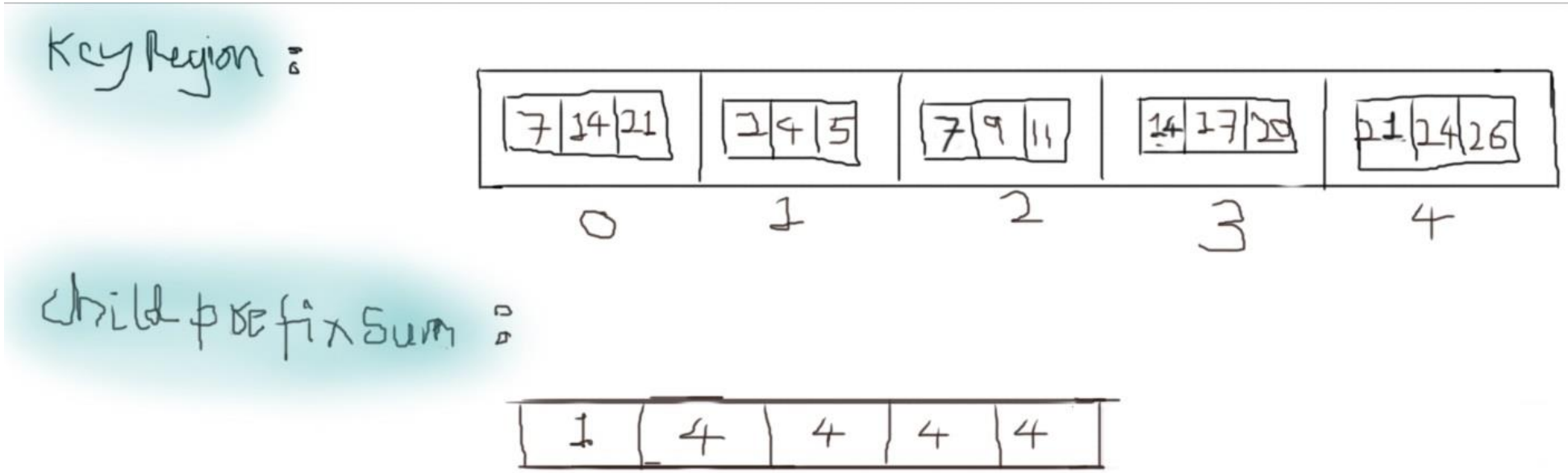
else

clear Blocks vector

recursively call createHarmonia with newBlocks and column_size i.e. createHarmonia(newBlocks , column_size)

Searches

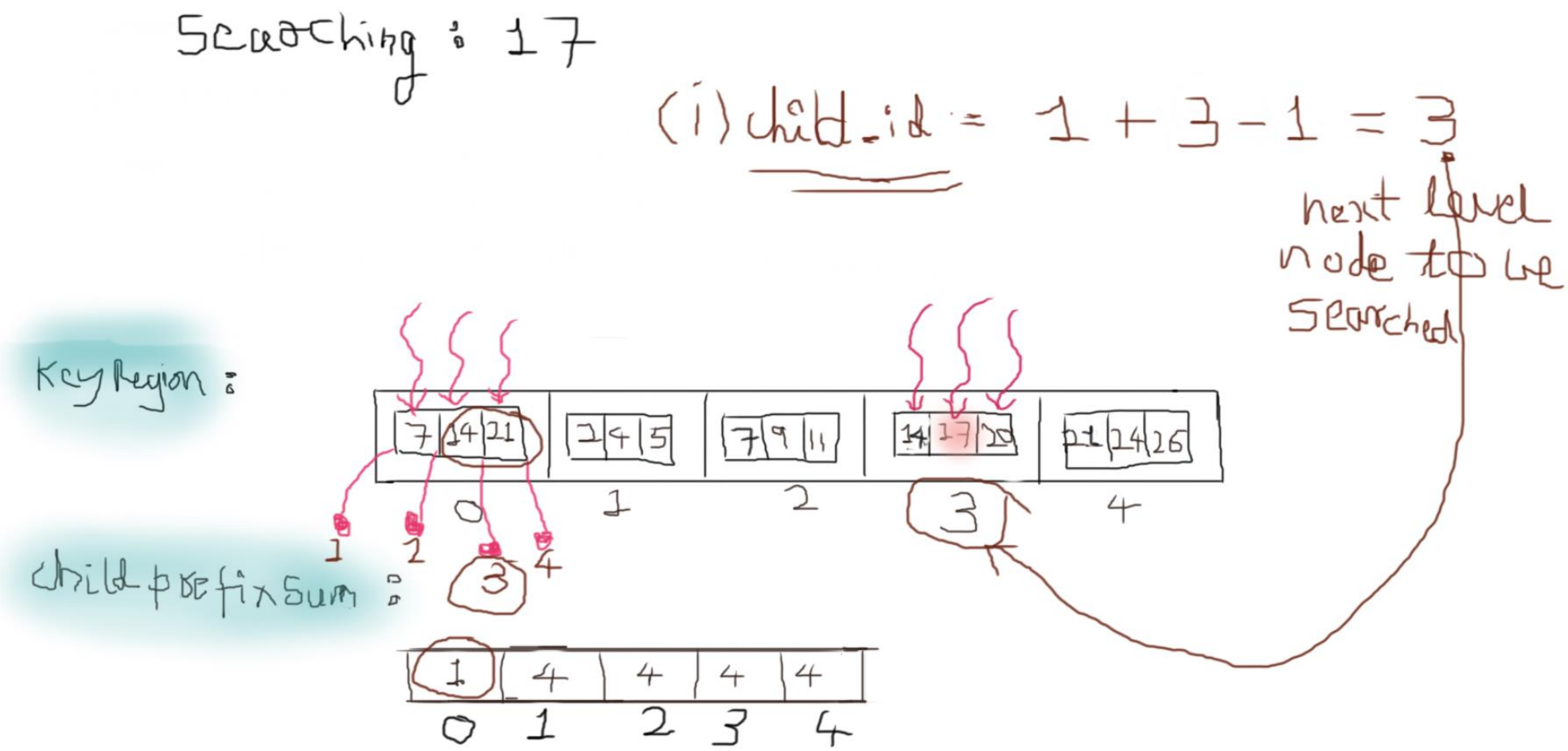
- Several other operations like Range queries and Update to the database requires the searching of the particular key firstly and then followed by that respective operation.
- Hence we will only discuss searches here in detail. Rest two operation are just variation of the search operation.
- Let’s search the value 17 in our previously constructed structure of Harmonia.



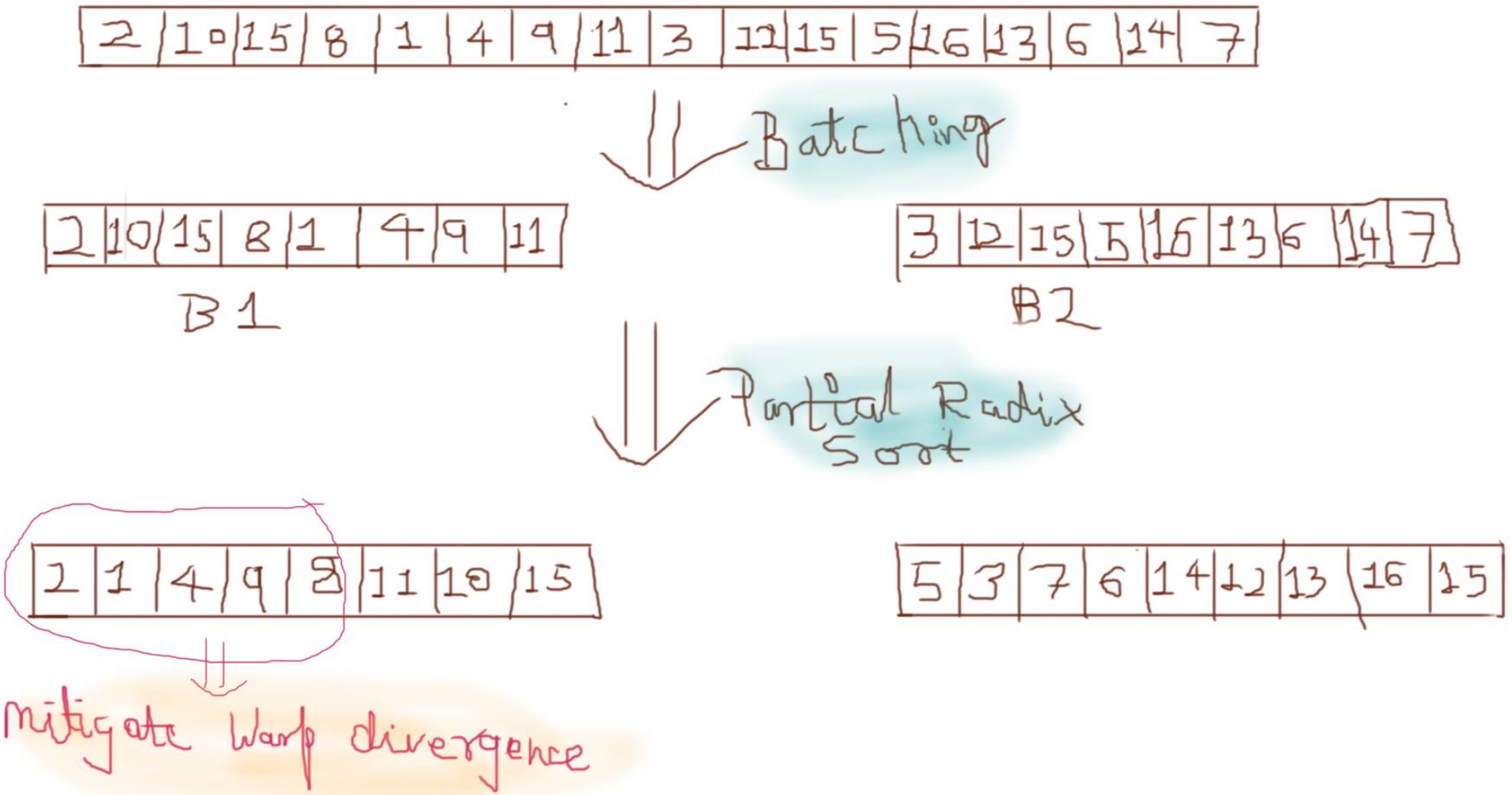
So, How we will Search using given structure?

- Following equation will help in searching in current structure of Harmonia.

$$child\_idx = PrefixSum[node\_idx] + i - 1 \qquad (1)$$

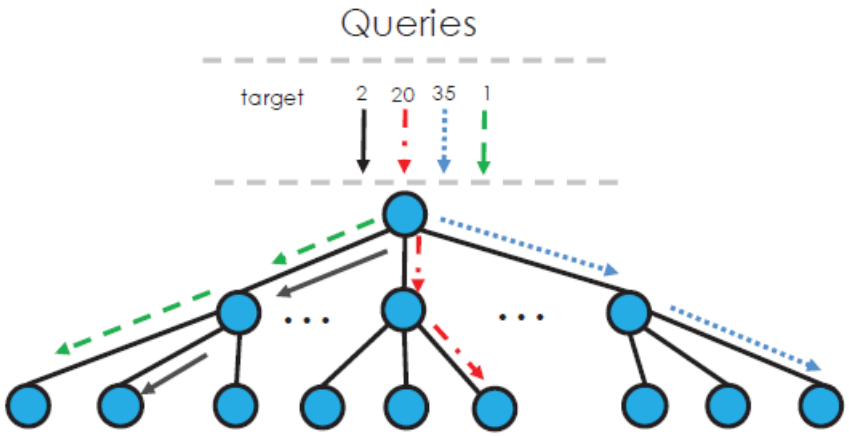


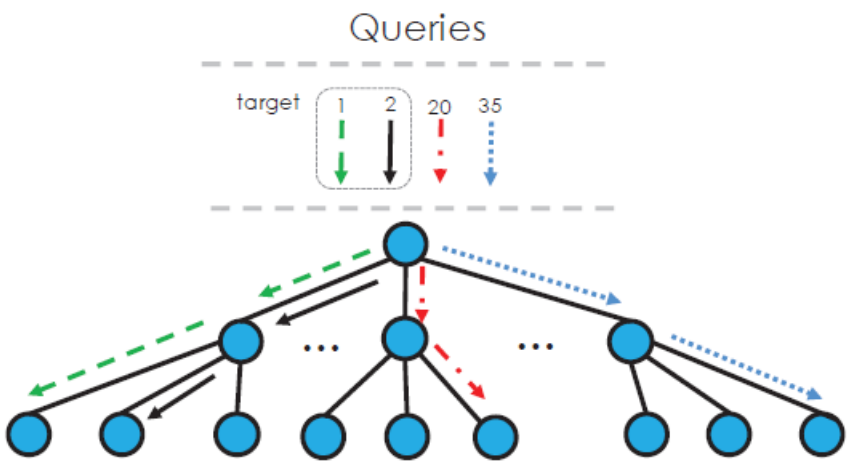
Optimization 1: Batch-wise Partial Radix Sort on GPU (on search keys)



But was is the use of that?

- It make memory access coalesced and also mitigate warp divergence





- Tuning of the number of MSB bits used for sorting is need to get optimal performance.

$$N = B - \log_2(\frac{2^B}{T} * K)$$

B = each key is represented by B bits

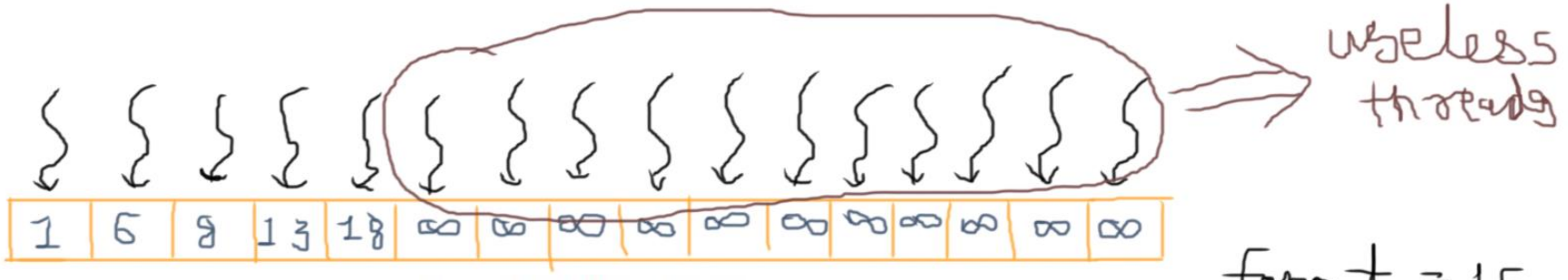
T = the size of traversed B+ tree is T

K = cache line can save K keys

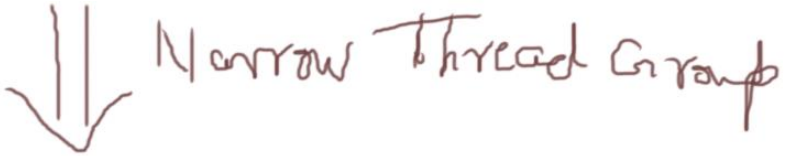
N = MSB N bits that has to be used for sorting by radix sort.

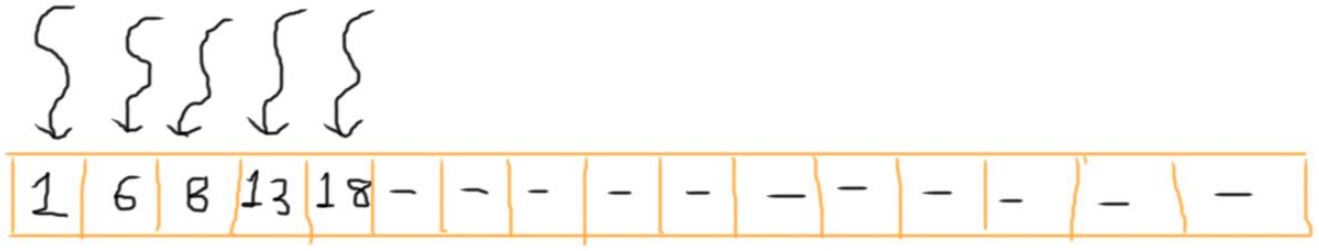
Optimization 2: Removing Unnecessary Computations (inside search procedure) or Narrow Thread Grouping

- Narrow the thread group based on the current number of keys present in the Node.



Fanout-based thread group



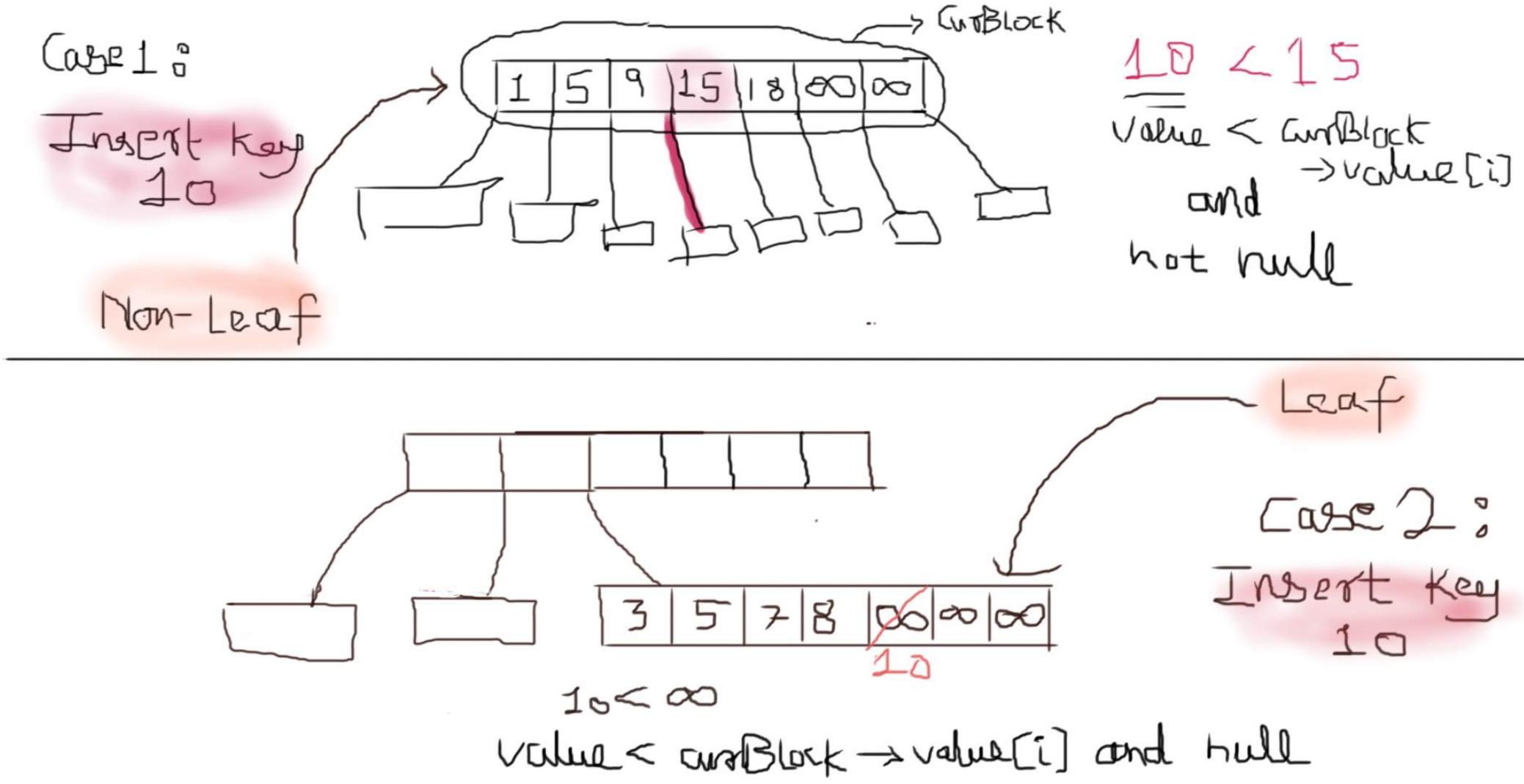


Narrowed thread group

Procedure Search()

```
__global__ void search( struct Node *a , int *b , int asize , int bsize , int *search_keys, int *mutex , int n , char mode){

    // task 1 is to assign individual searches to each threads
    int key = search_keys[blockIdx.x];
    __shared__ int index ;
    __shared__ int prev_index;

    index = 0;
    prev_index = 0;

    __syncthreads();


    // task 2 is to perform search using harmonia
    while(true){

        if( index > asize-1 ){
            break;
        }
        prev_index = index;
        // need to divide this for loop among several threads to implement NTG.

        if( threadIdx.x < a[index].count ){
            if( a[index].keys[ threadIdx.x][0] == key ){
                index = b[index] + threadIdx.x + 1;
                goto bottom;
            }
            if(threadIdx.x != a[index].count - 1)
            if( a[index].keys[ threadIdx.x][0] < key  && key < a[index].keys[threadIdx.x + 1][0]  ){
                index = b[index] + threadIdx.x +1;
                goto bottom;
            }
            if(threadIdx.x == 0){
                 if( a[index].keys[0][0] > key ){
                index = b[index] + 0;
                goto bottom;
                }
                if( a[index].keys[ a[index].count-1 ][0] < key ){
                index = b[index] + a[index].count;
                goto bottom;
                }

            }

        }
      bottom:  __syncthreads();
    }
```

How InsertKey works?



Algorithm InsertKey(curBlock, value , recordptr)

for each keys in the curBlock

if value < curBlock->value[i] and curBlock->childBlock[i] is not empty then // case 1

recursively call InsertKey on next level of tree pointed by that childBlock[i] i.e. InsertKey(curBlock->childBlock[i] , value , recordptr)

if curBlock is at its max capacity

split curBlock as Non Leaf node

return as insertion is completed

else if value < curBlock->value[i] and curBlock->childBlock[i] is empty then // case 2

swap curBlock->value[i], and value

update the number of keys present in curBlock

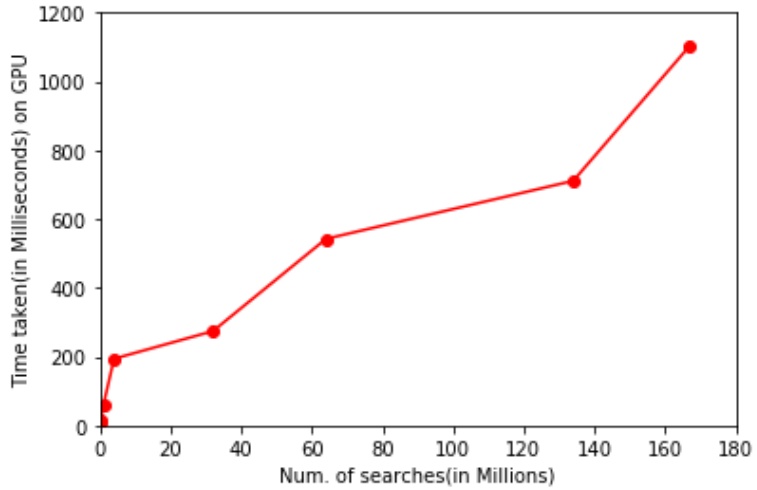
for end.

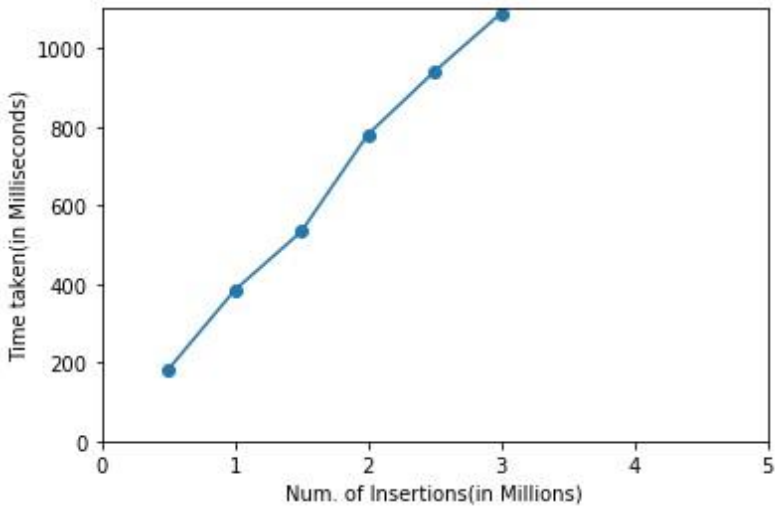
if curBlock is at its max capacity

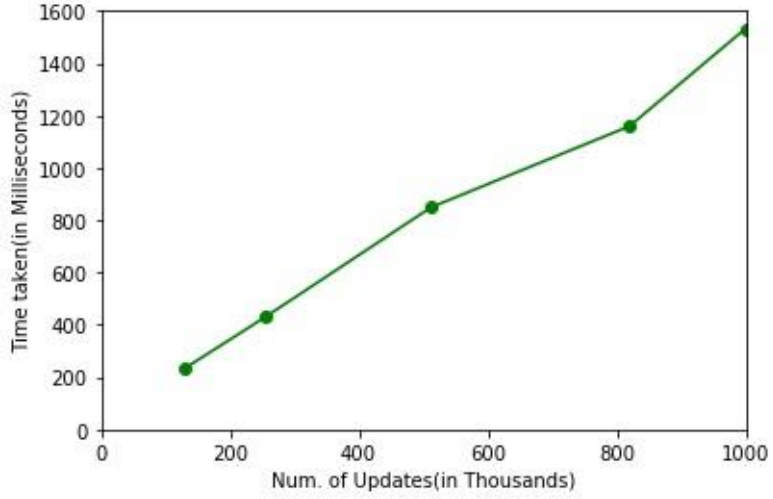
split curBlock as Leaf Node.

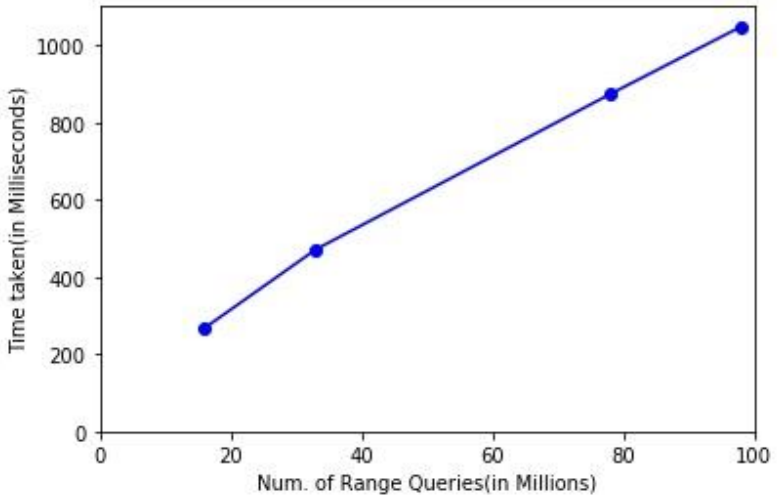
end.

but what about performance of all four operations?









And what about its comparison with CPU code?

- From the below Graph we can see that given implementation of Harmonia on GPU gives almost 23X speed up compared to the sequential code on CPU for Searches.