



ساختمان داده ها

تمرین درج و حذف در درخت بی

Practicing insertion and deletion in B-Trees

مدرس: غیاثی شیرازی

دانشگاه فردوسی مشهد

با تشکر از خانم فرشته رمضانی برای تهیه نسخه اولیه این اسلاید
و آقای محمد جواد مشیری برای برطرف کردن برخی اشتباهات

Insert 60 :

$$m = 5$$

$$\lceil \frac{m}{2} \rceil = 3$$

بازگردانی شود

حائل تعداد زوج اکیلیه تعداد بازگردانی شود



60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 40 :



~~60~~ 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 41 :



~~60~~ ~~40~~ 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 41 :



~~60 40~~ **41** 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 44 :



~~60 40 41 44~~ 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 44 :



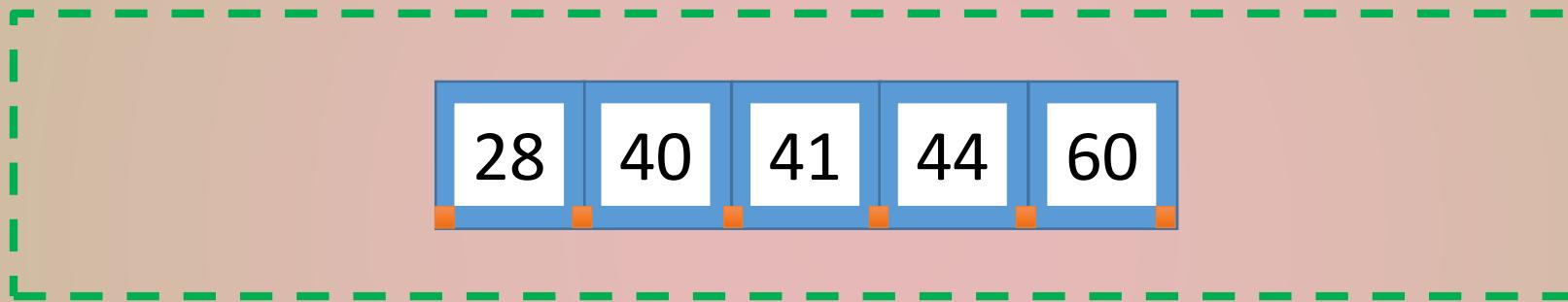
~~60 40 41 44~~ 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 28 :



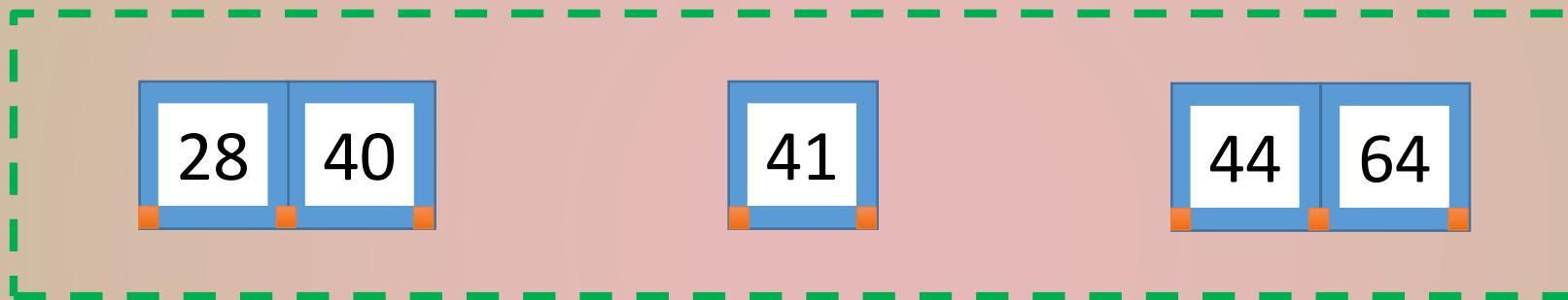
~~60 40 41 44~~ **28** 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Split :



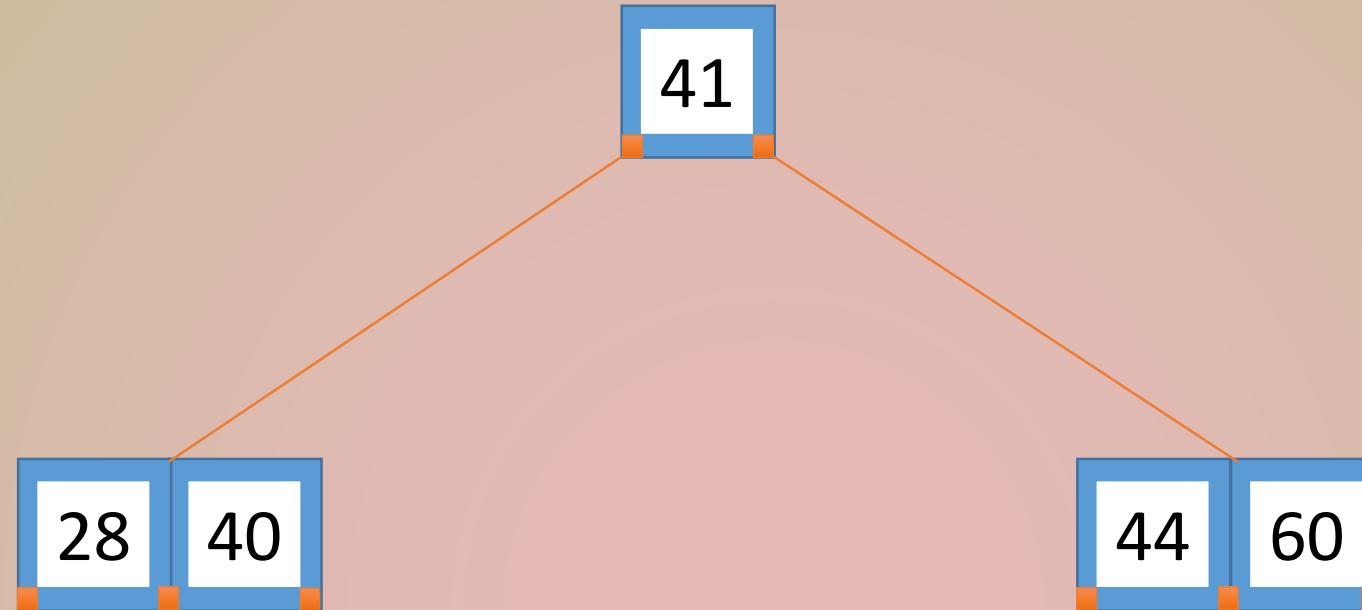
~~60 40 41 44 28~~ 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Split :



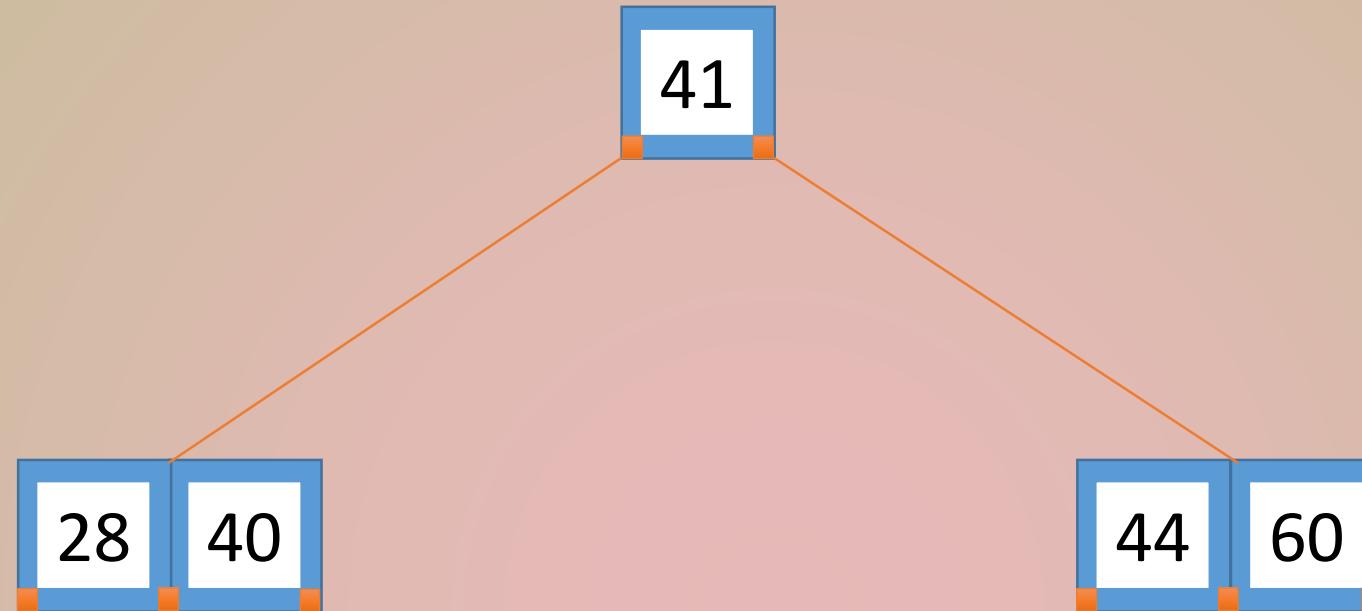
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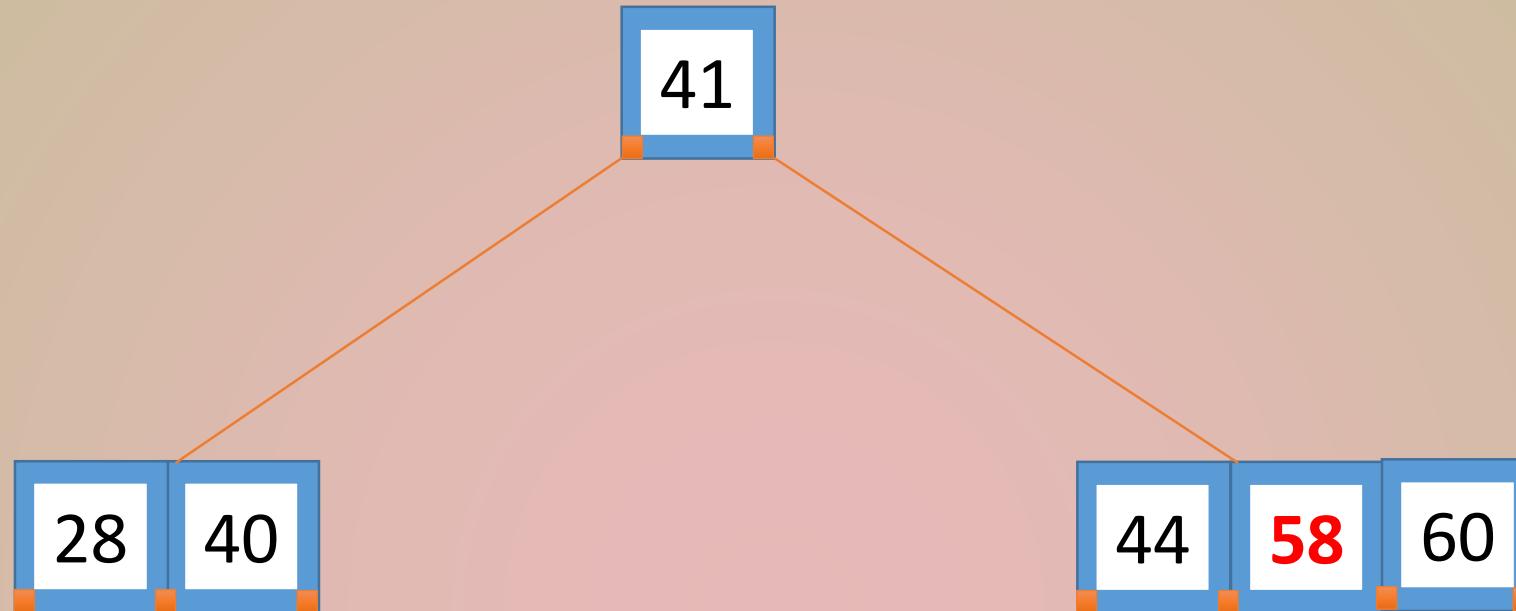
~~60 40 41 44 28~~ 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 58 :



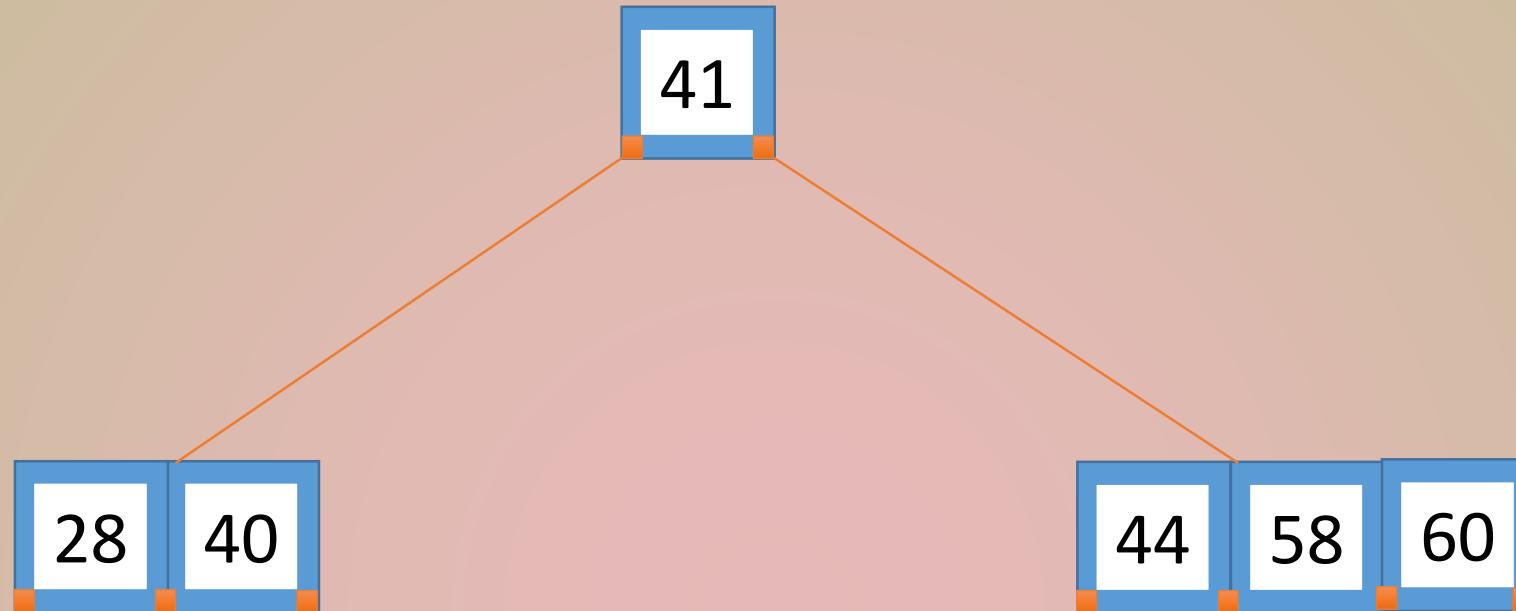
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Insert 58 :



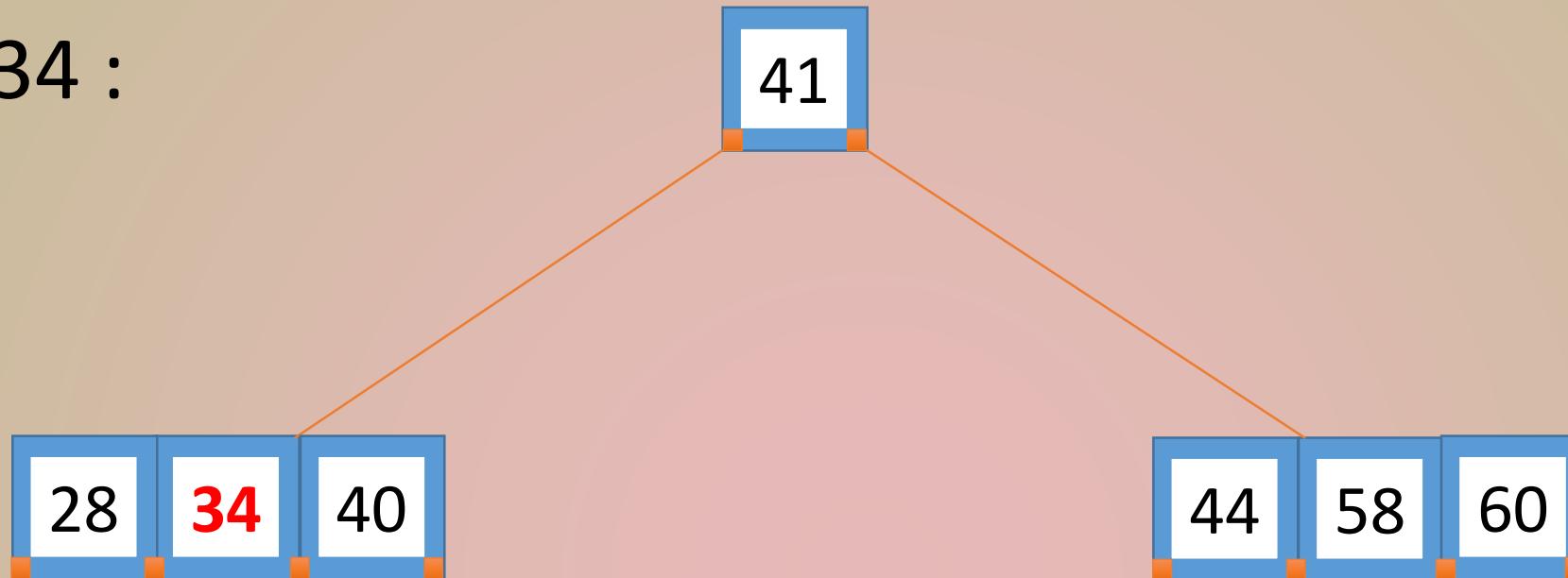
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 34 :



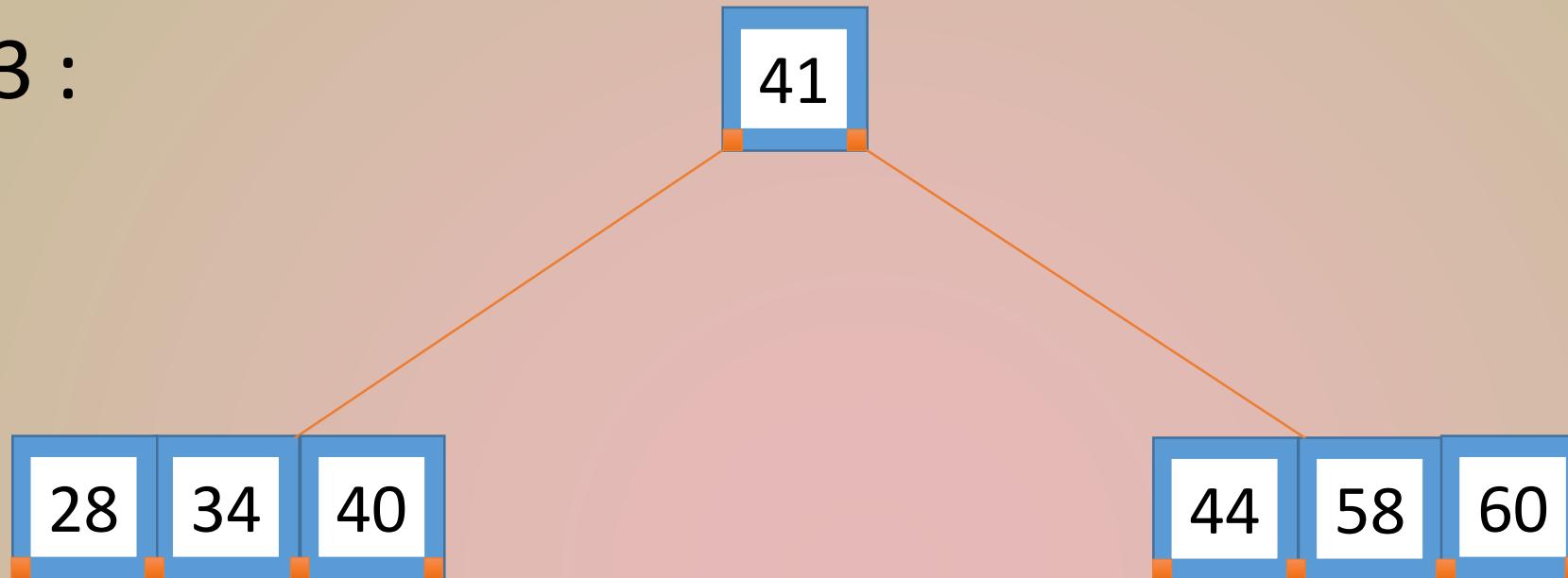
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Insert 34 :



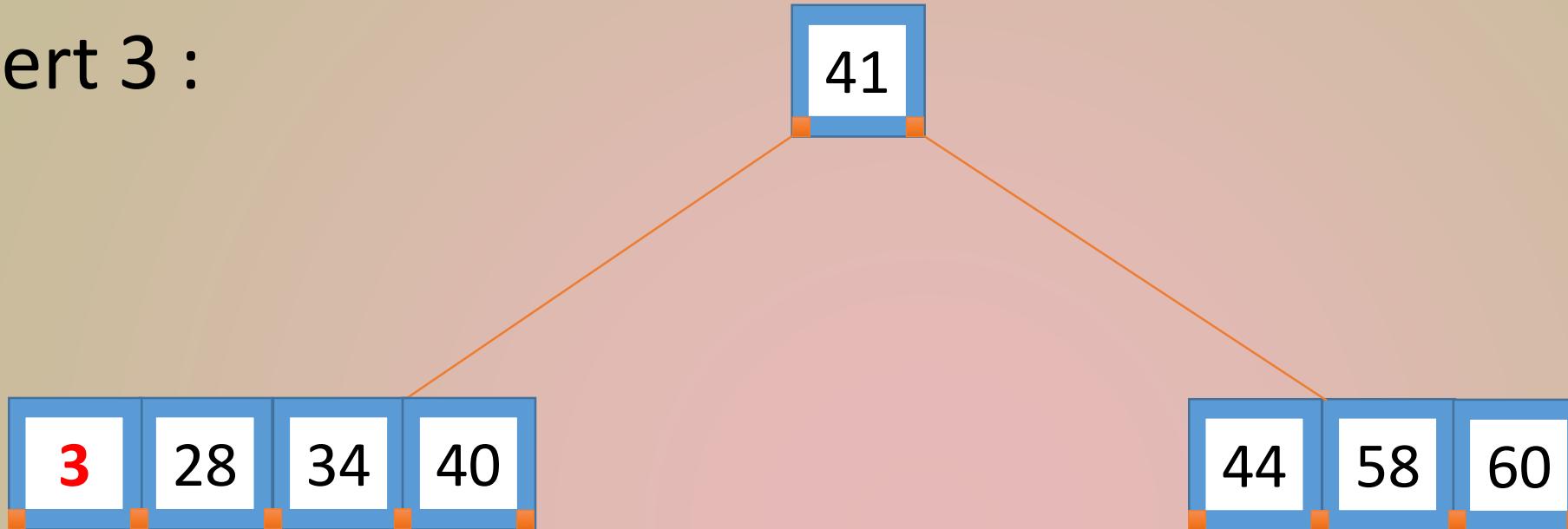
~~60 40 41 44 28 58~~ 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 3 :



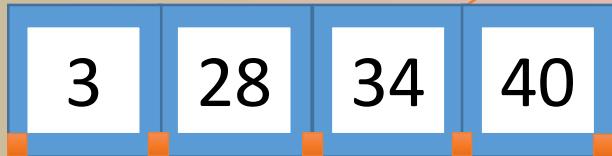
~~60 40 41 44 28 58 34~~ **3** 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 3 :



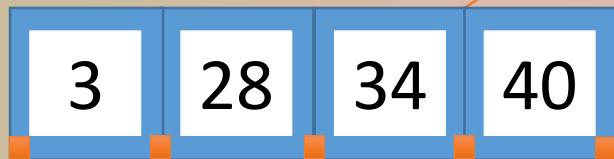
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Insert 70 :



~~60 40 41 44 28 58 34 3~~ **70** 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Insert 70 :



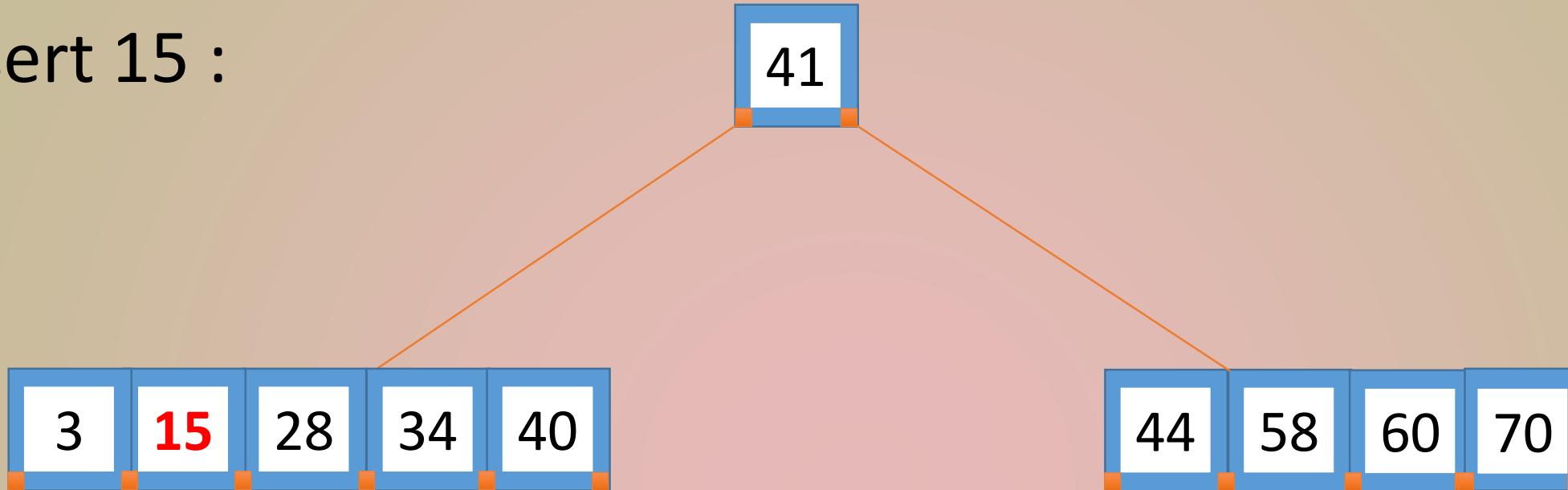
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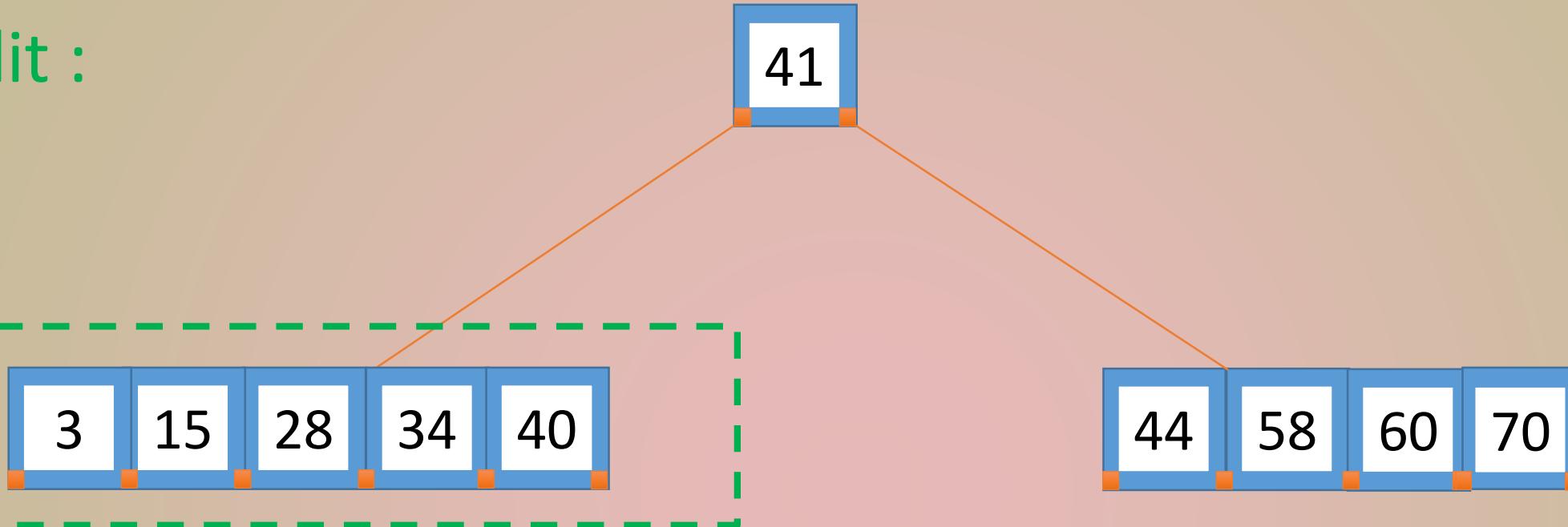
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Insert 15 :



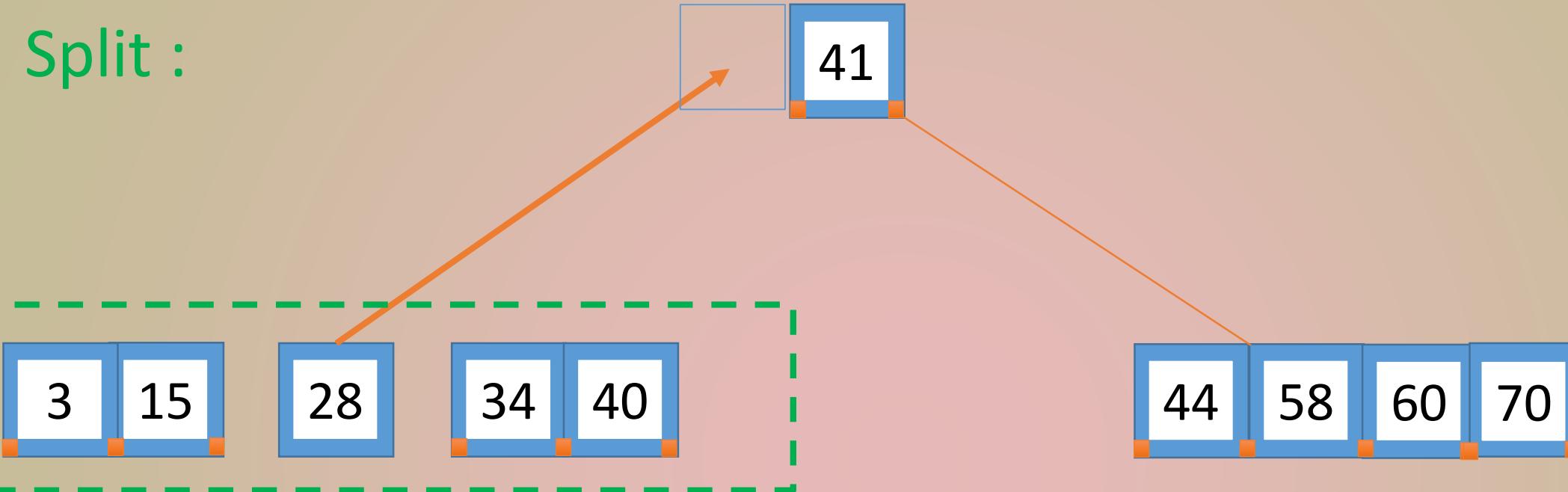
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :



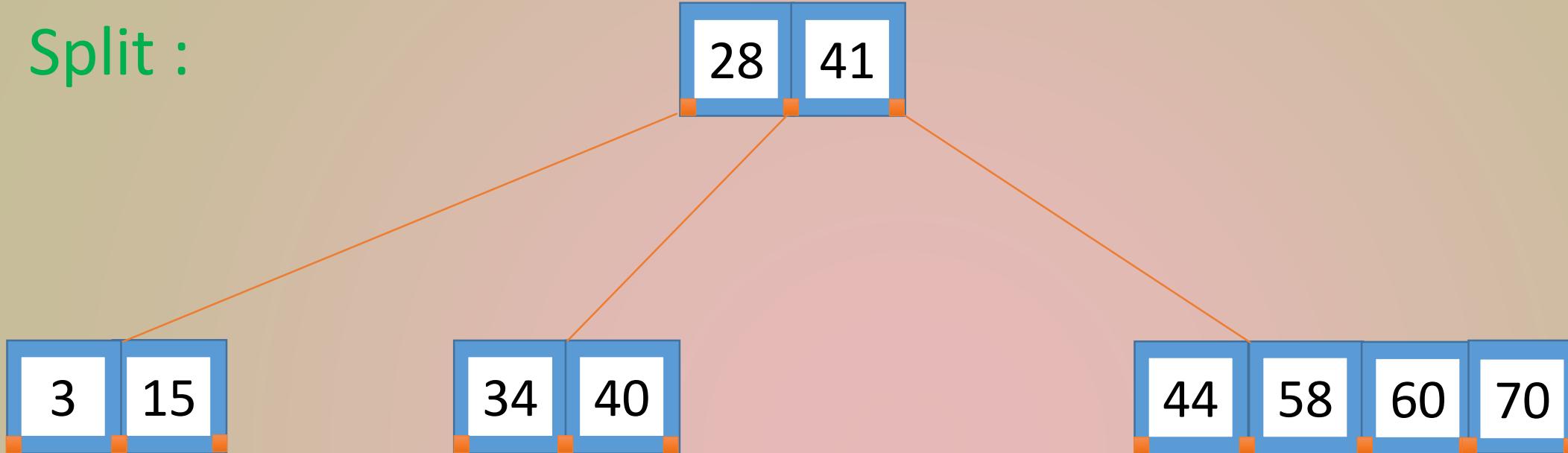
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :



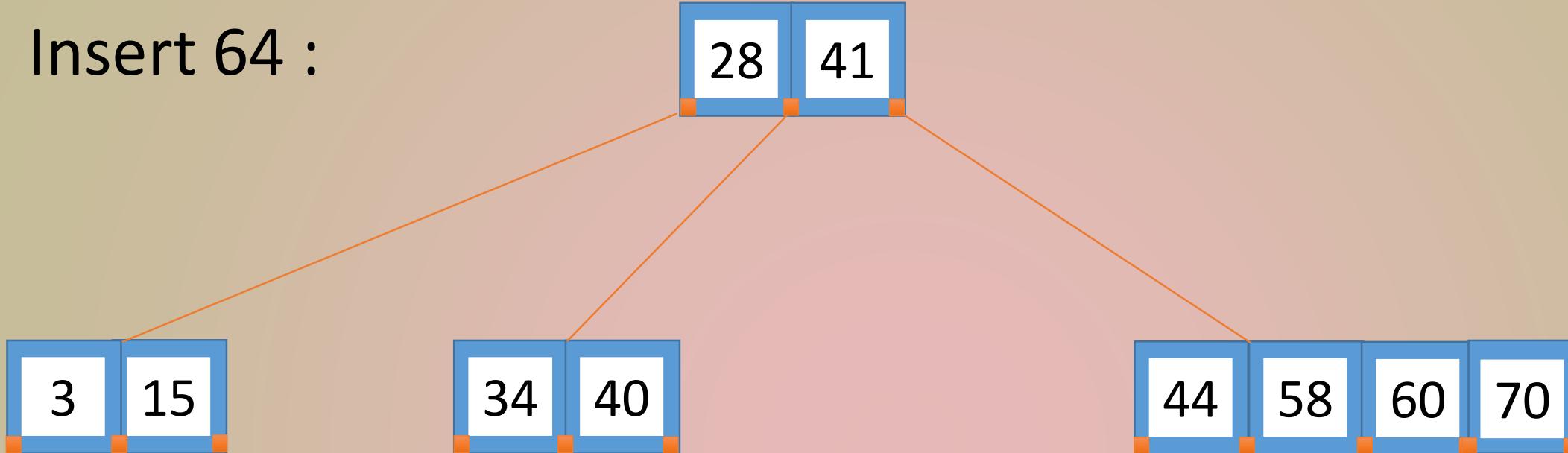
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :



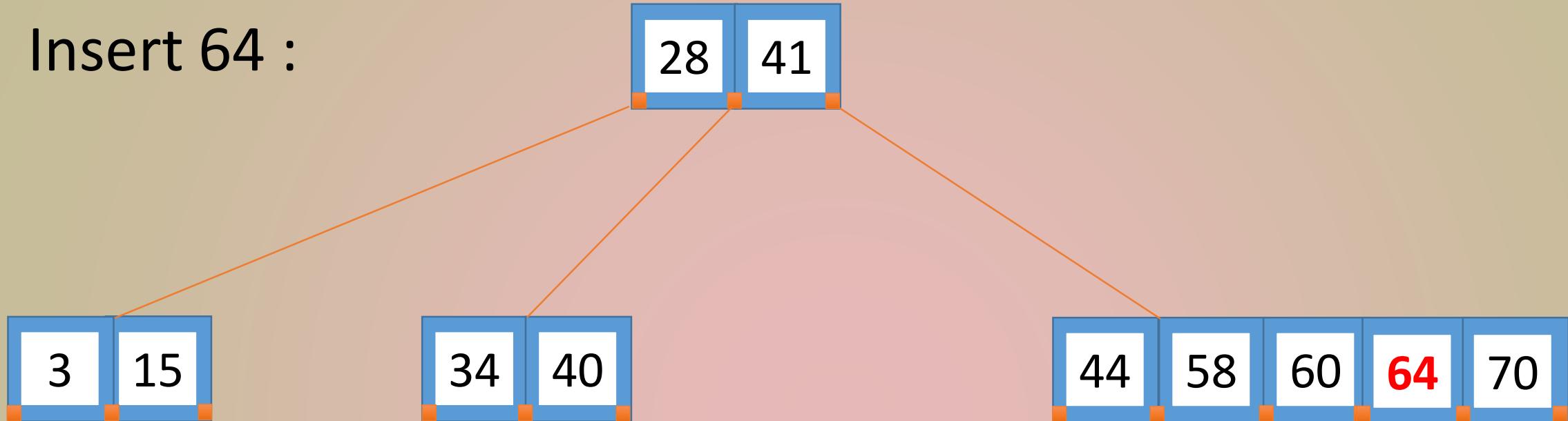
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 64 :



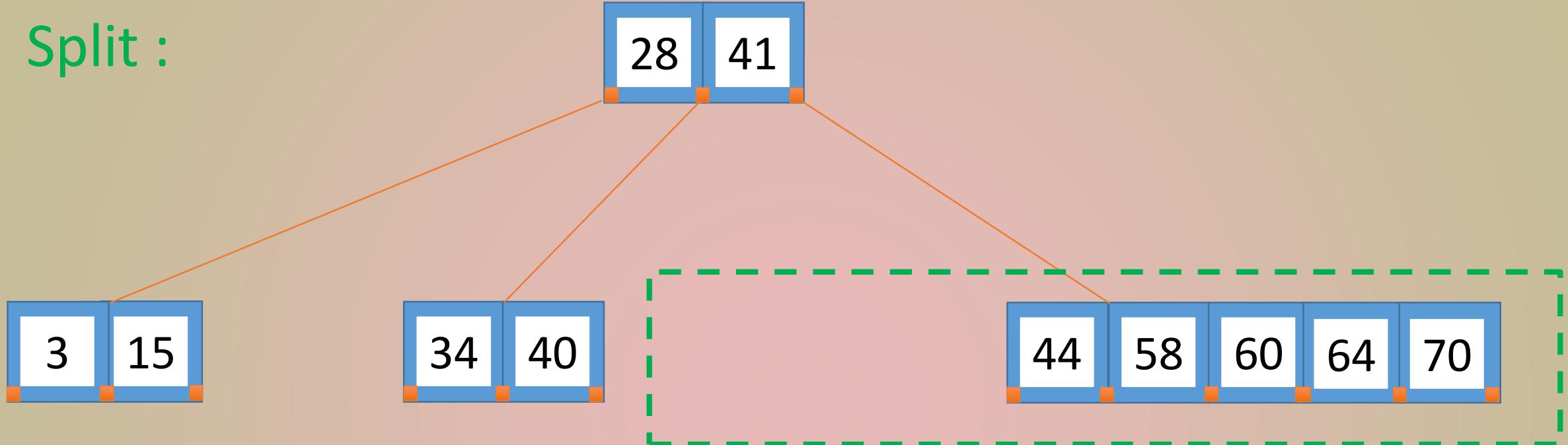
~~60 40 41 44 28 58 34 37 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 64 :



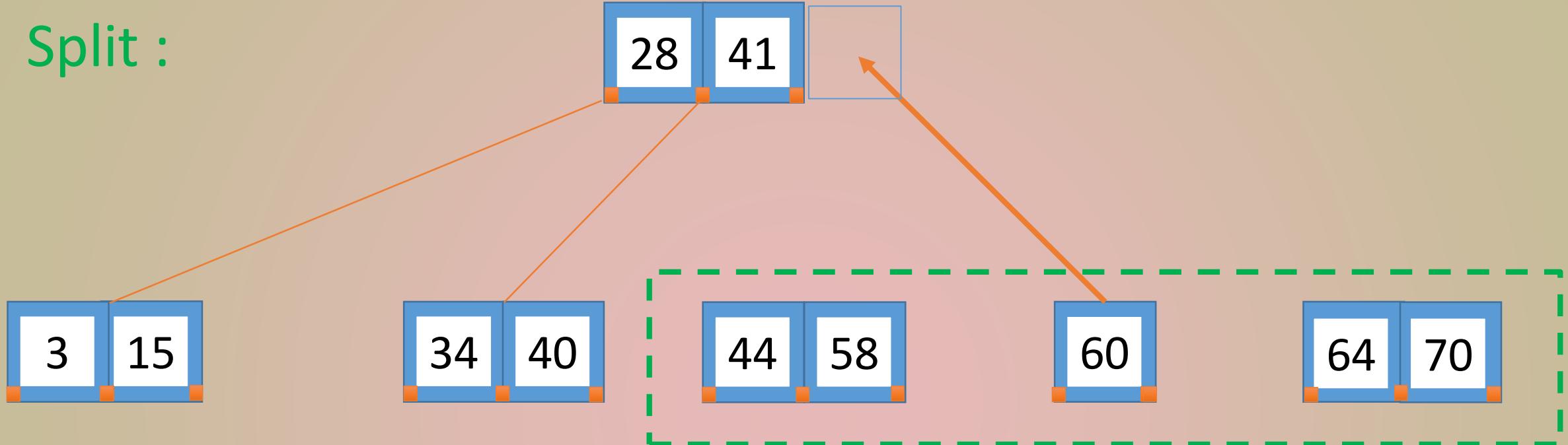
~~60 40 41 44 28 58 34 37 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :

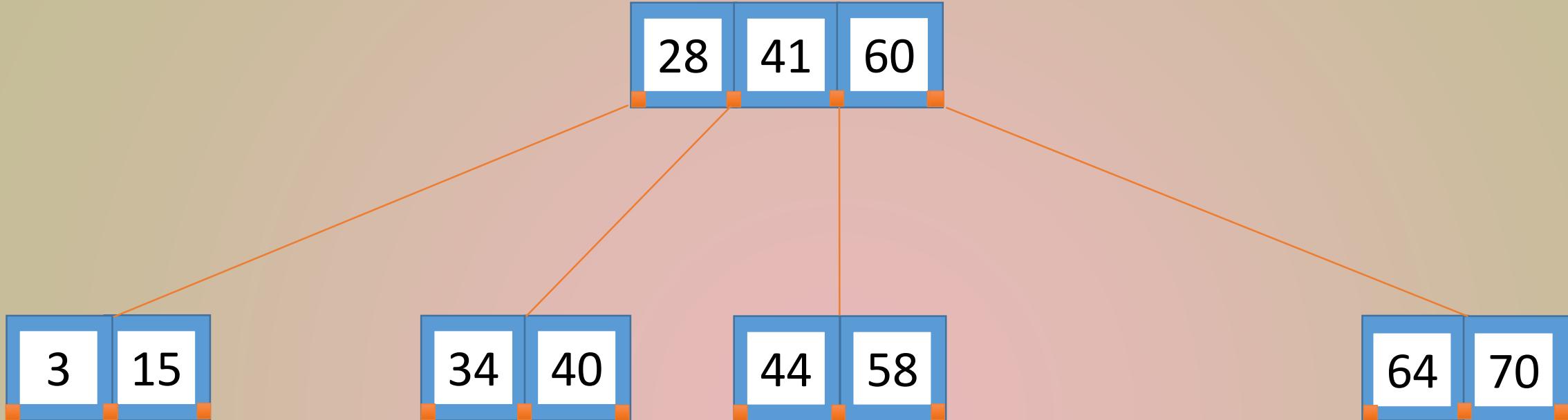


~~60 40 41 44 28 58 34 37 15 64~~ 86 75 16 84 45 42 77 81 94 18 25 87 13 52

Split :

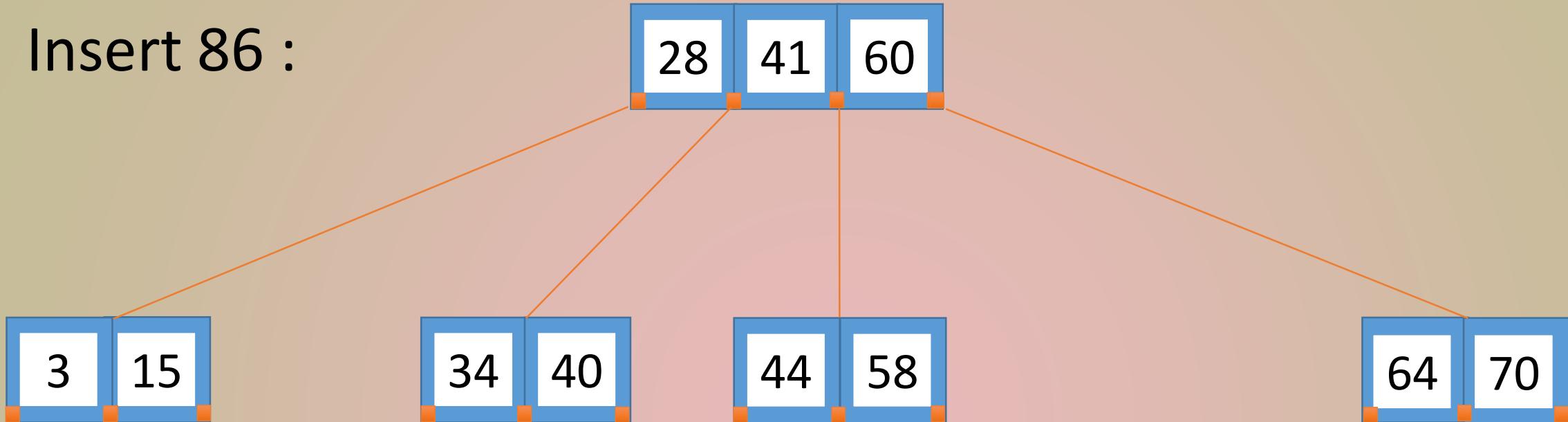


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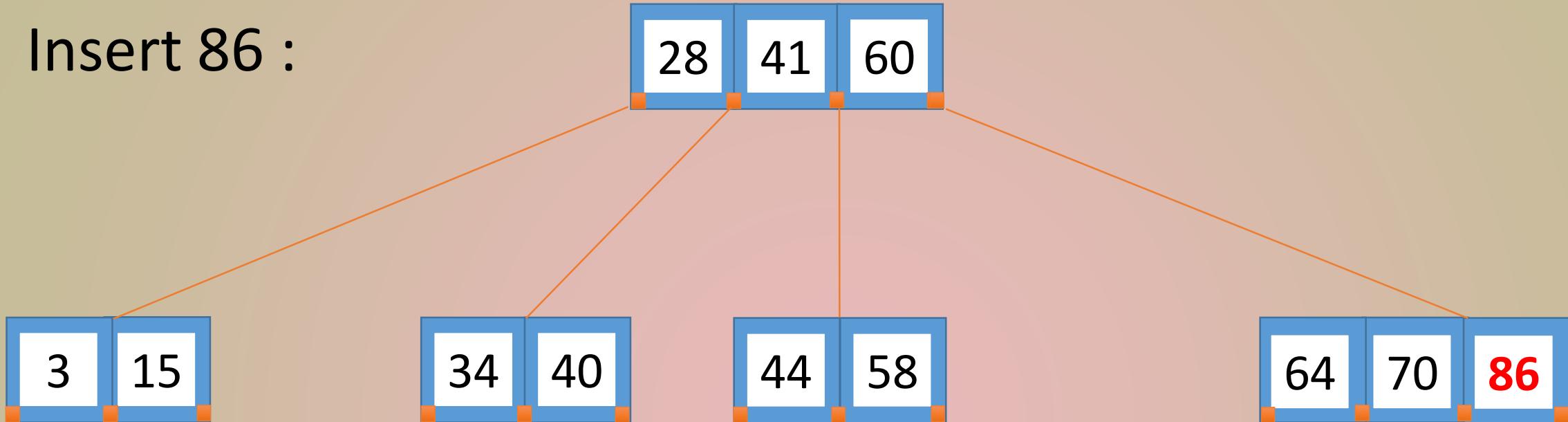
~~60 40 41 44 28 58 34 37 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 86 :



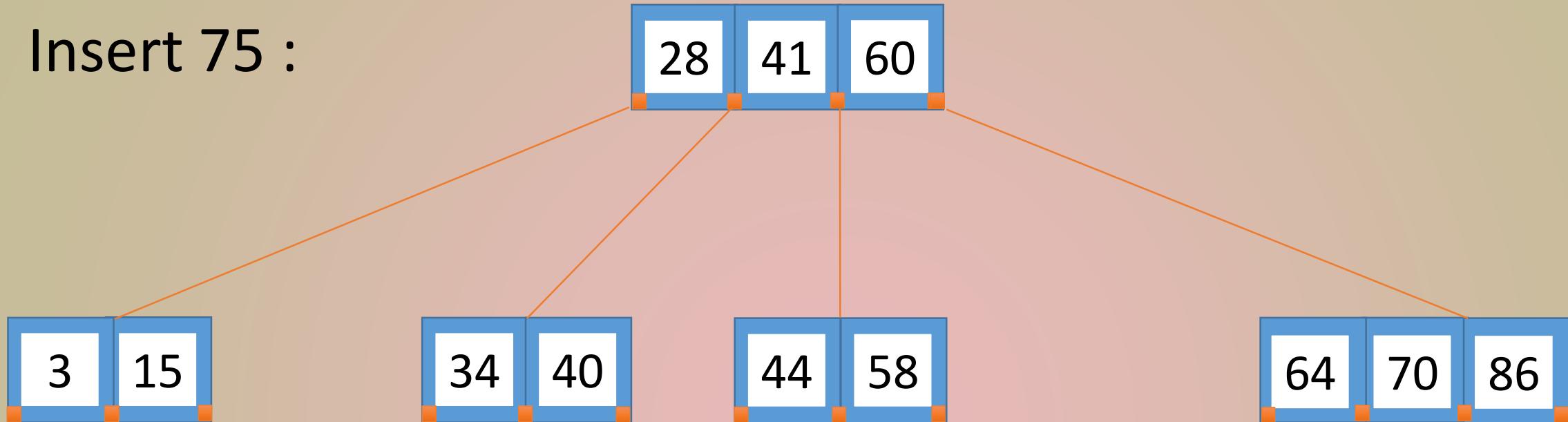
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 86 :



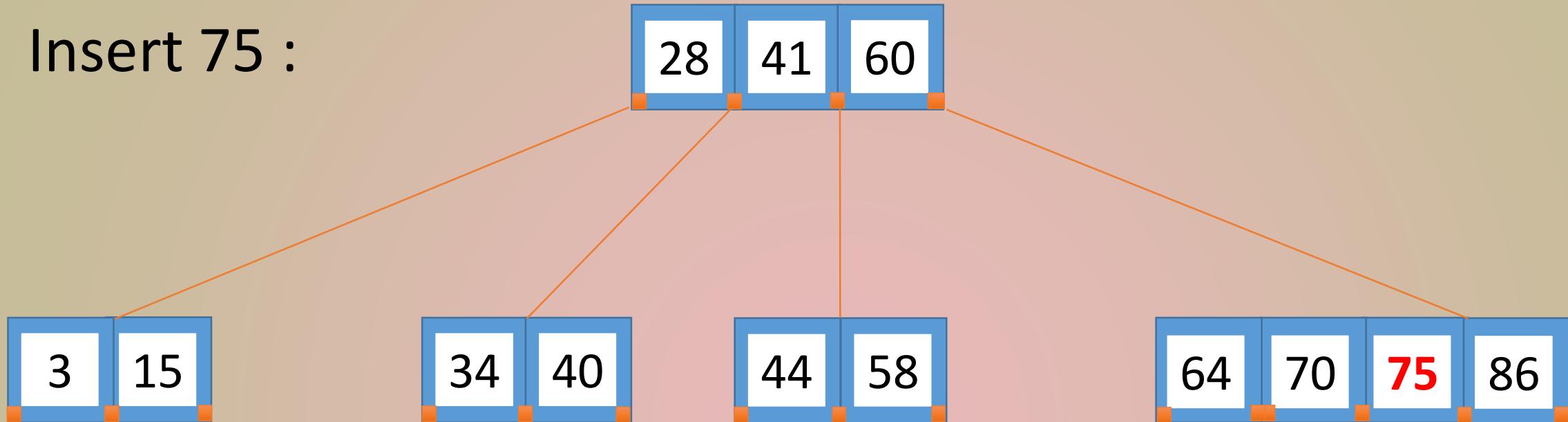
~~60 40 41 44 28 58 34 370 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 75 :



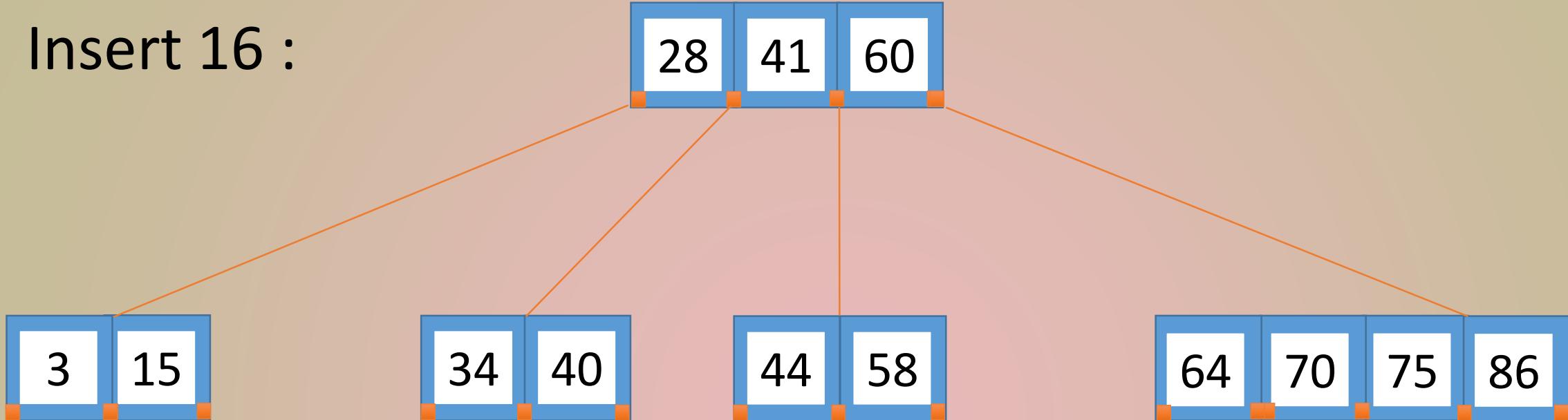
~~60 40 41 44 28 58 34 37 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 75 :



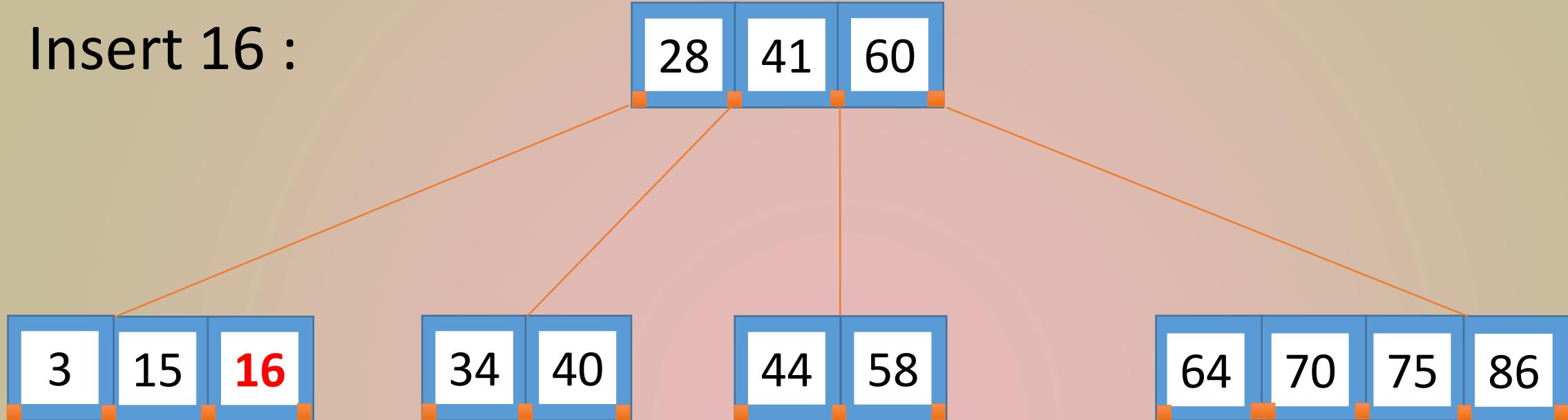
~~60 40 41 44 28 58 34 37 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 16 :



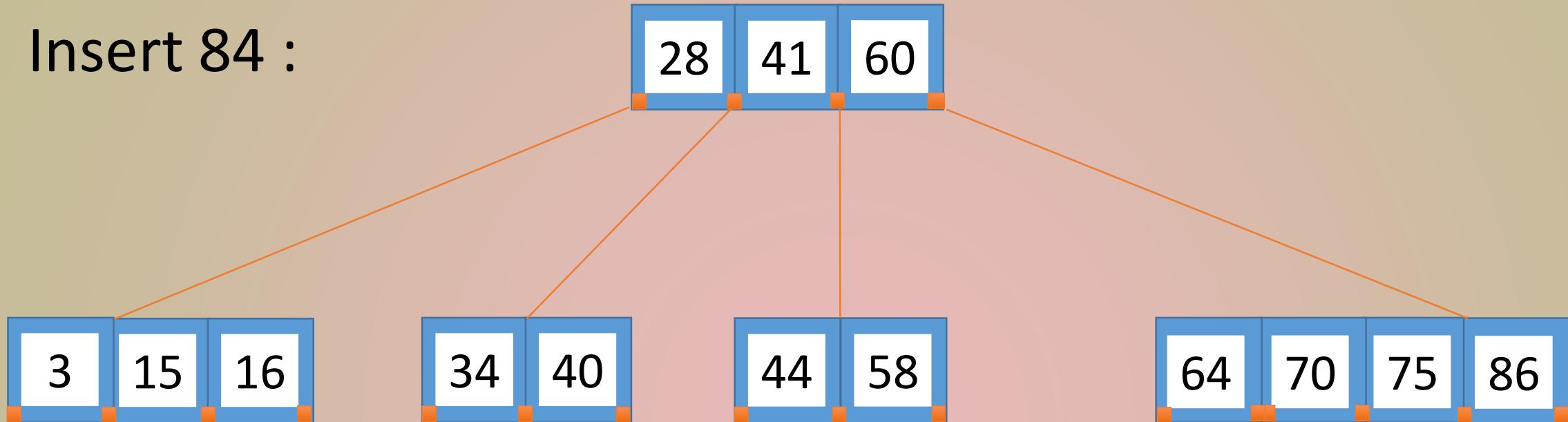
~~60 40 41 44 28 58 34 376 15 64 86 75 16~~ 84 45 42 77 81 94 18 25 87 13 52

Insert 16 :



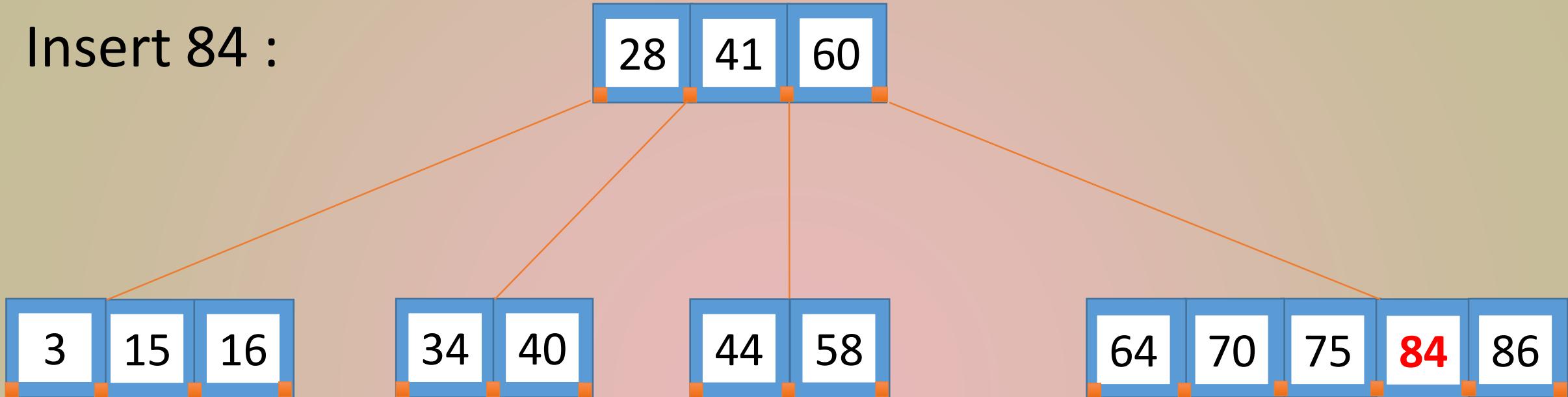
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Insert 84 :



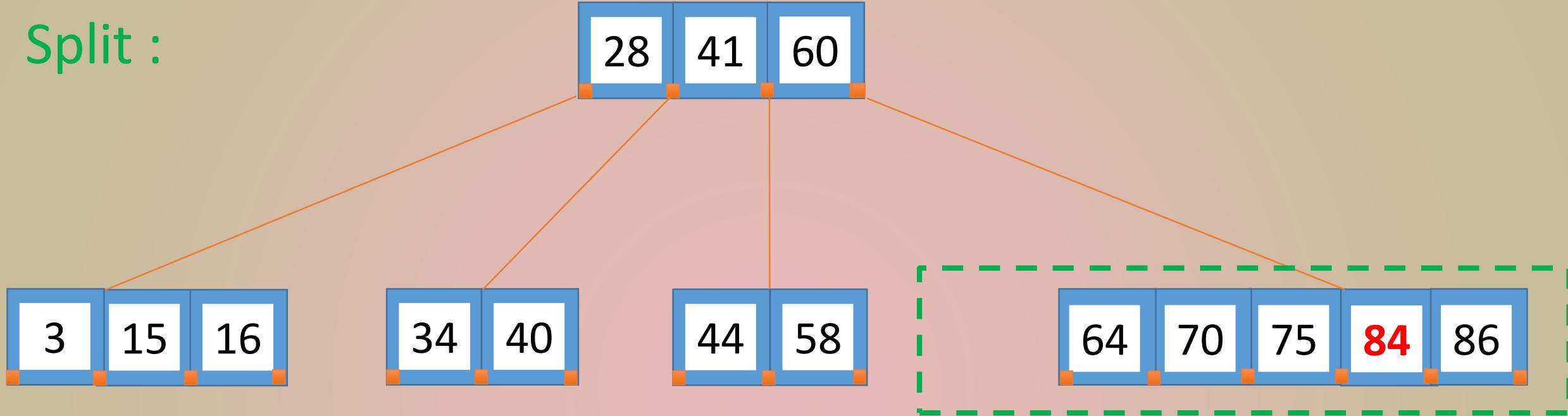
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 84 :



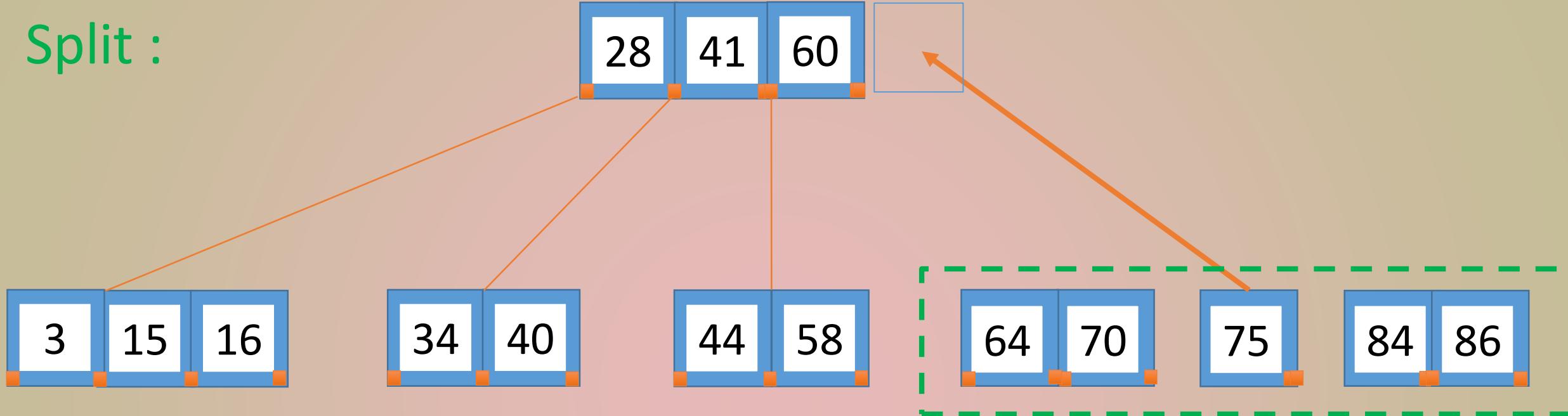
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :

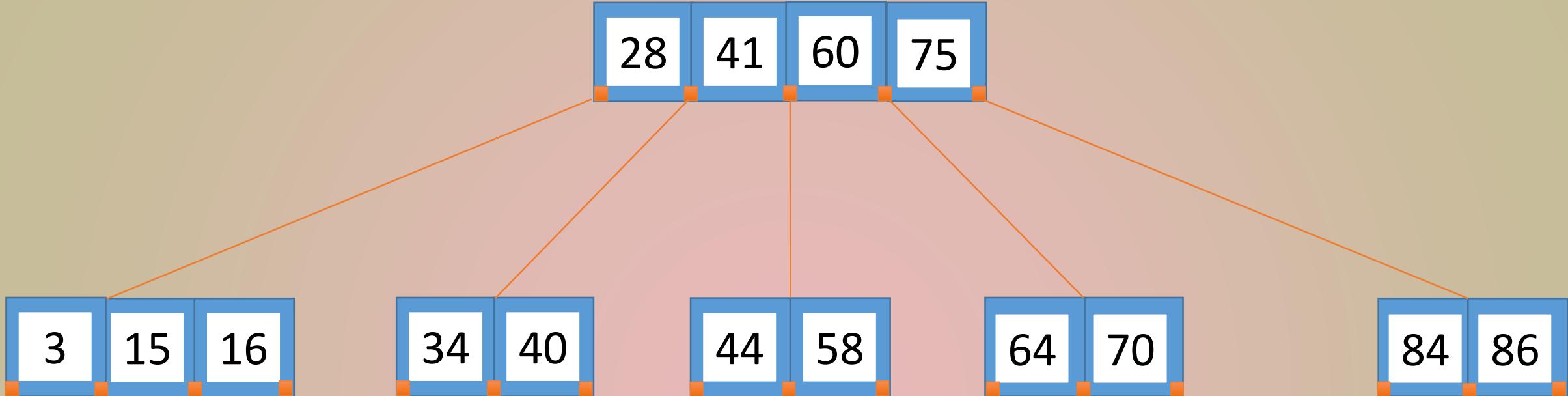


~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :

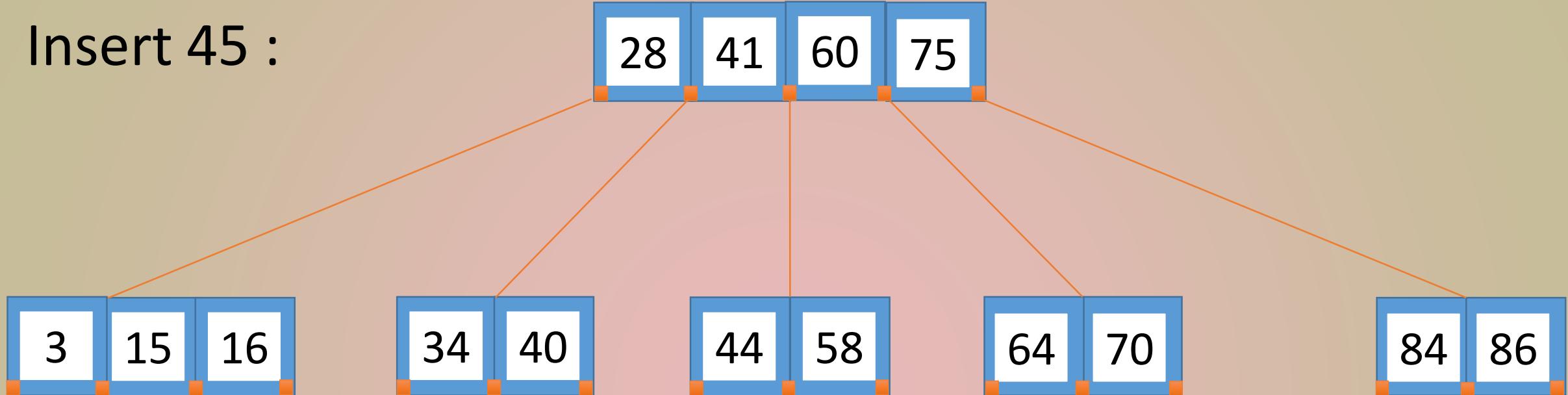


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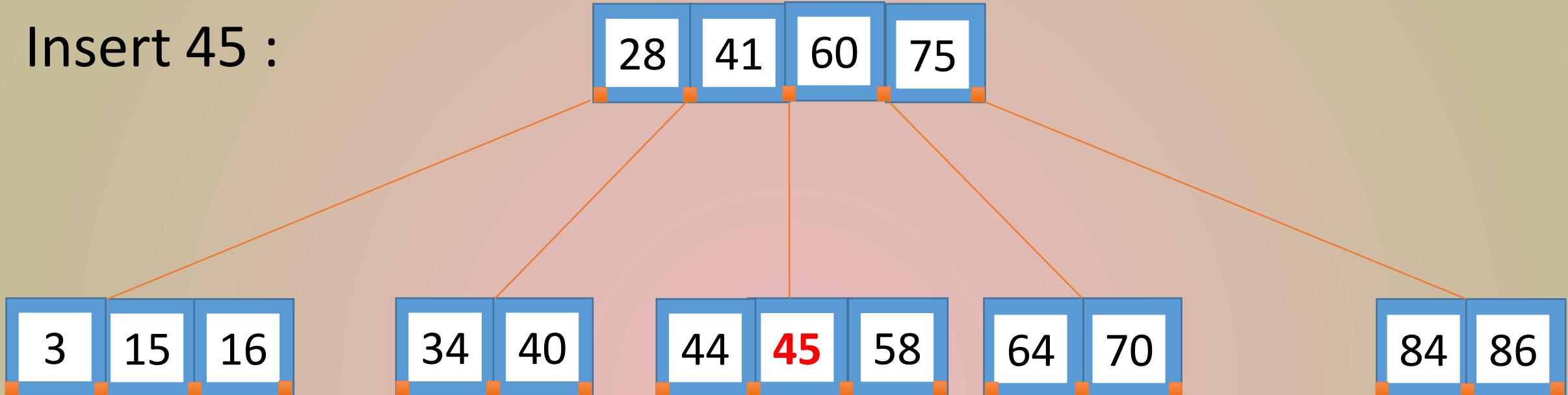
~~60 40 41 44 28 58 34 37 16 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 45 :



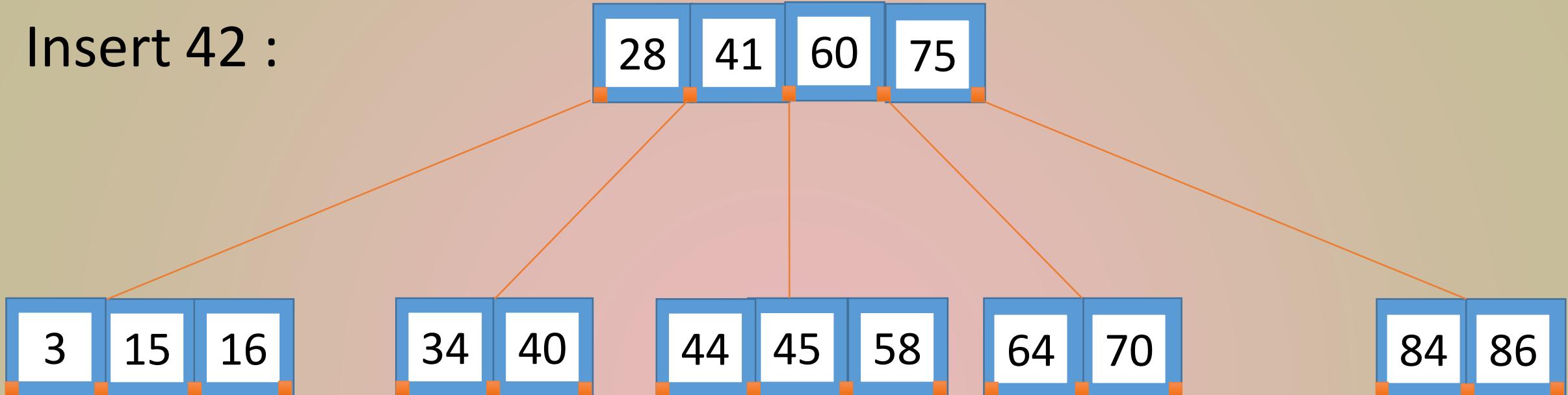
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 45 :



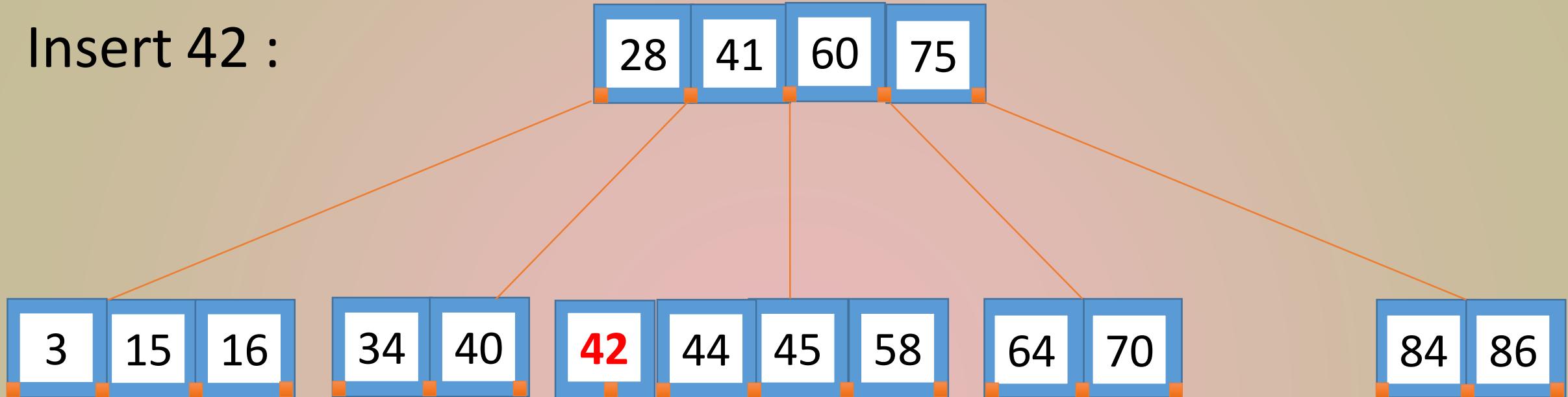
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 42 :



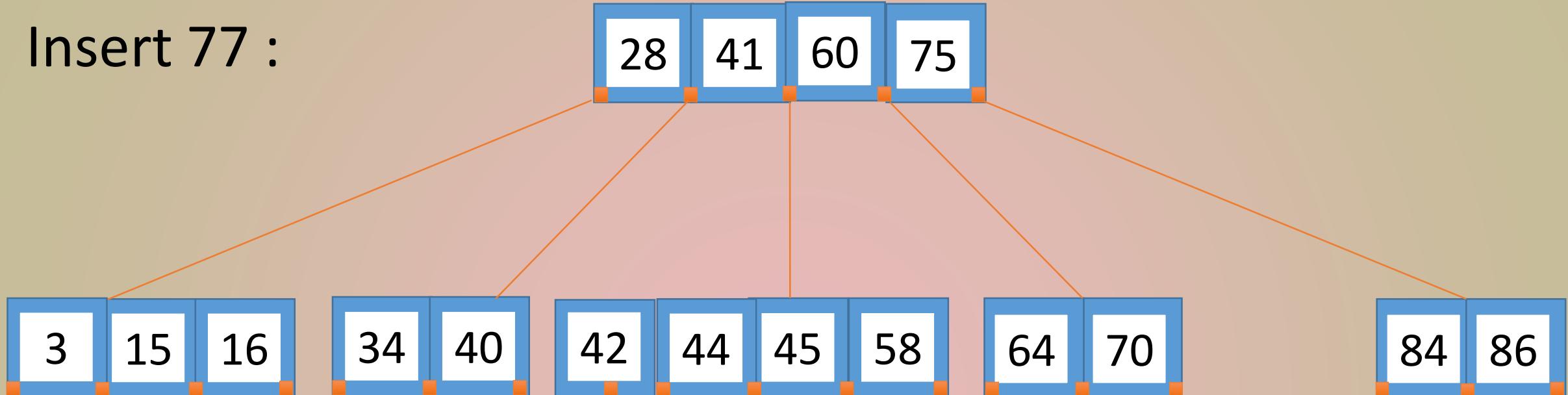
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 42 :



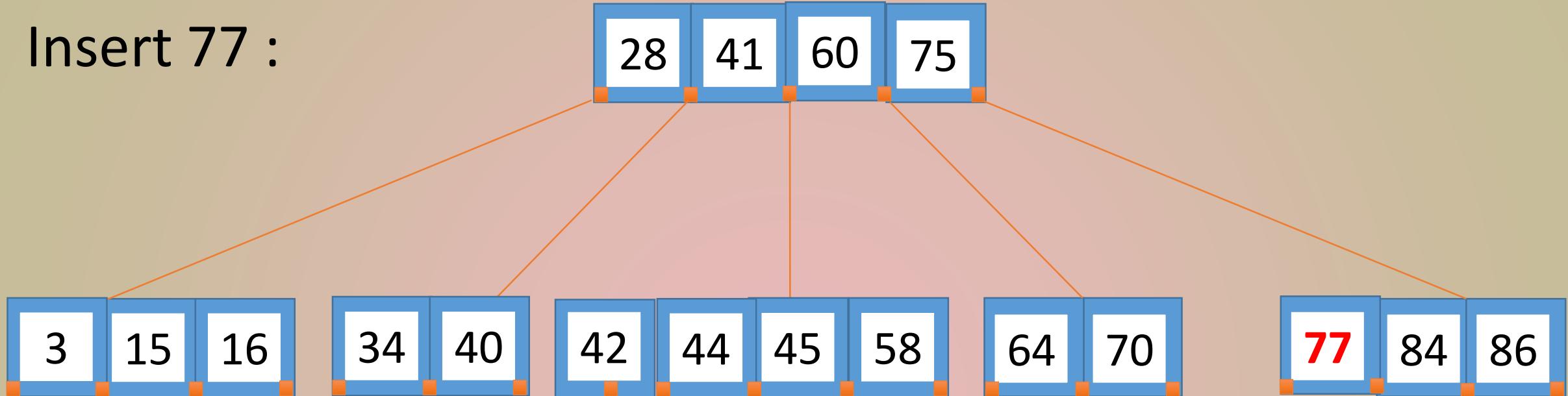
~~60 40 41 44 28 58 34 376 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 77 :



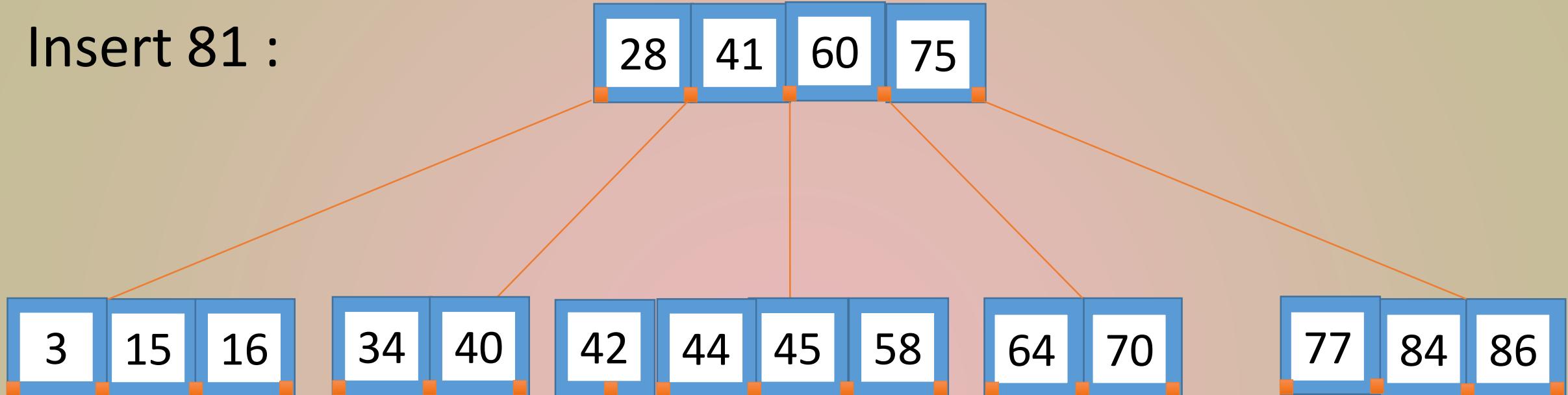
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Insert 77 :



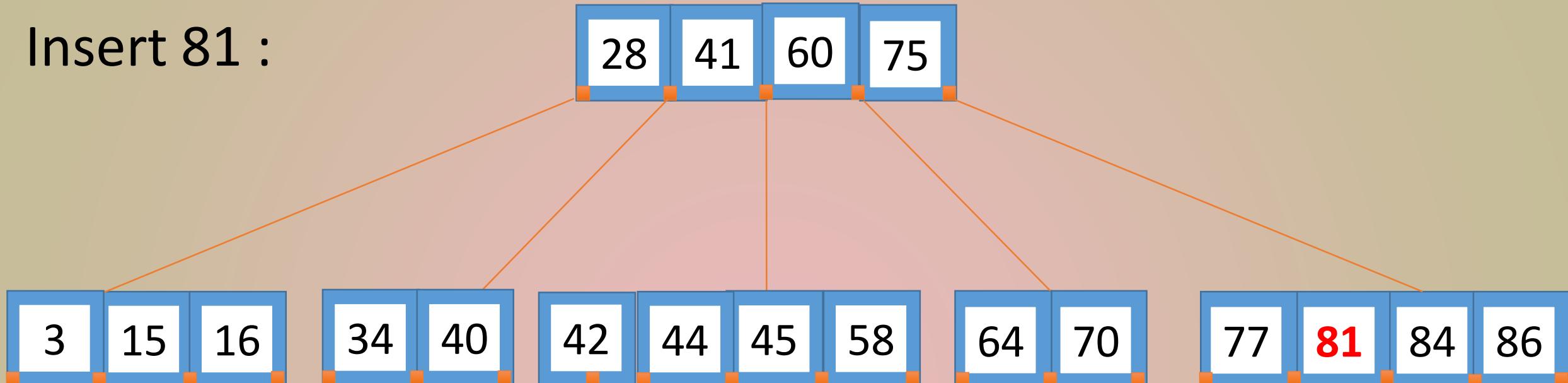
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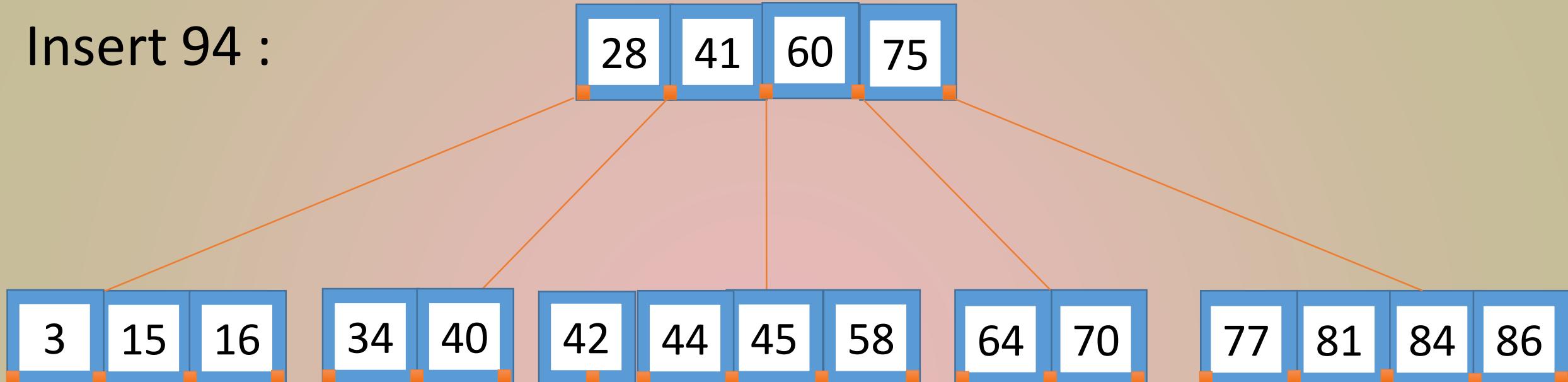
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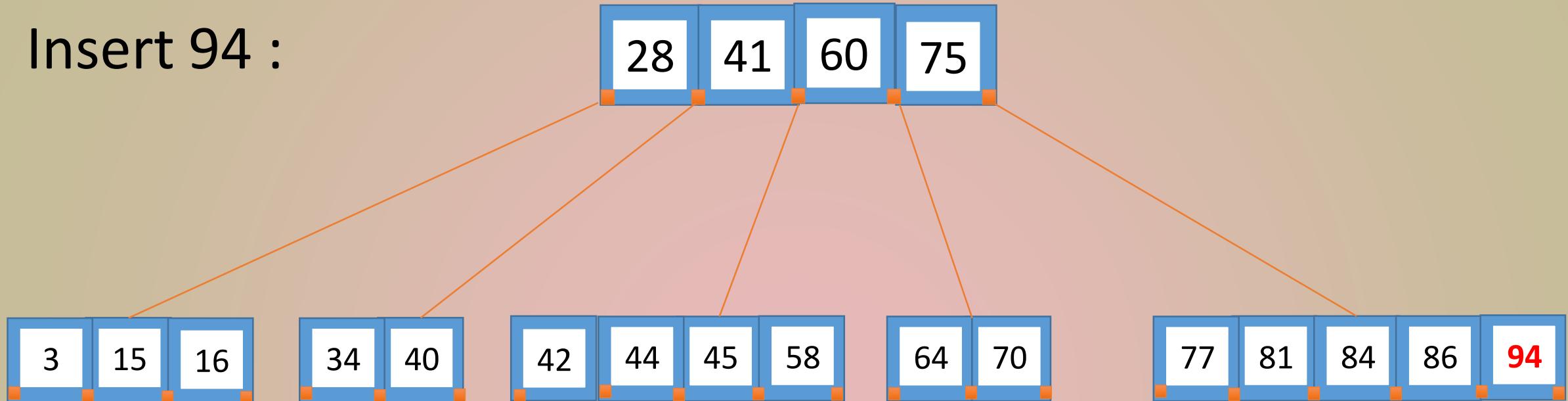
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Insert 94 :

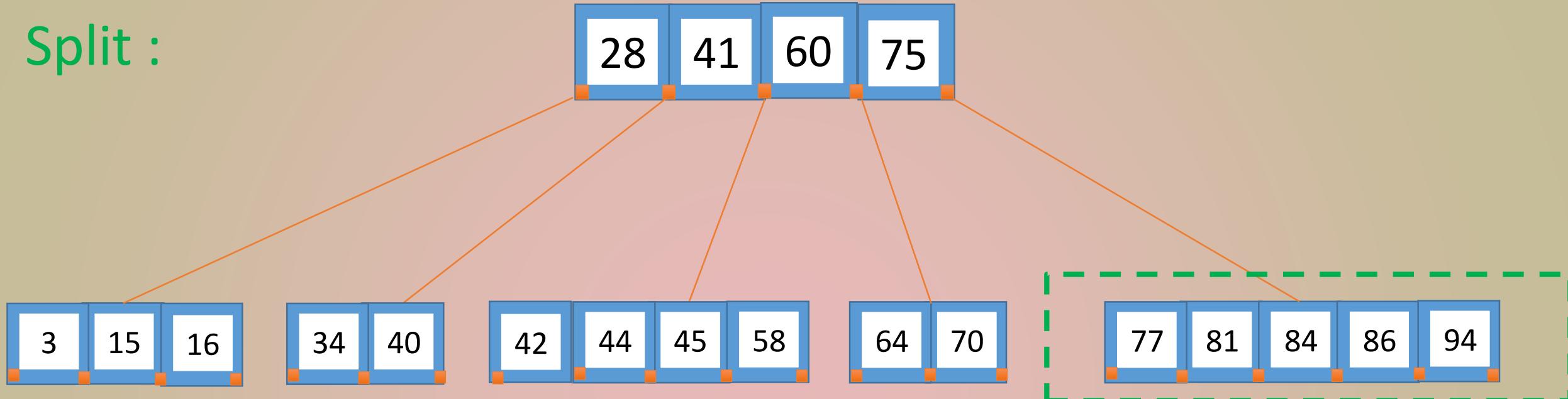


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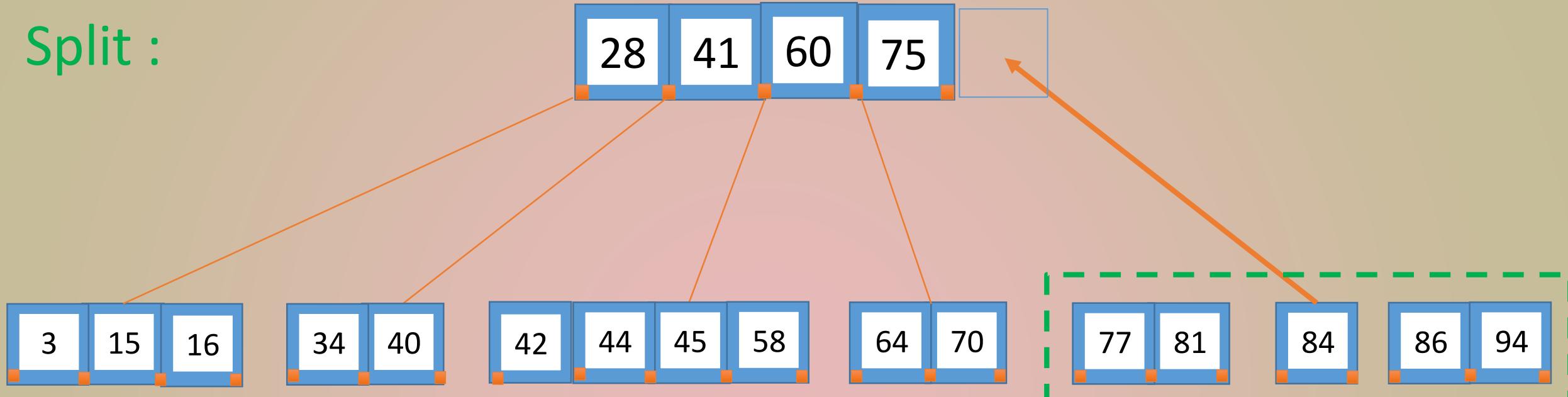


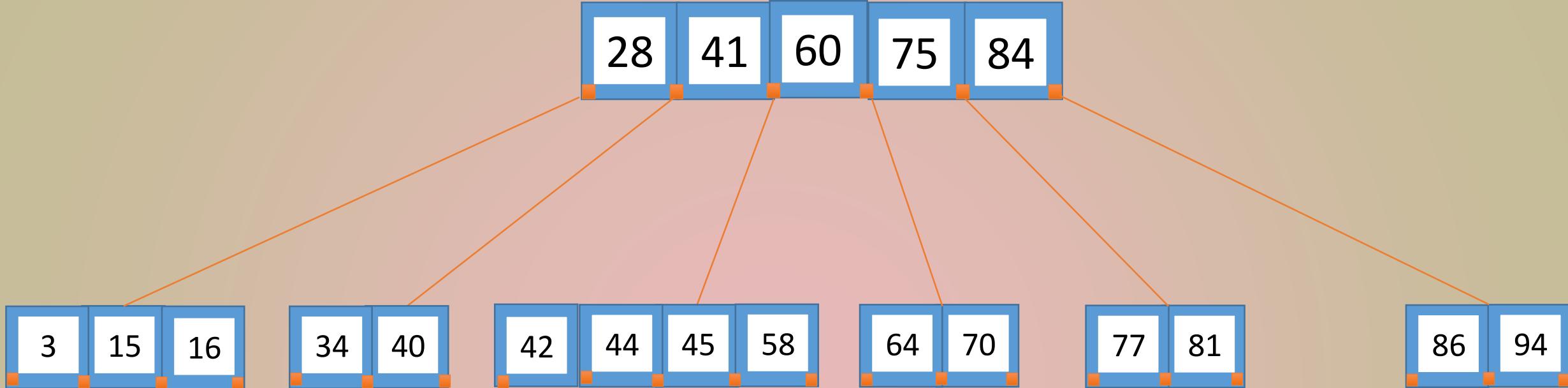
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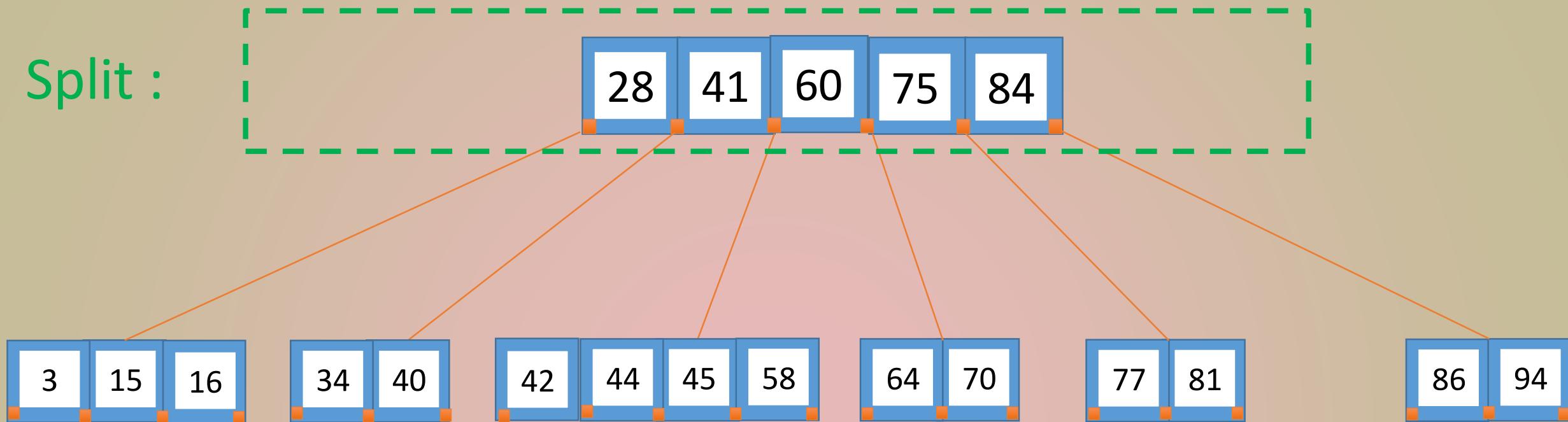
Split :





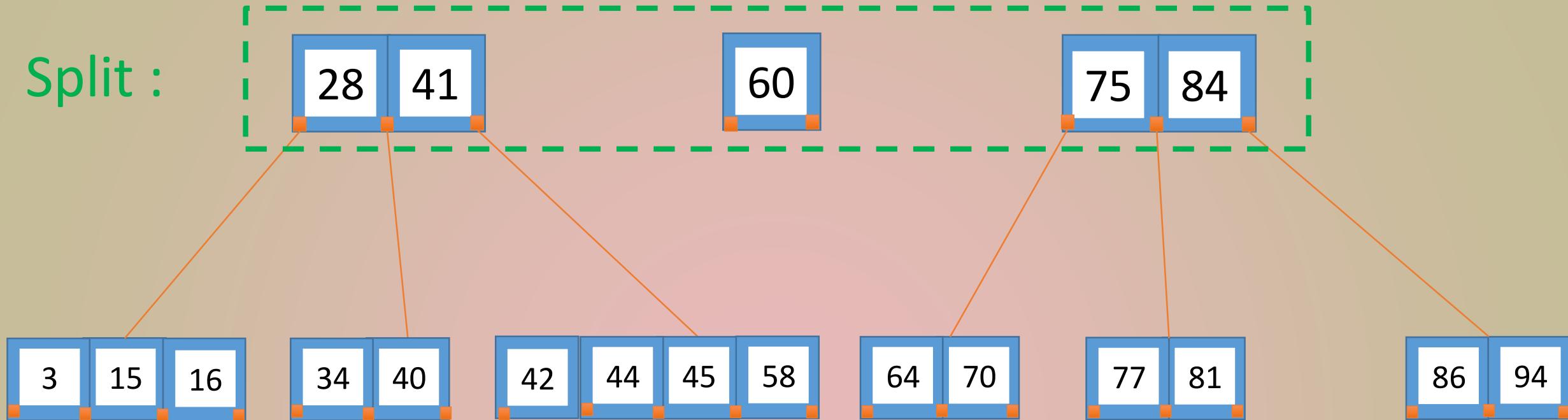
~~60 40 41 44 28 58 34 3 76 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :



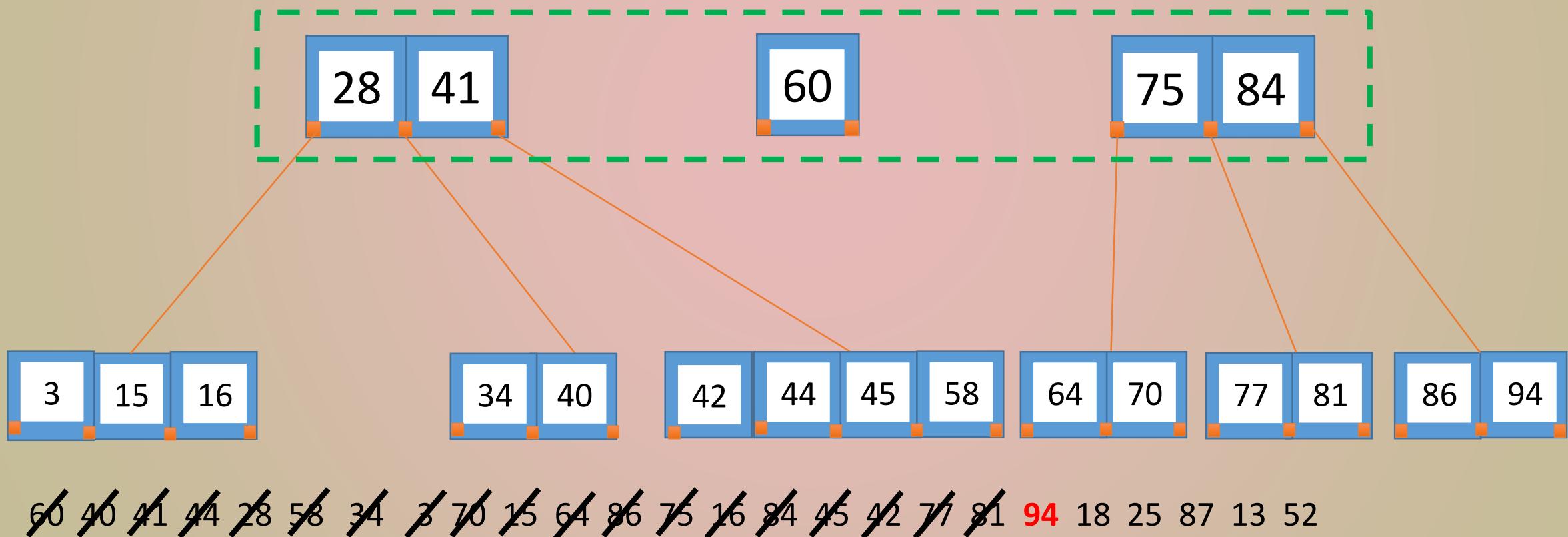
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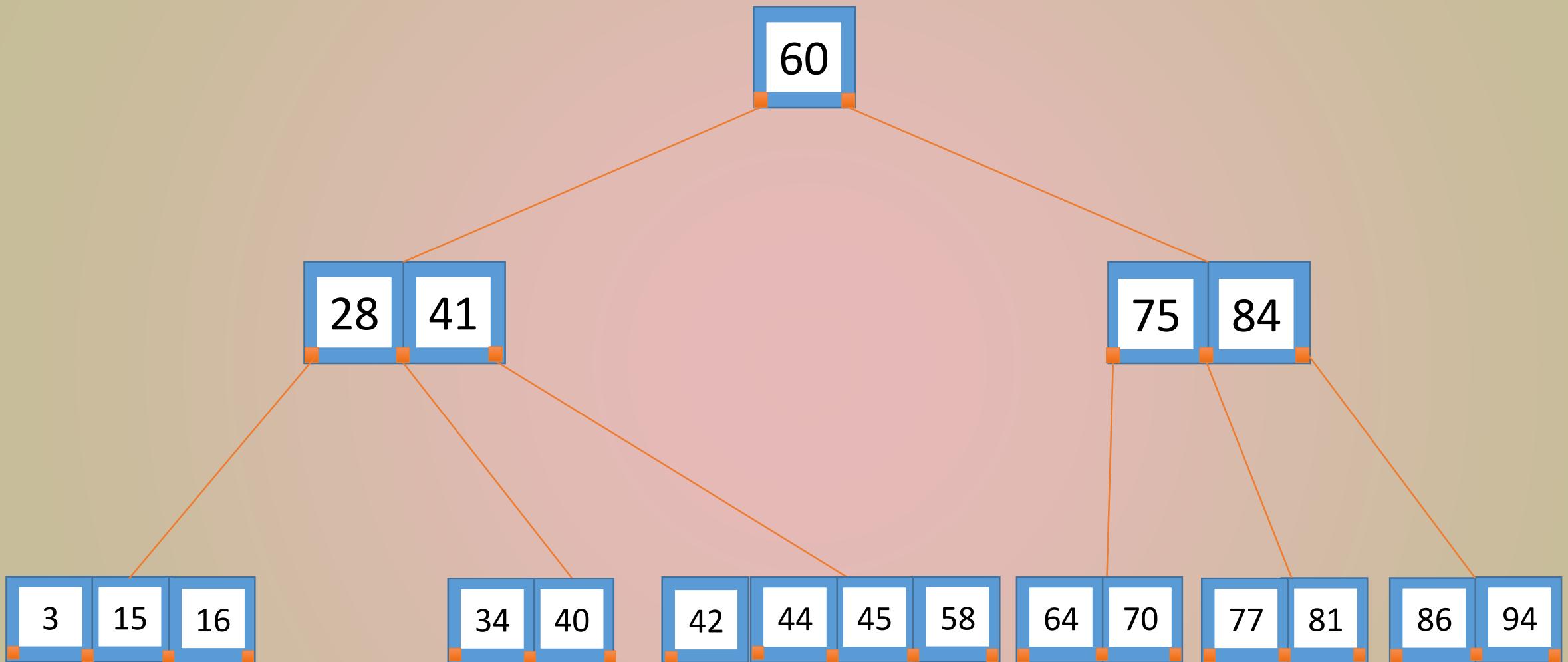
Split :



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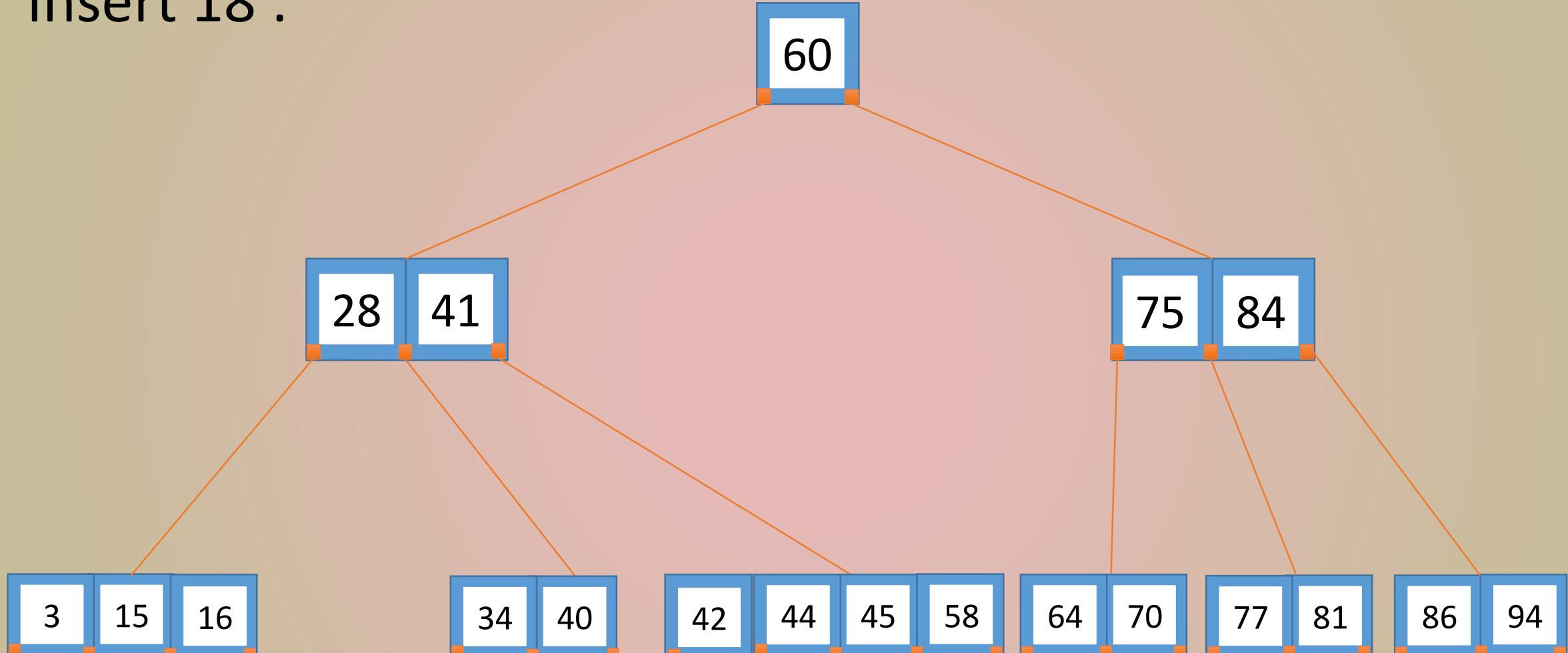
Split :





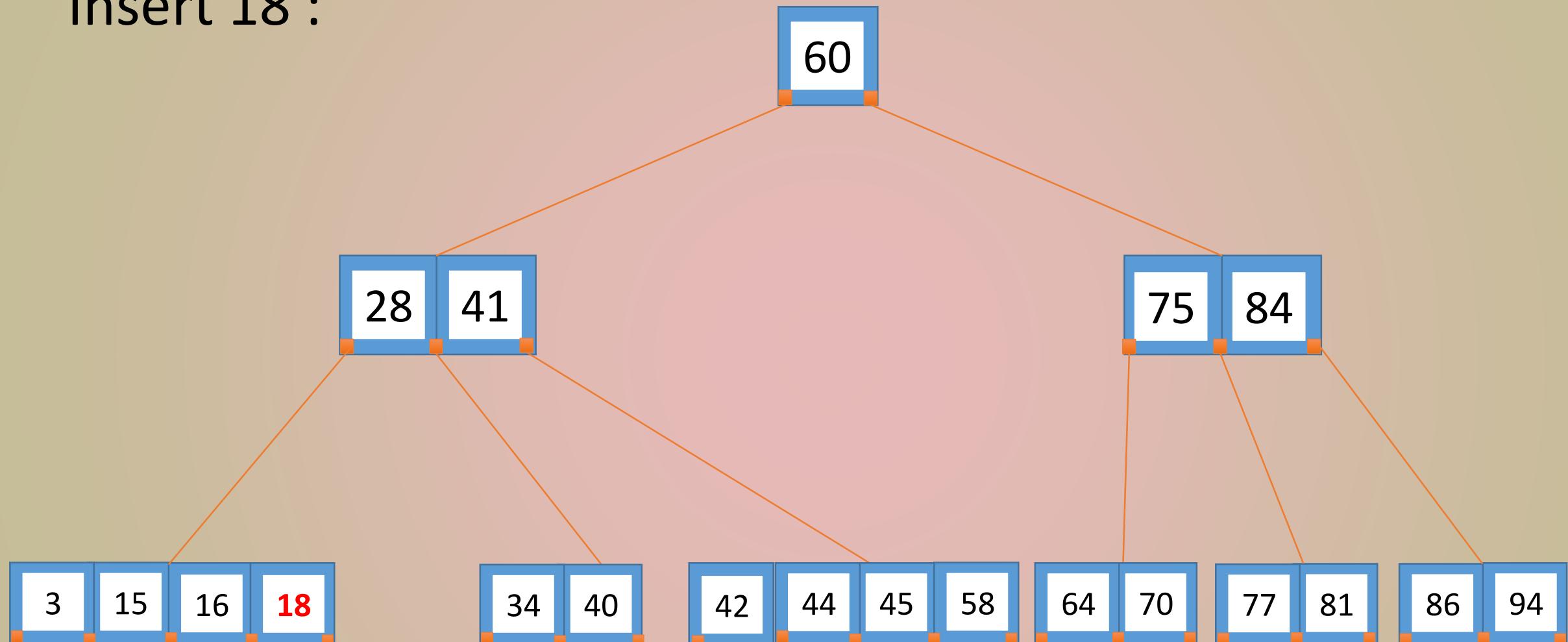
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Insert 18 :



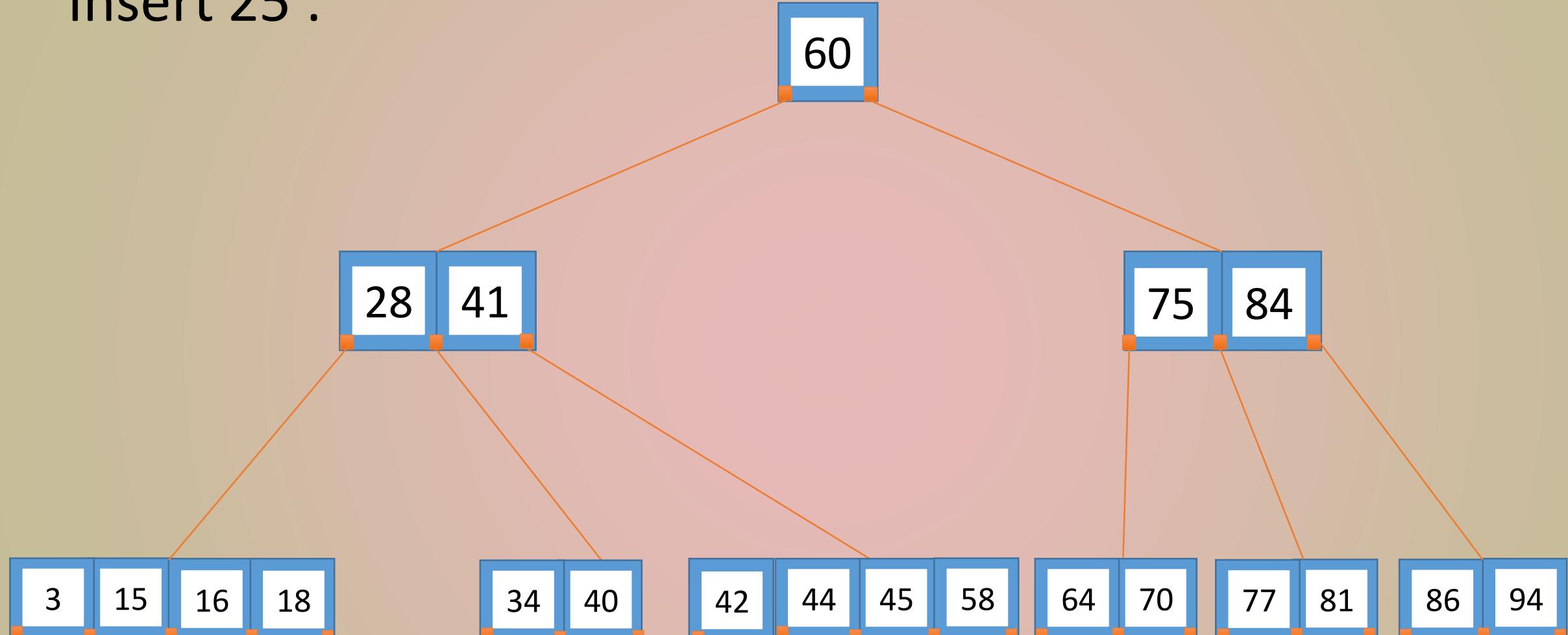
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Insert 18 :



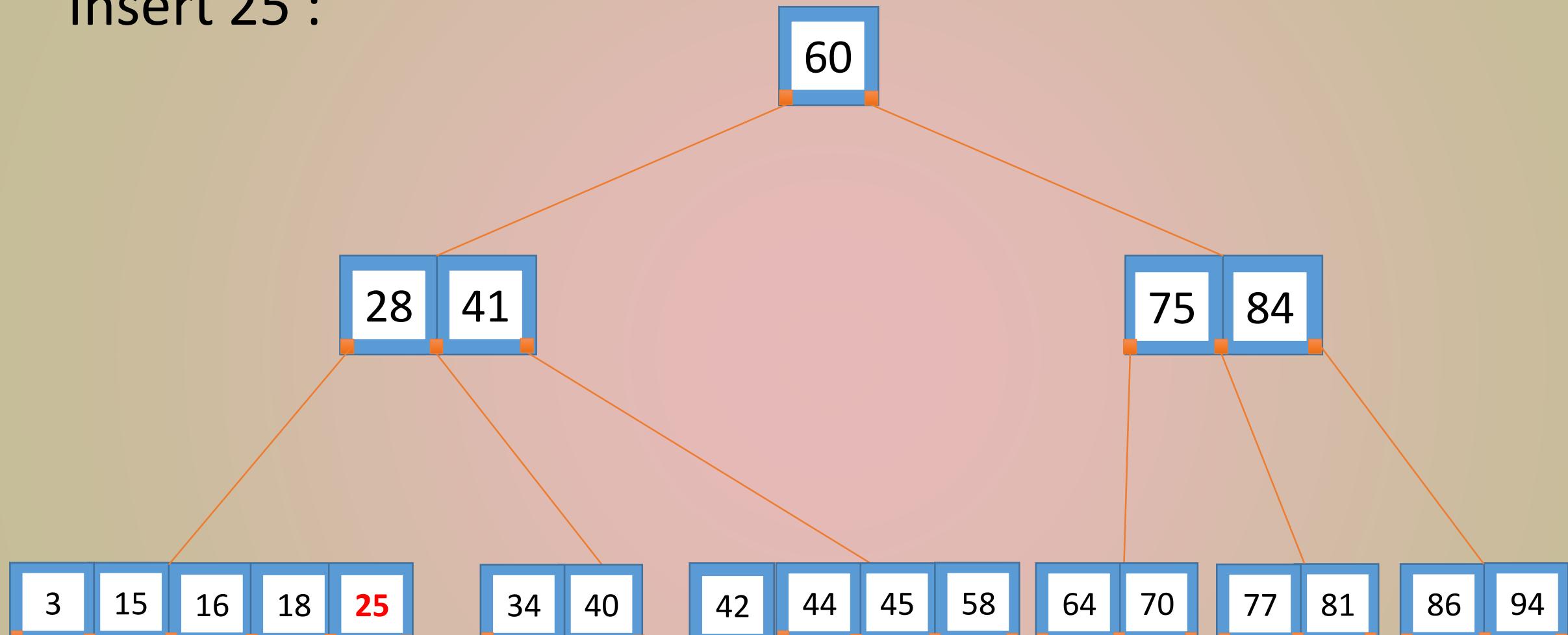
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Insert 25 :



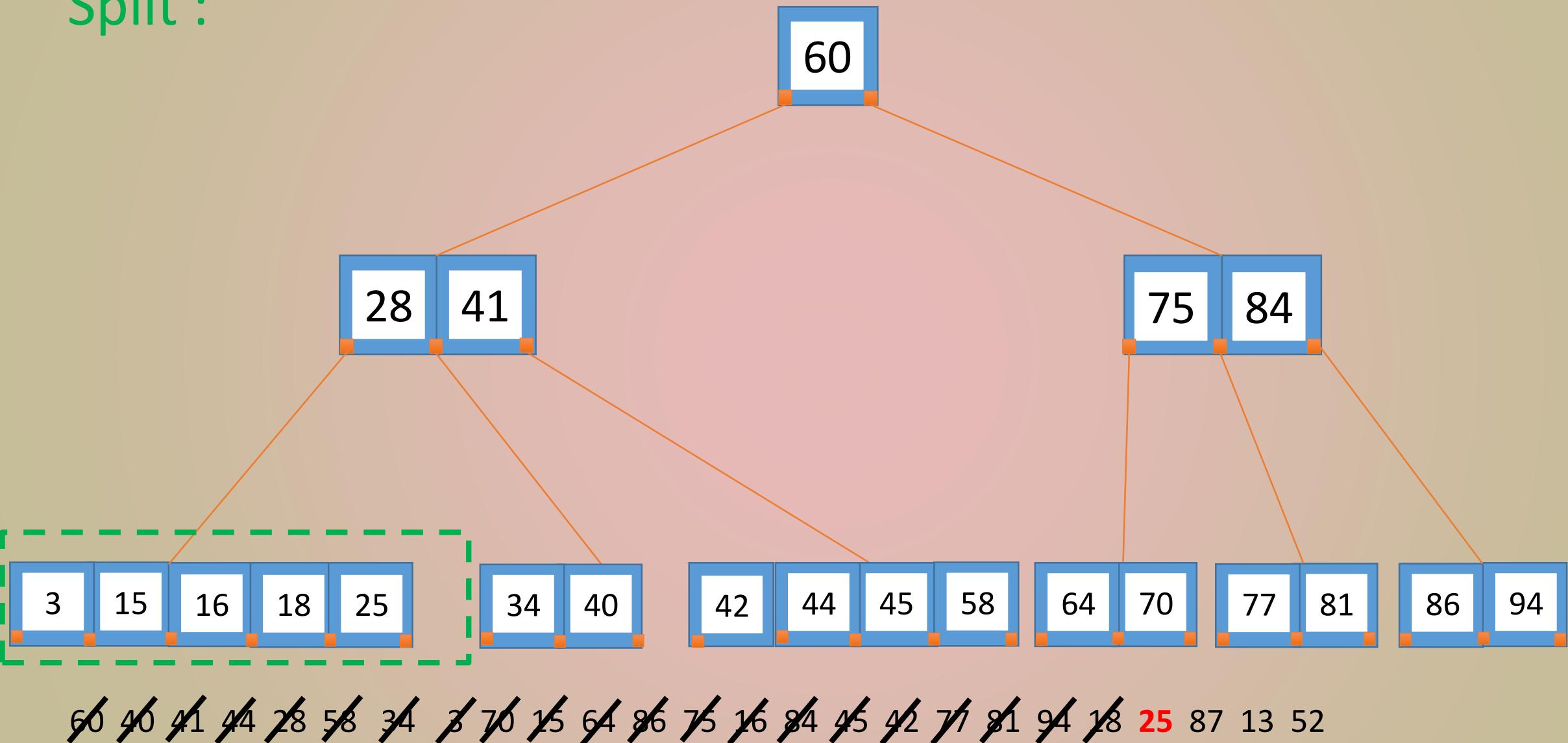
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Insert 25 :

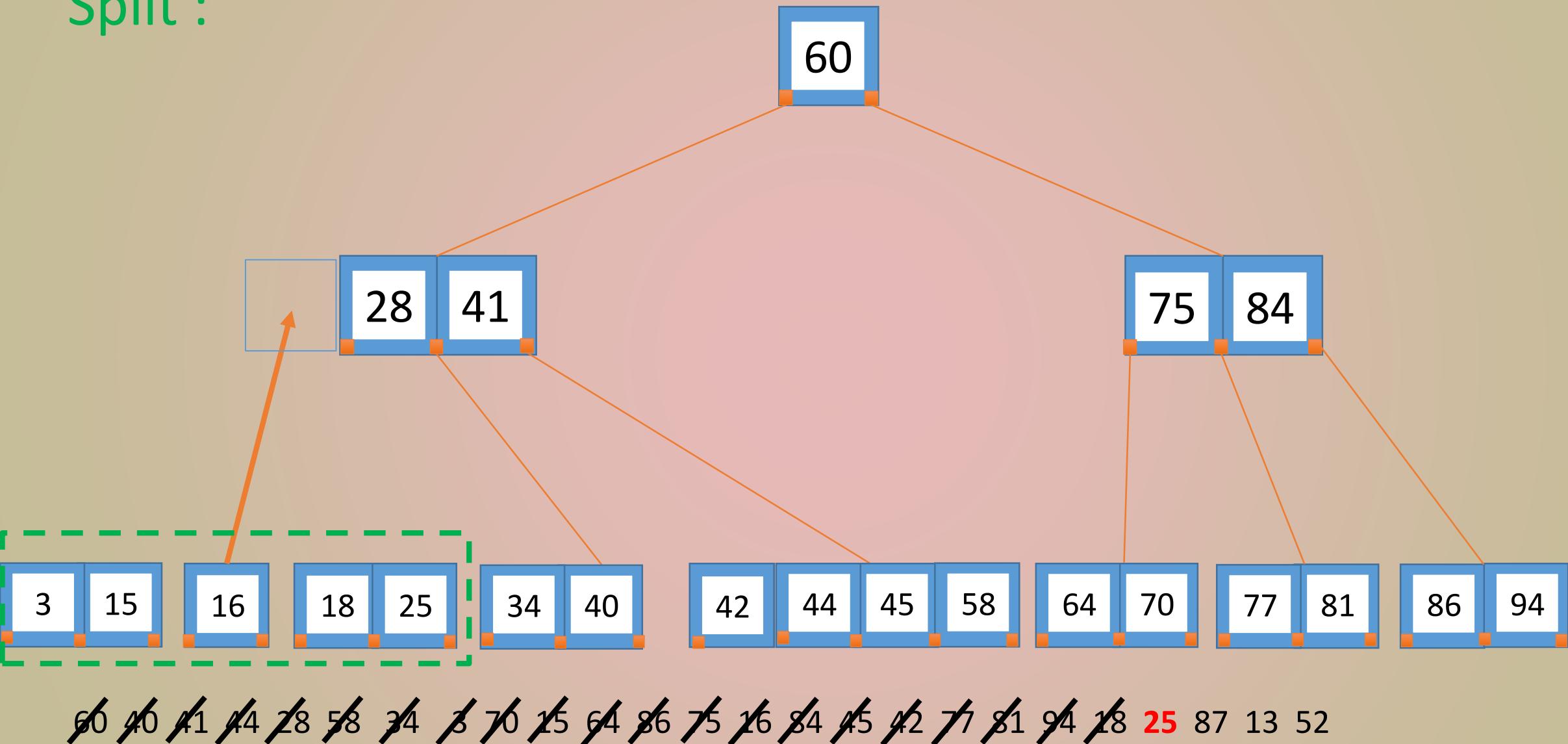


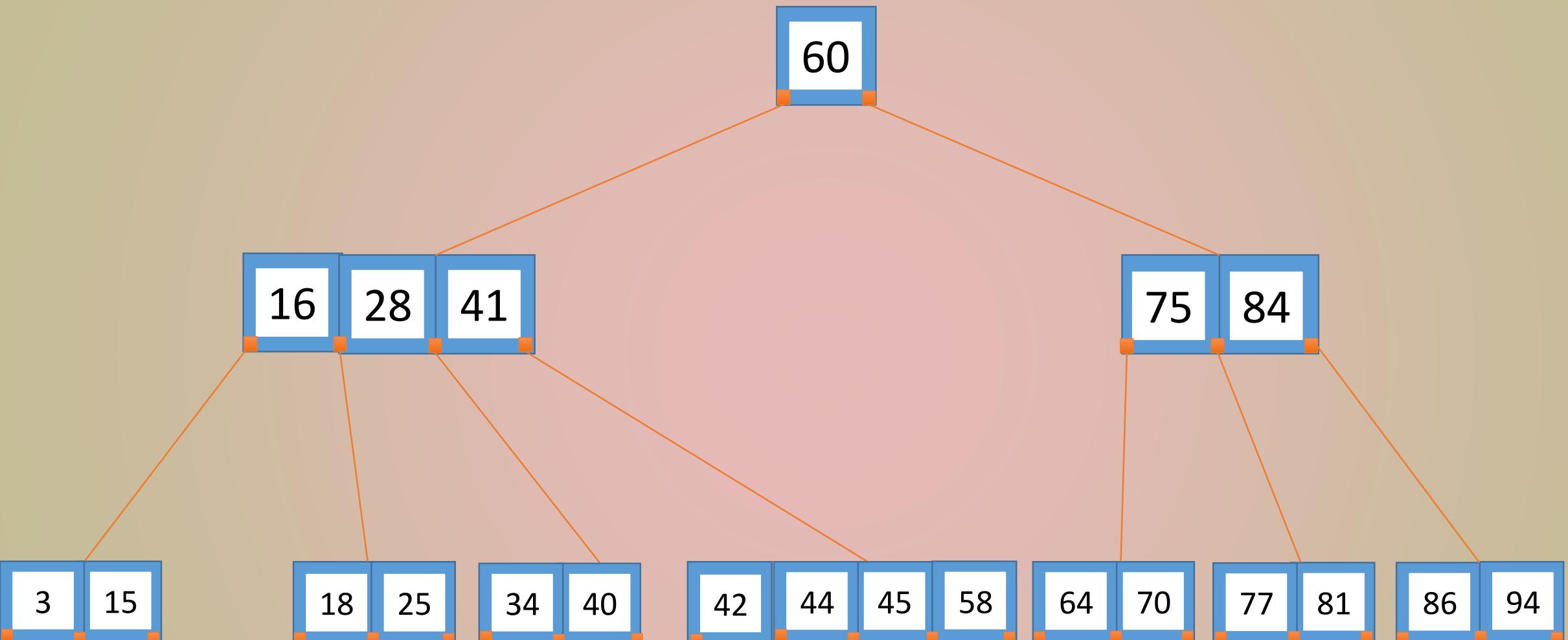
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Split :



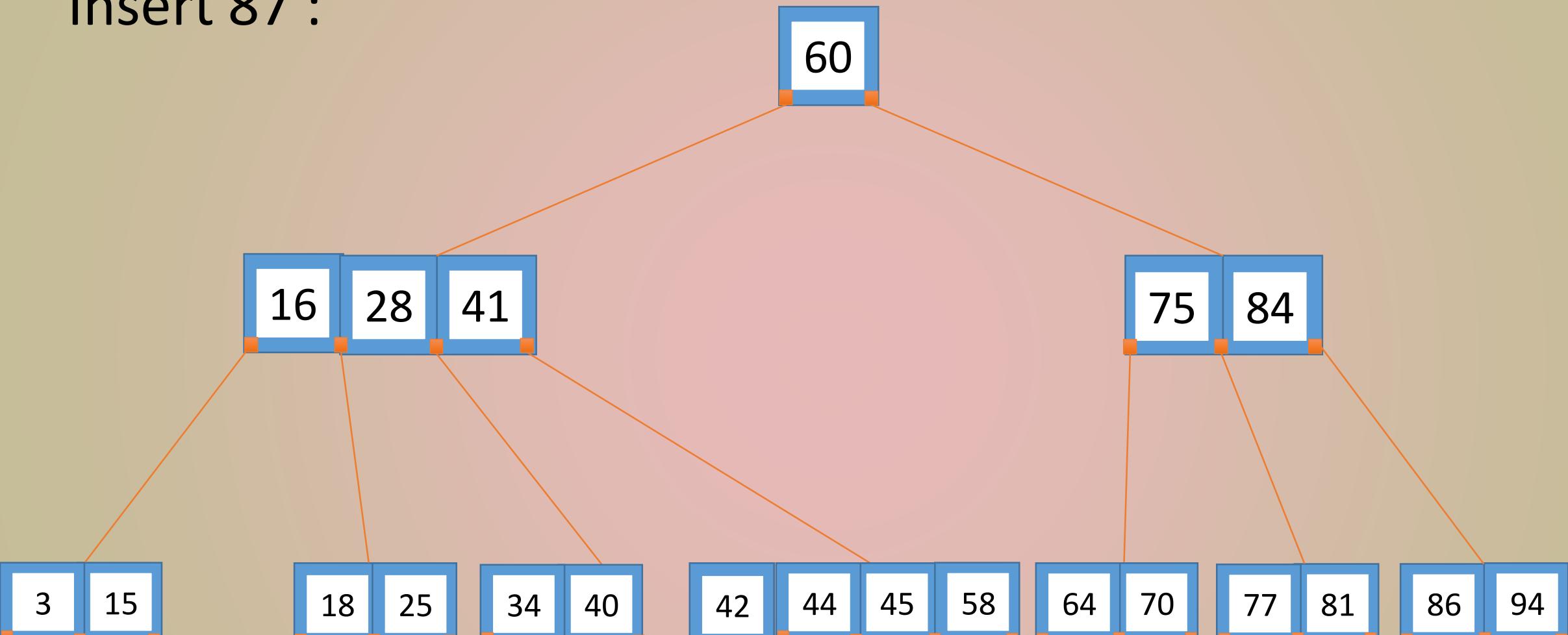
Split :





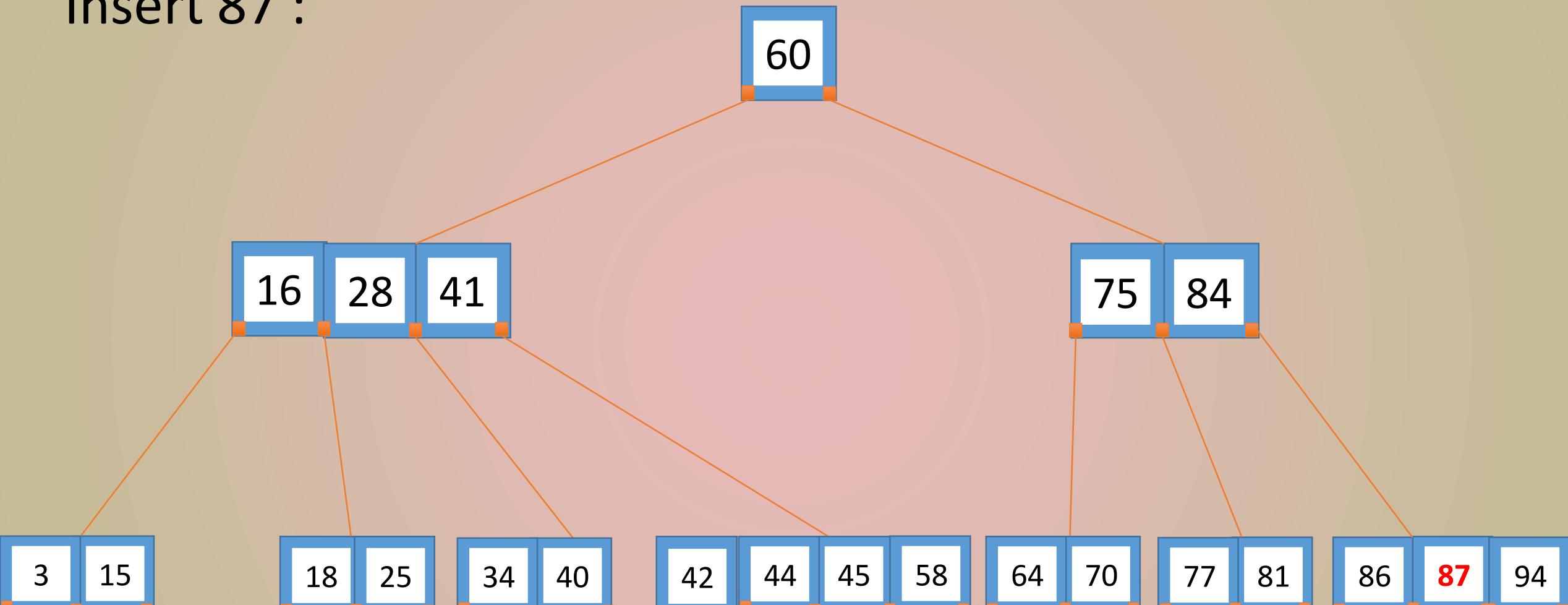
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 87 :



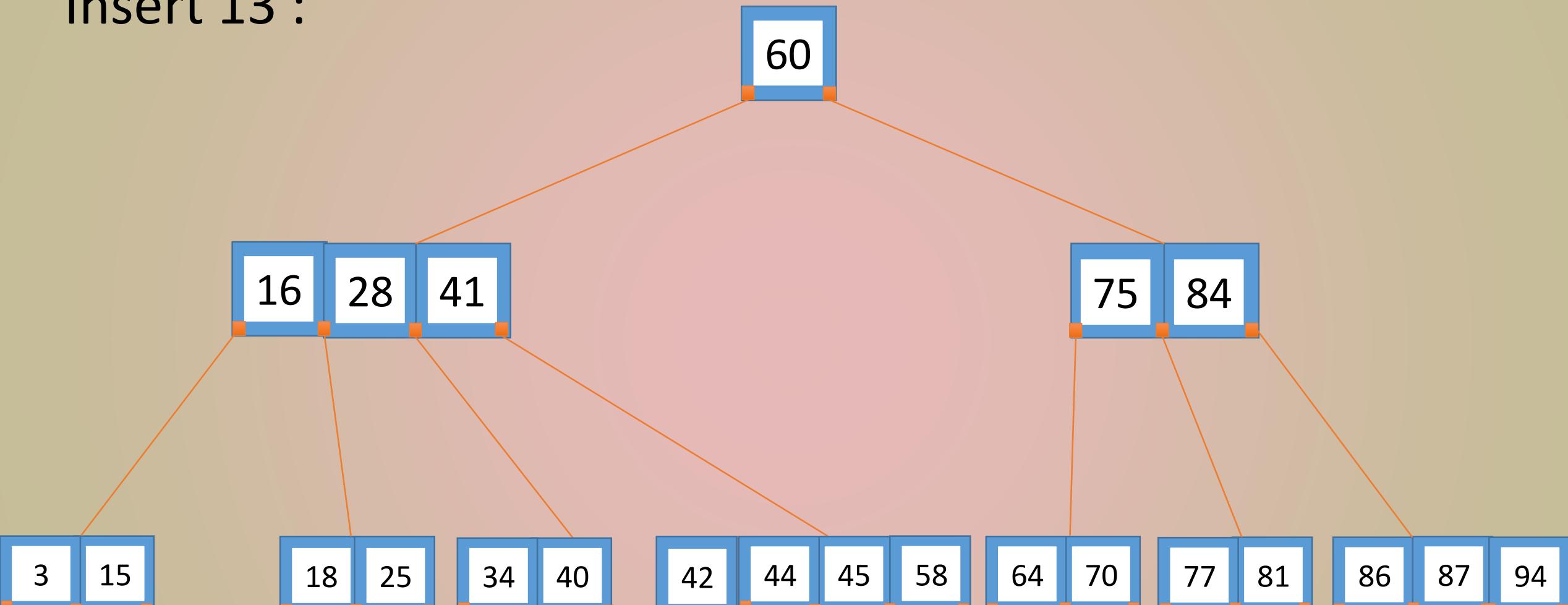
~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Insert 87 :



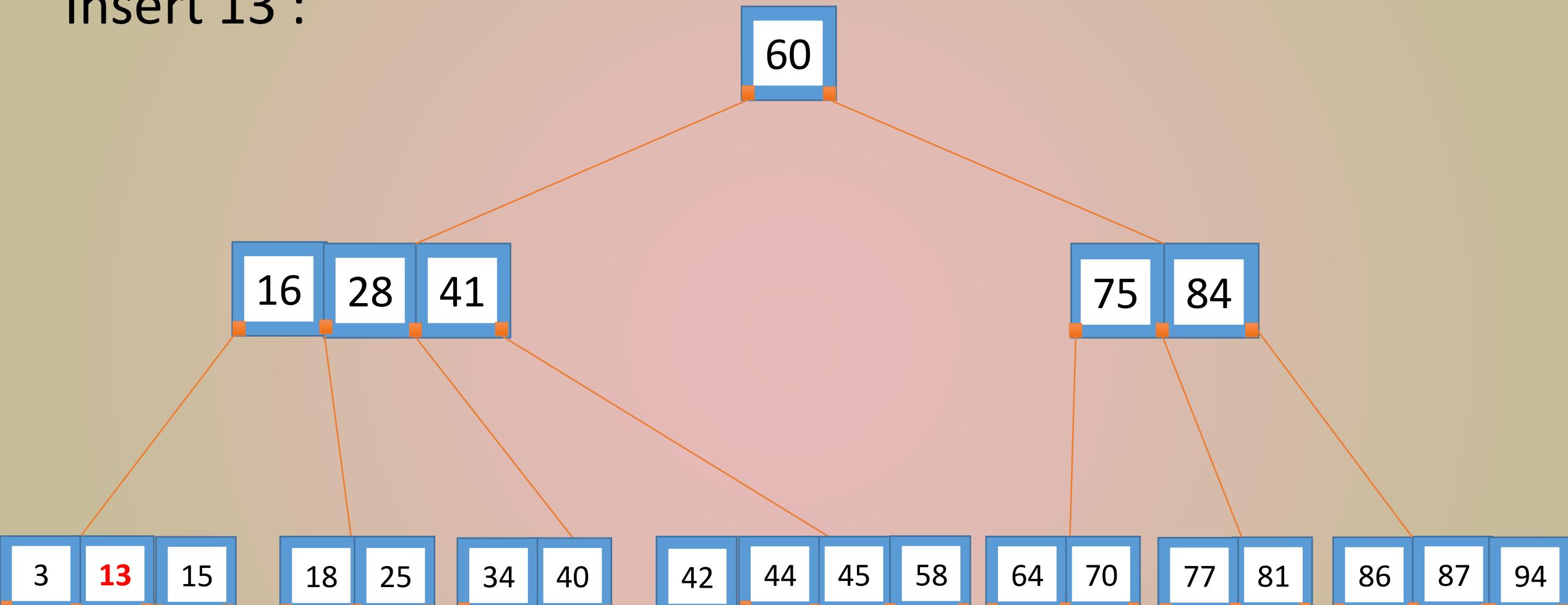
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Insert 13 :



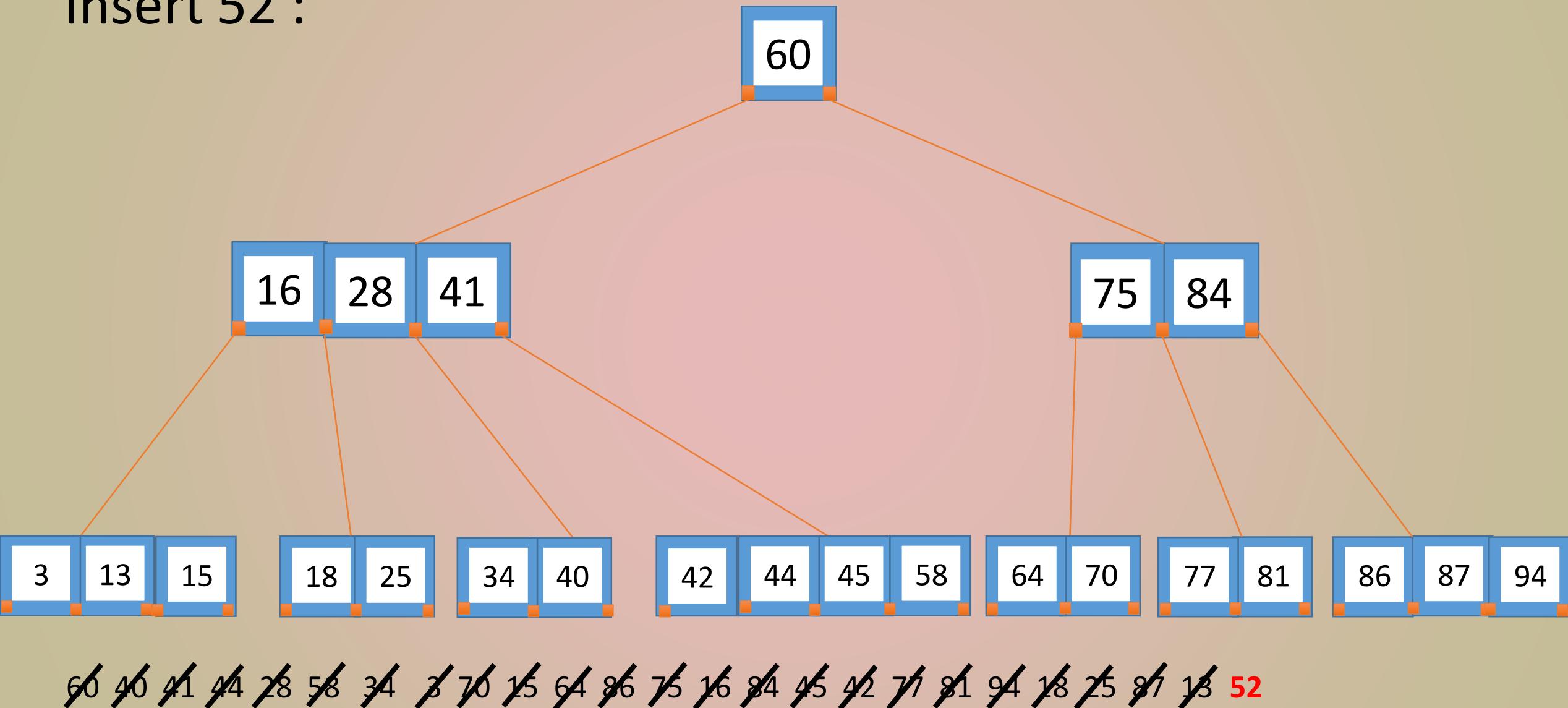
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Insert 13 :

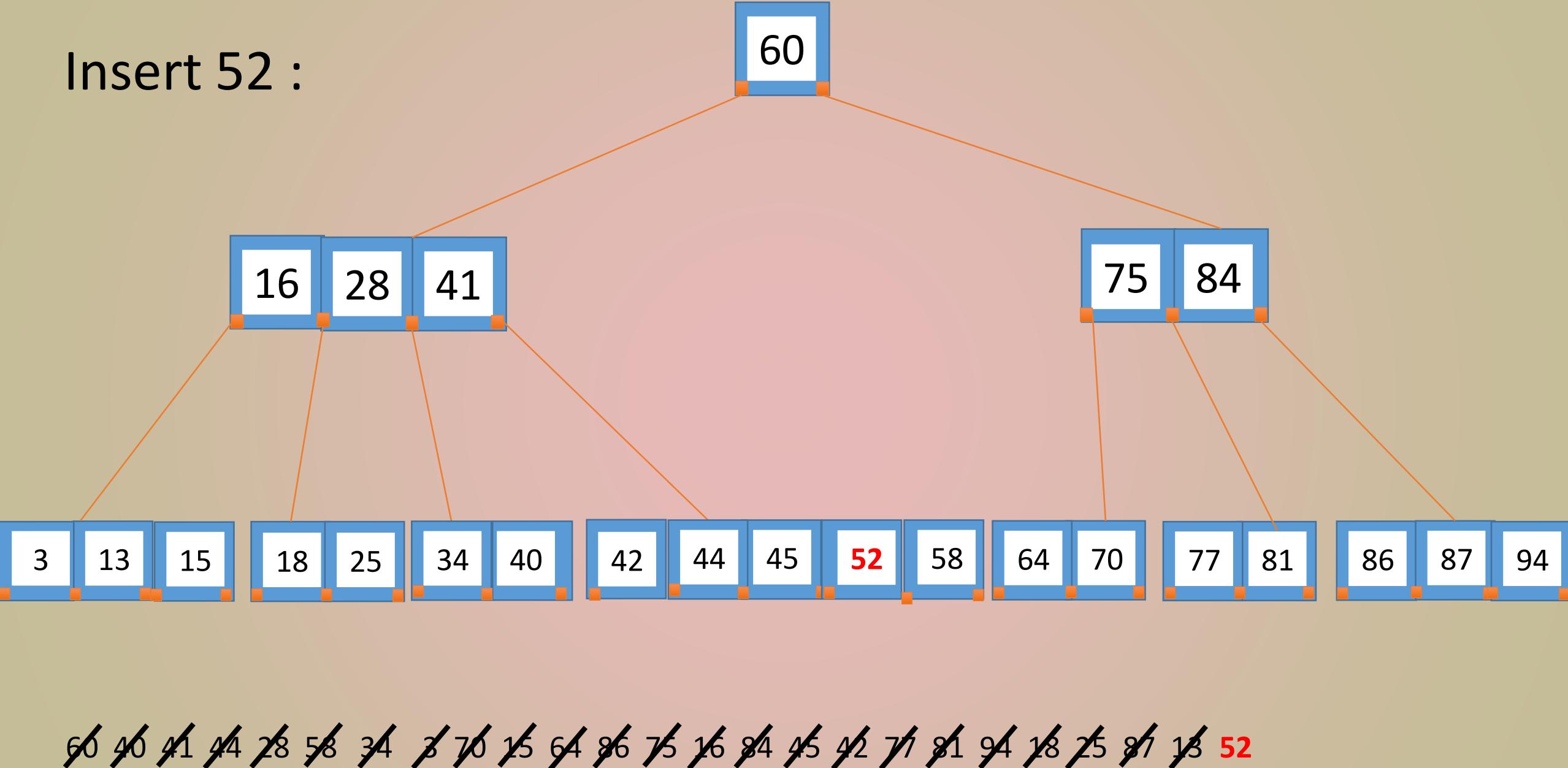


~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

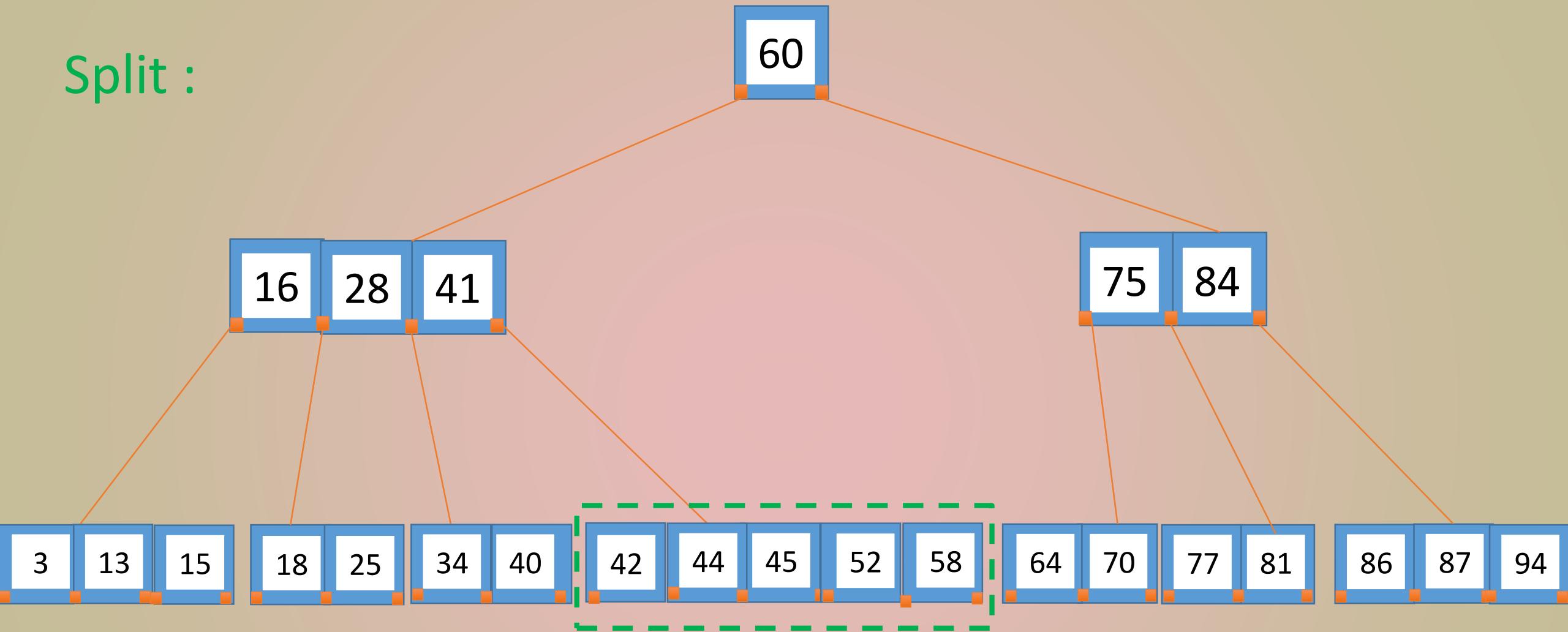
Insert 52 :



Insert 52 :

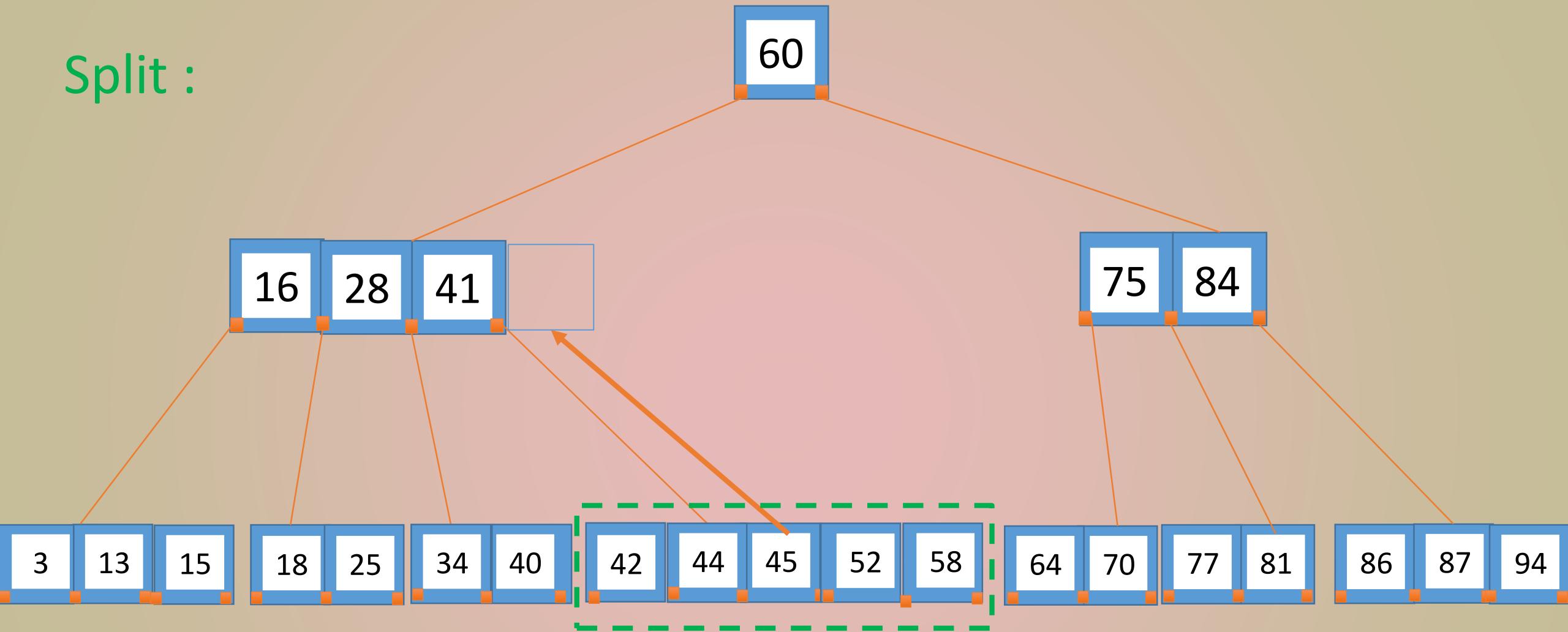


Split :

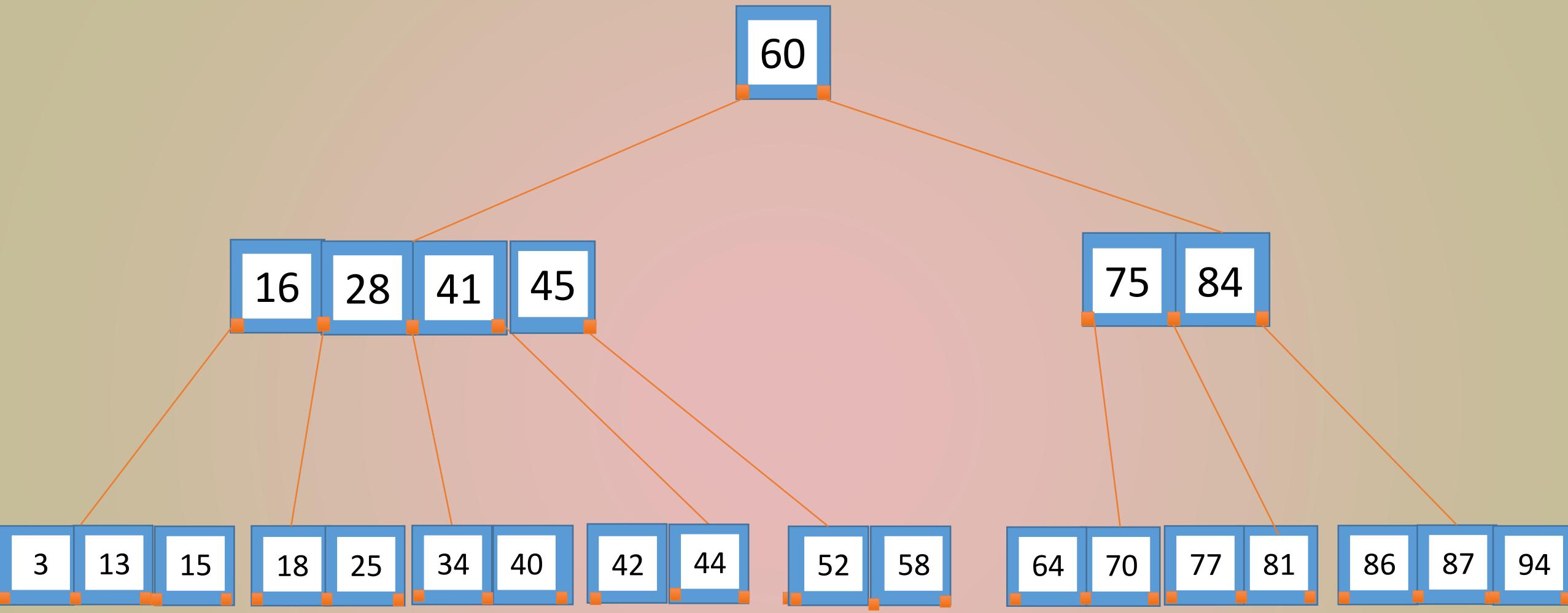


~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13~~ 52

Split :



~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~



~~60 40 41 44 28 58 34 3 70 15 64 86 75 16 84 45 42 77 81 94 18 25 87 13 52~~

Deletion

Deletion from a leaf node

1. Search for the value to delete.
2. If the value is in a leaf node, simply delete it from the node.
3. If underflow happens, rebalance the tree as described in section "Rebalancing after deletion" below.

Deletion from an internal node

Each element in an internal node acts as a separation value for two subtrees, therefore we need to find a replacement for separation. Note that the largest element in the left subtree is still less than the separator. Likewise, the smallest element in the right subtree is still greater than the separator. Both of those elements are in leaf nodes, and either one can be the new separator for the two subtrees. Algorithmically described below:

1. Choose a new separator (either the largest element in the left subtree or the smallest element in the right subtree), remove it from the leaf node it is in, and replace the element to be deleted with the new separator.
2. The previous step deleted an element (the new separator) from a leaf node. If that leaf node is now deficient (has fewer than the required number of nodes), then rebalance the tree starting from the leaf node.

Rebalancing after deletion Rebalancing starts from a leaf and proceeds toward the root until the tree is balanced. If deleting an element from a node has brought it under the minimum size, then some elements must be redistributed to bring all nodes up to the minimum. Usually, the redistribution involves moving an element from a sibling node that has more than the minimum number of nodes. That redistribution operation is called a **rotation**. If no sibling can spare an element, then the deficient node must be **merged** with a sibling. The merge causes the parent to lose a separator element, so the parent may become deficient and need rebalancing. The merging and rebalancing may continue all the way to the root. Since the minimum element count doesn't apply to the root, making the root be the only deficient node is not a problem. The algorithm to rebalance the tree is as follows:

- If the deficient node's right sibling exists and has more than the minimum number of elements, then rotate left

- Copy the separator from the parent to the end of the deficient node (the separator moves down; the deficient node now has the minimum number of elements)
- Replace the separator in the parent with the first element of the right sibling (right sibling loses one node but still has at least the minimum number of elements)
- The tree is now balanced

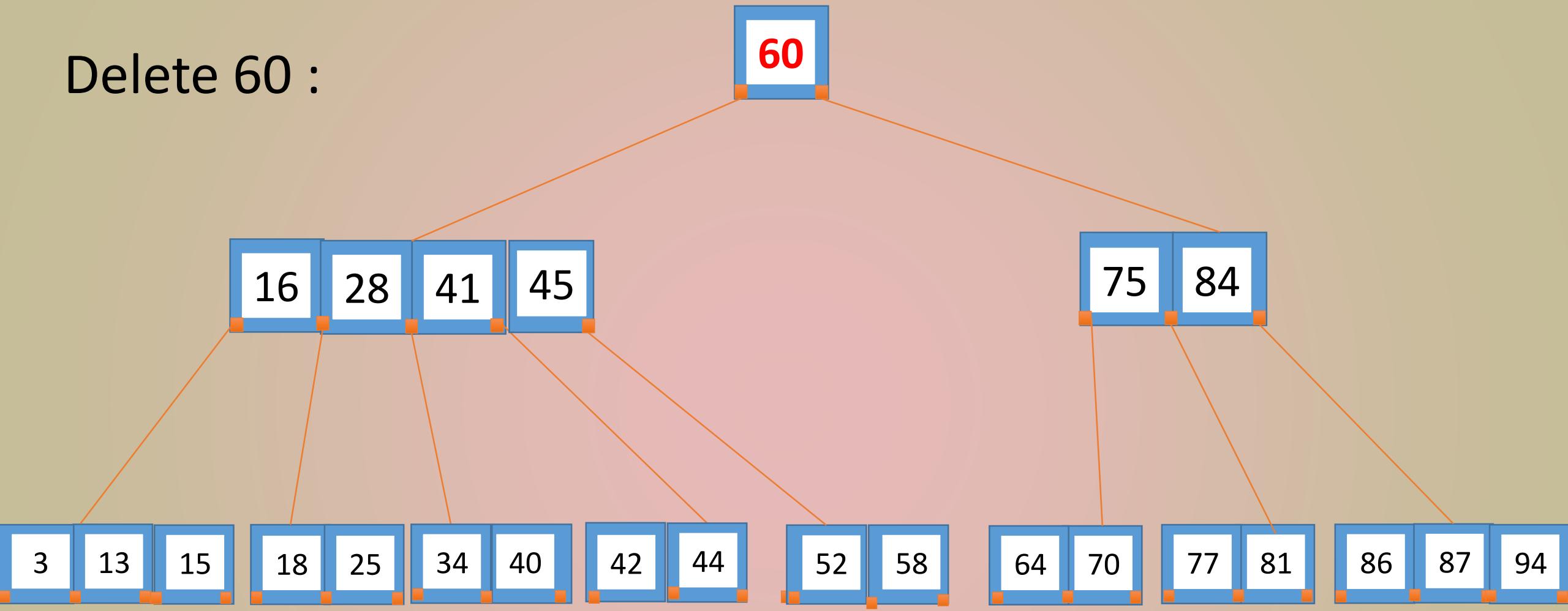
- Otherwise, if the deficient node's left sibling exists and has more than the minimum number of elements, then rotate right

- Copy the separator from the parent to the start of the deficient node (the separator moves down; deficient node now has the minimum number of elements)
- Replace the separator in the parent with the last element of the left sibling (left sibling loses one node but still has at least the minimum number of elements)
- The tree is now balanced

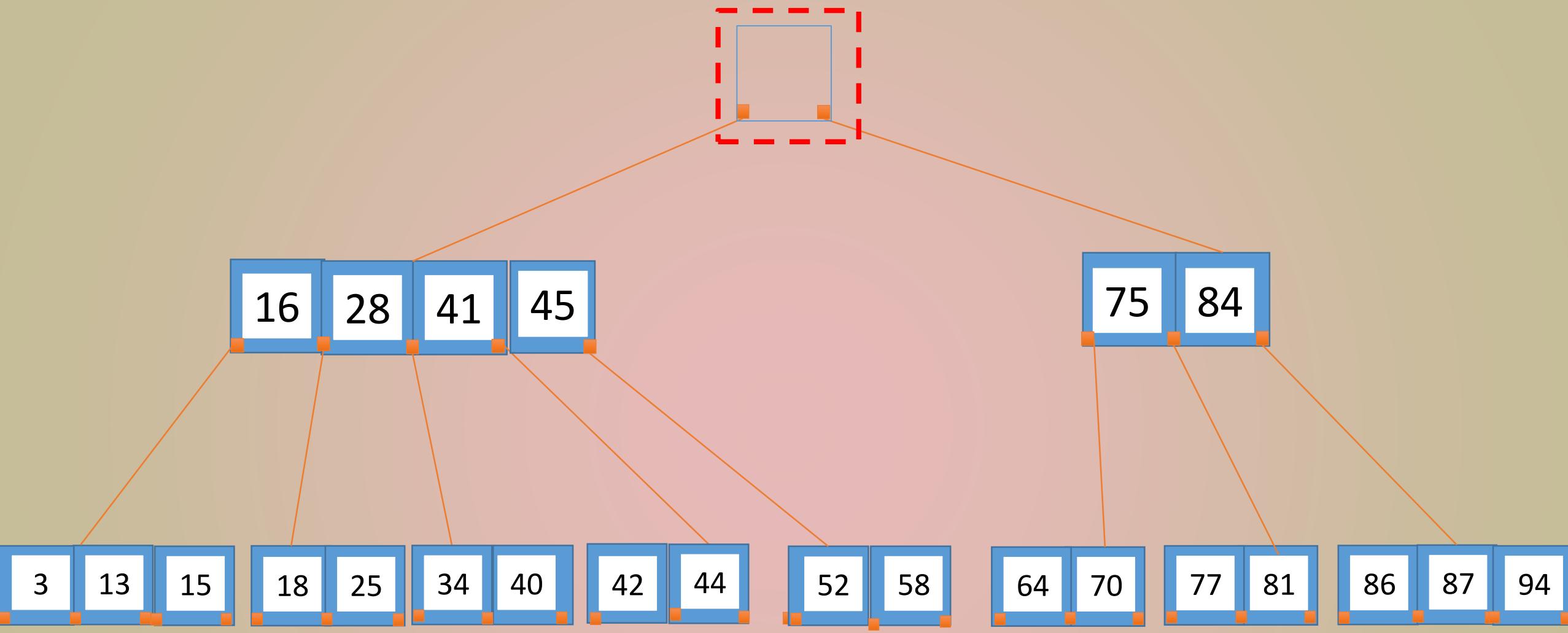
- Otherwise, if both immediate siblings have only the minimum number of elements, then merge with a sibling sandwiching their separator taken off from their parent

- Copy the separator to the end of the left node (the left node may be the deficient node or it may be the sibling with the minimum number of elements)
- Move all elements from the right node to the left node (the left node now has the maximum number of elements, and the right node – empty)
- Remove the separator from the parent along with its empty right child (the parent loses an element)
 - If the parent is the root and now has no elements, then free it and make the merged node the new root (tree becomes shallower)
 - Otherwise, if the parent has fewer than the required number of elements, then rebalance the parent

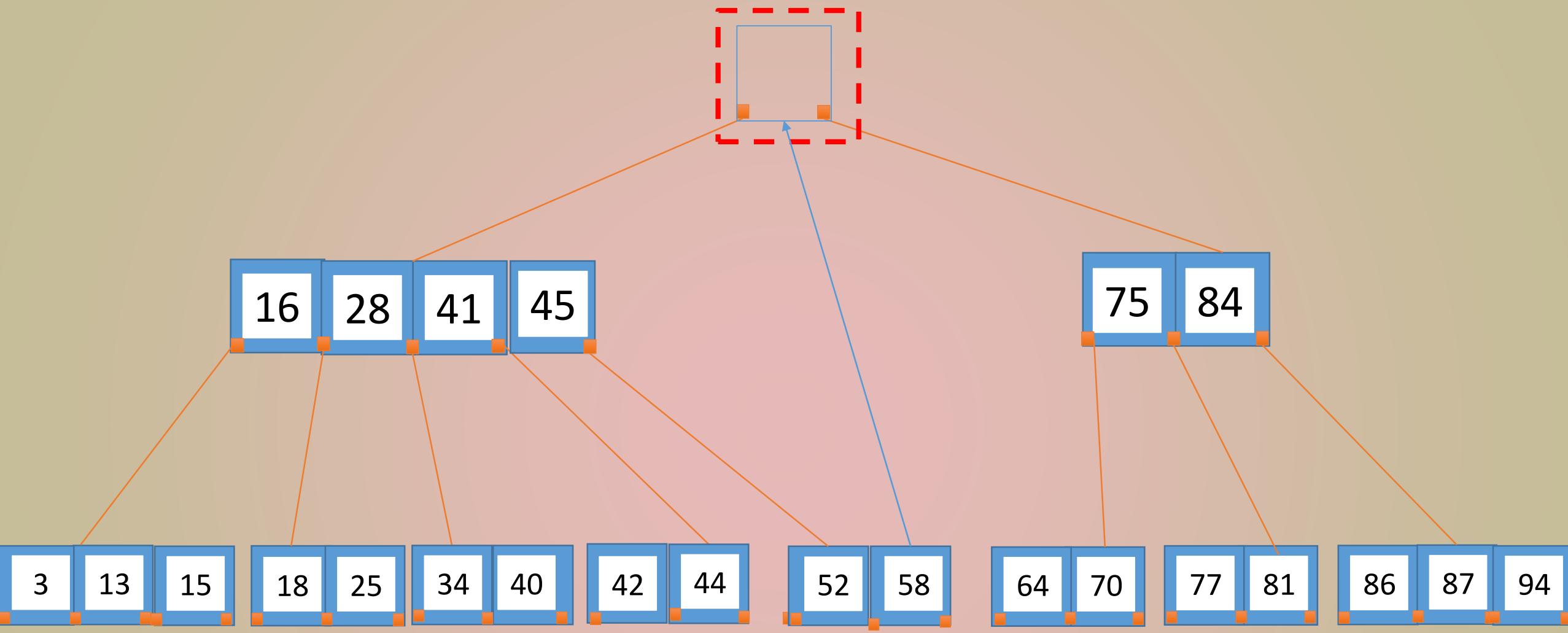
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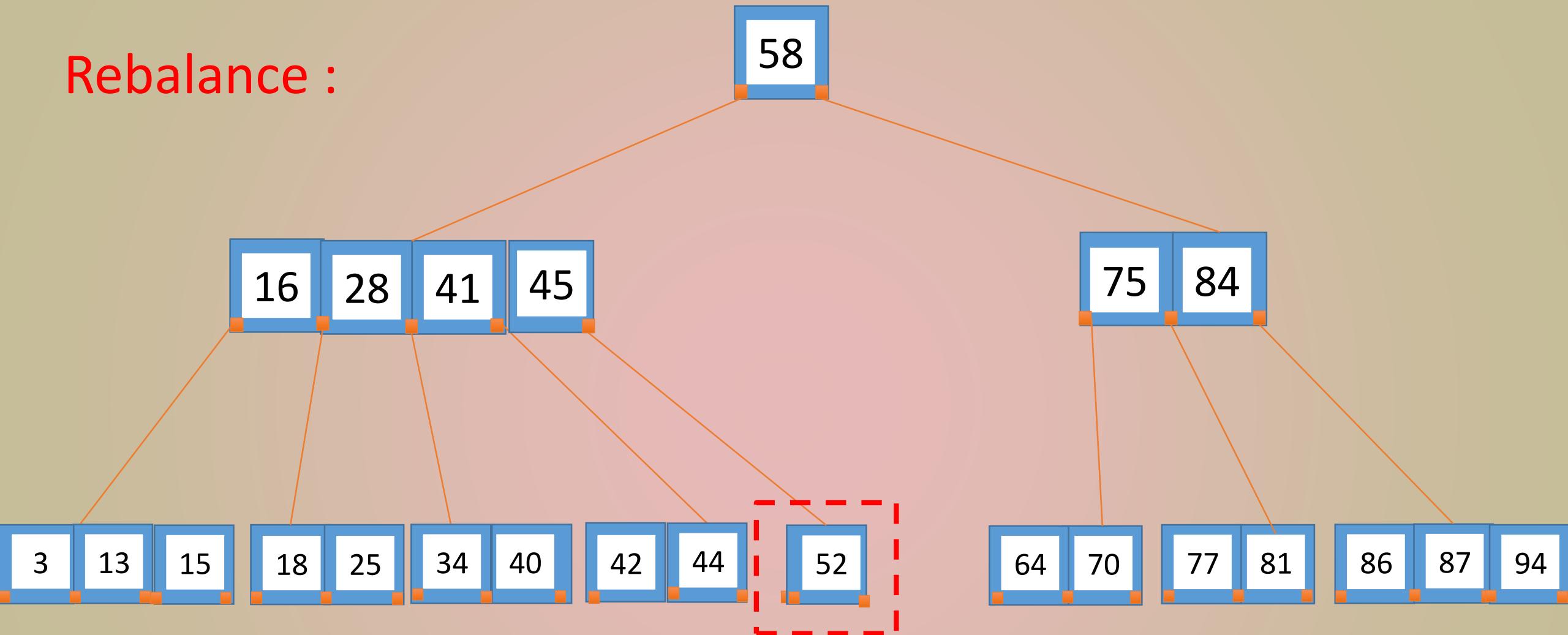


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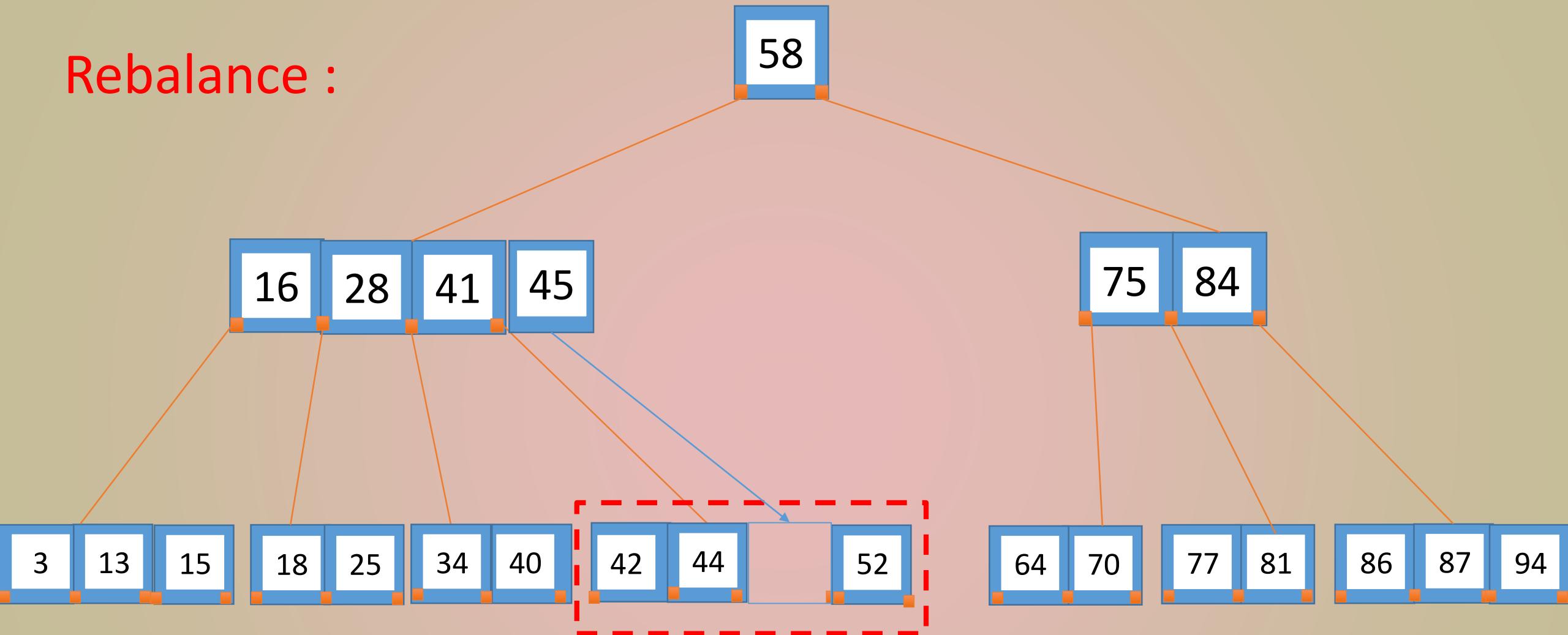
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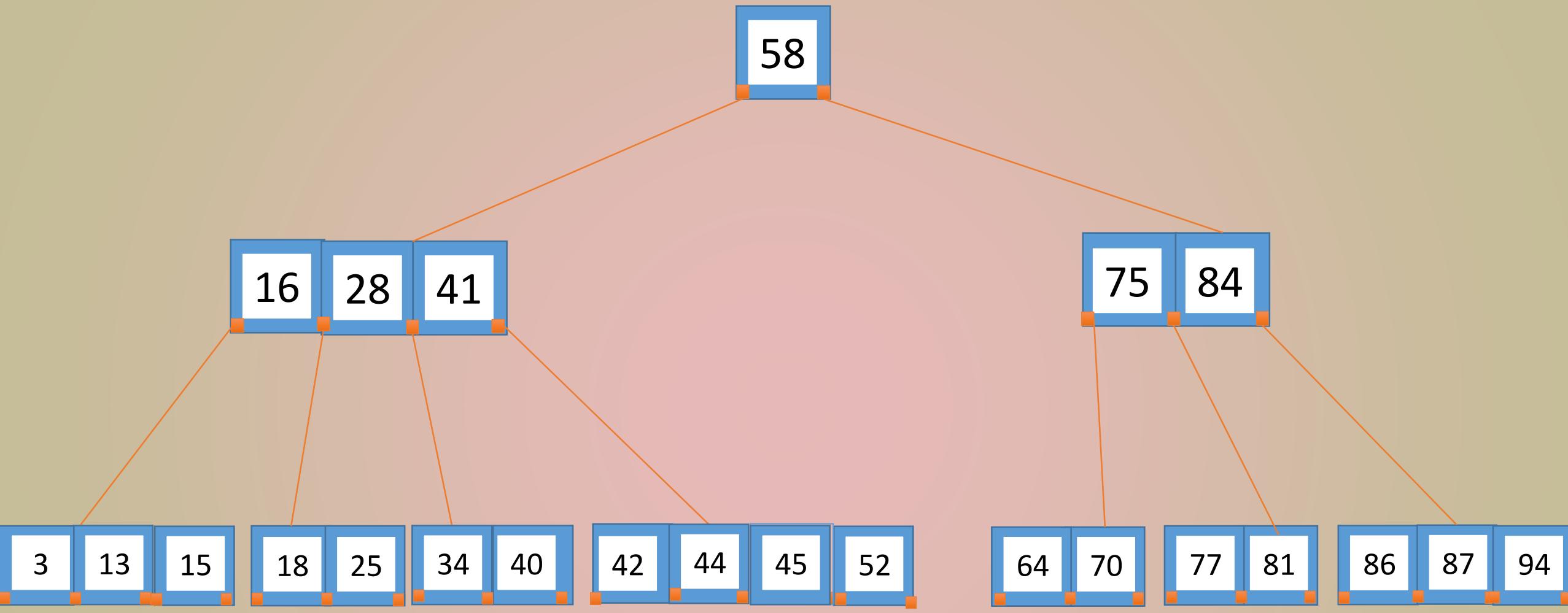


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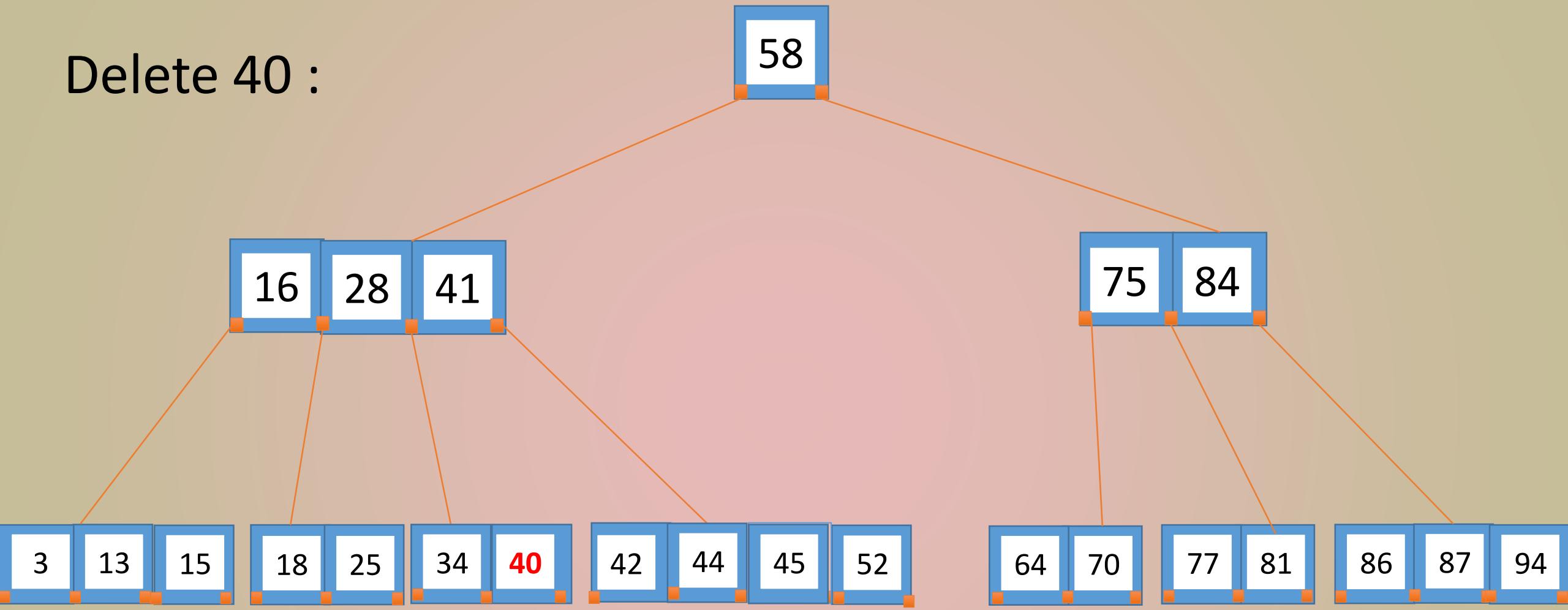


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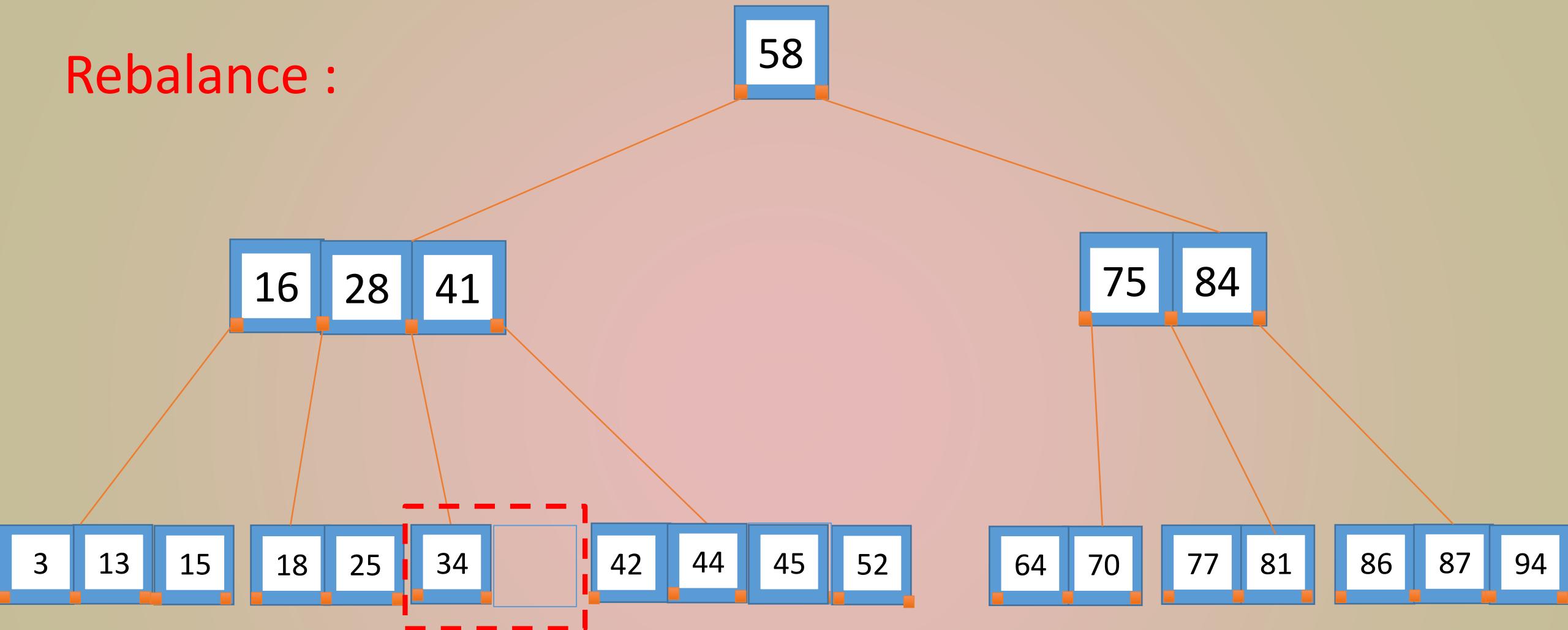
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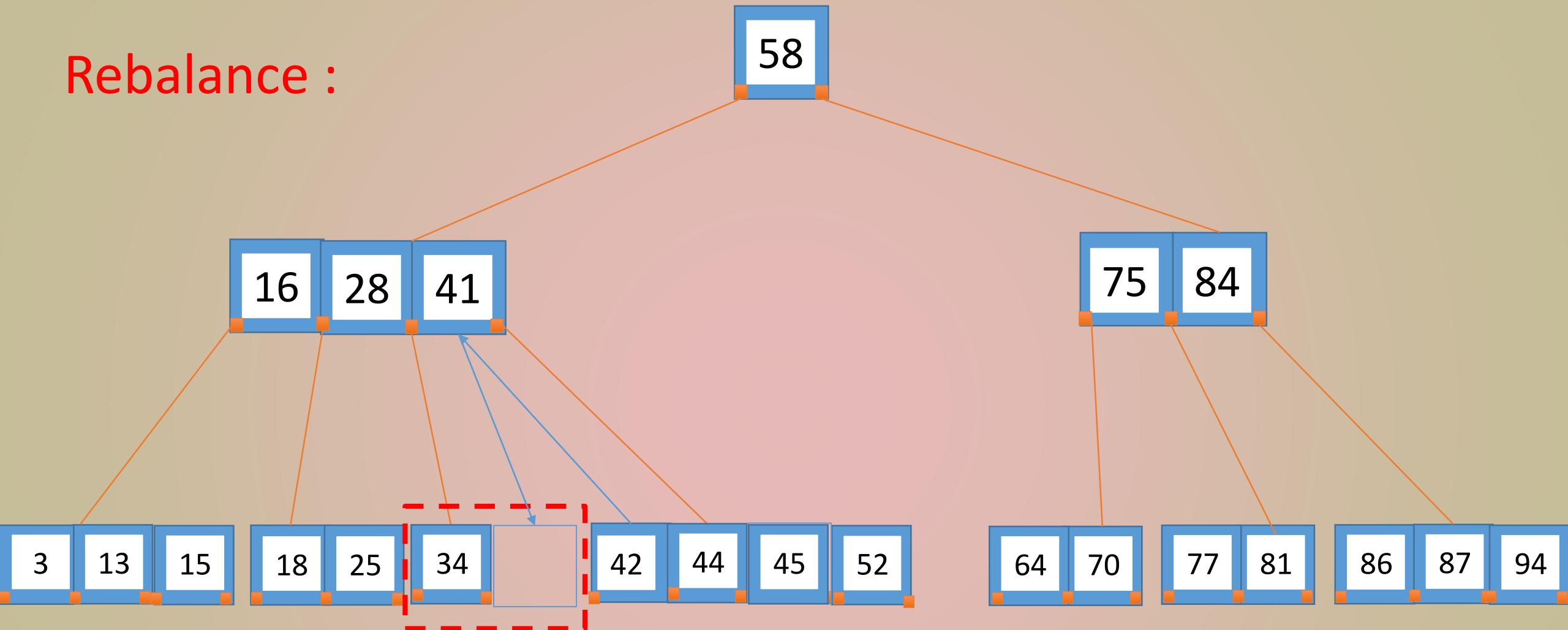
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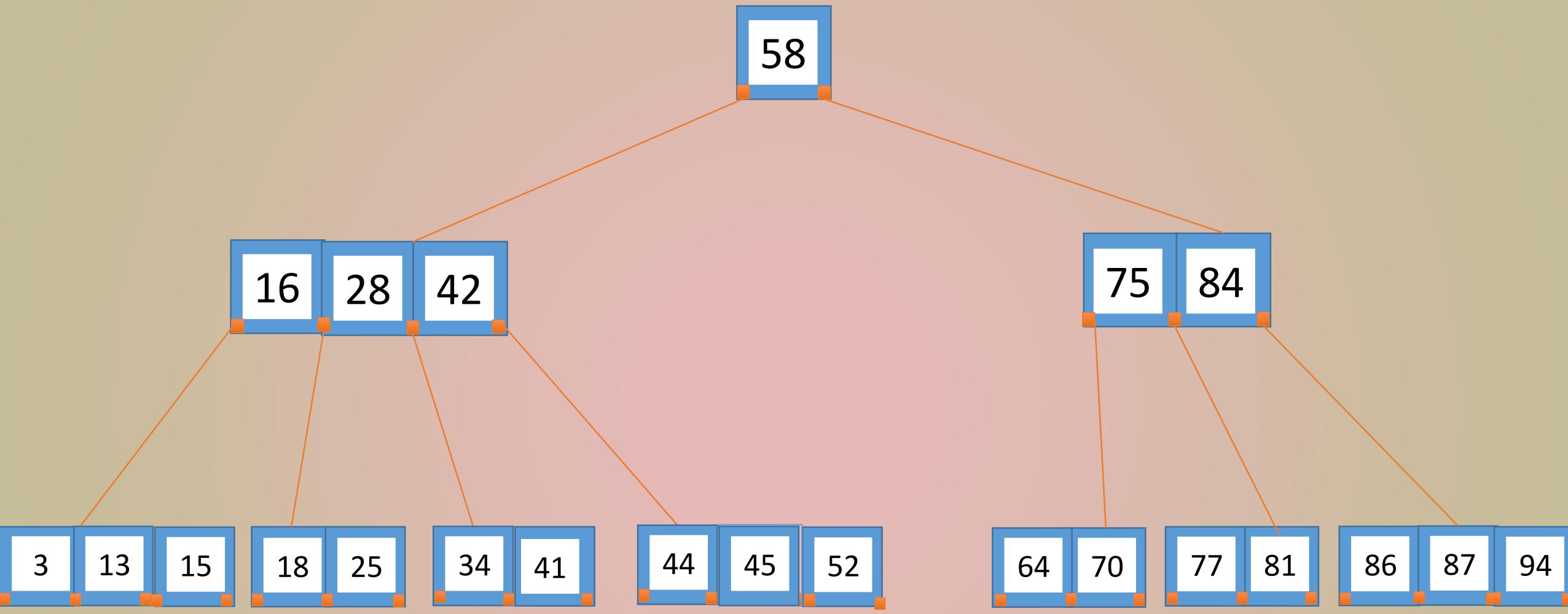


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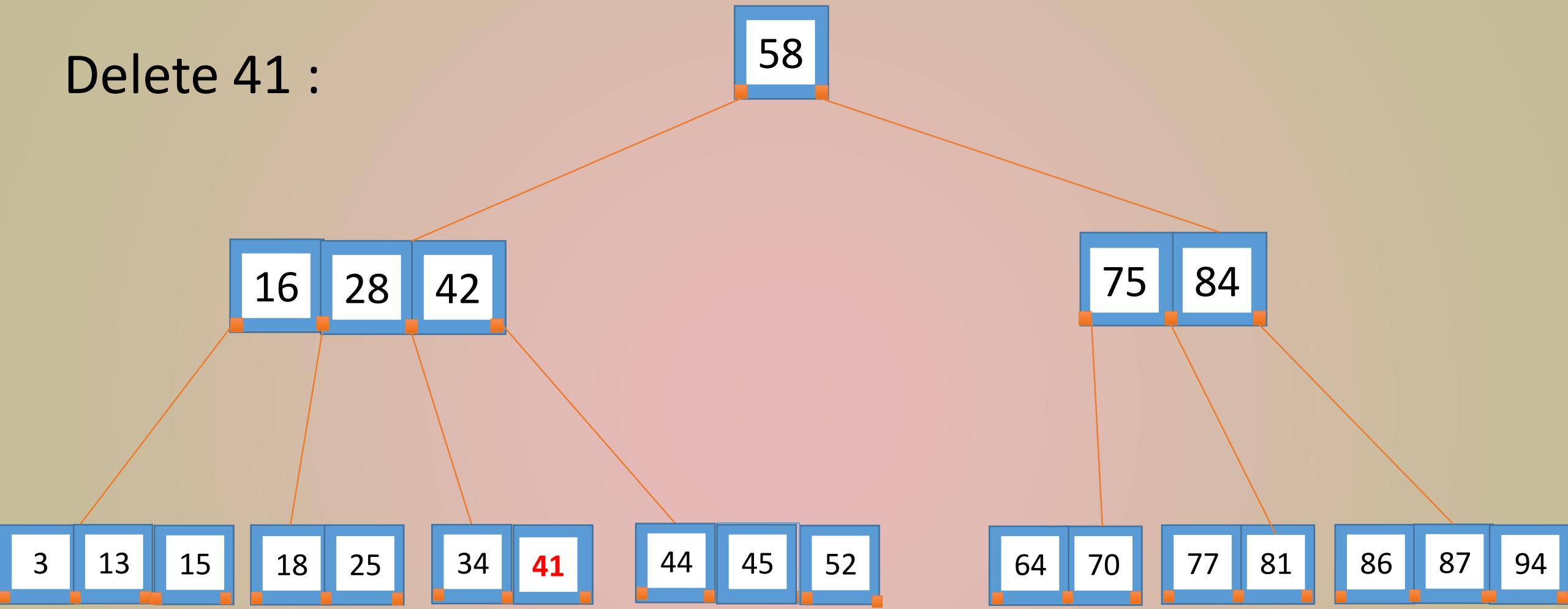


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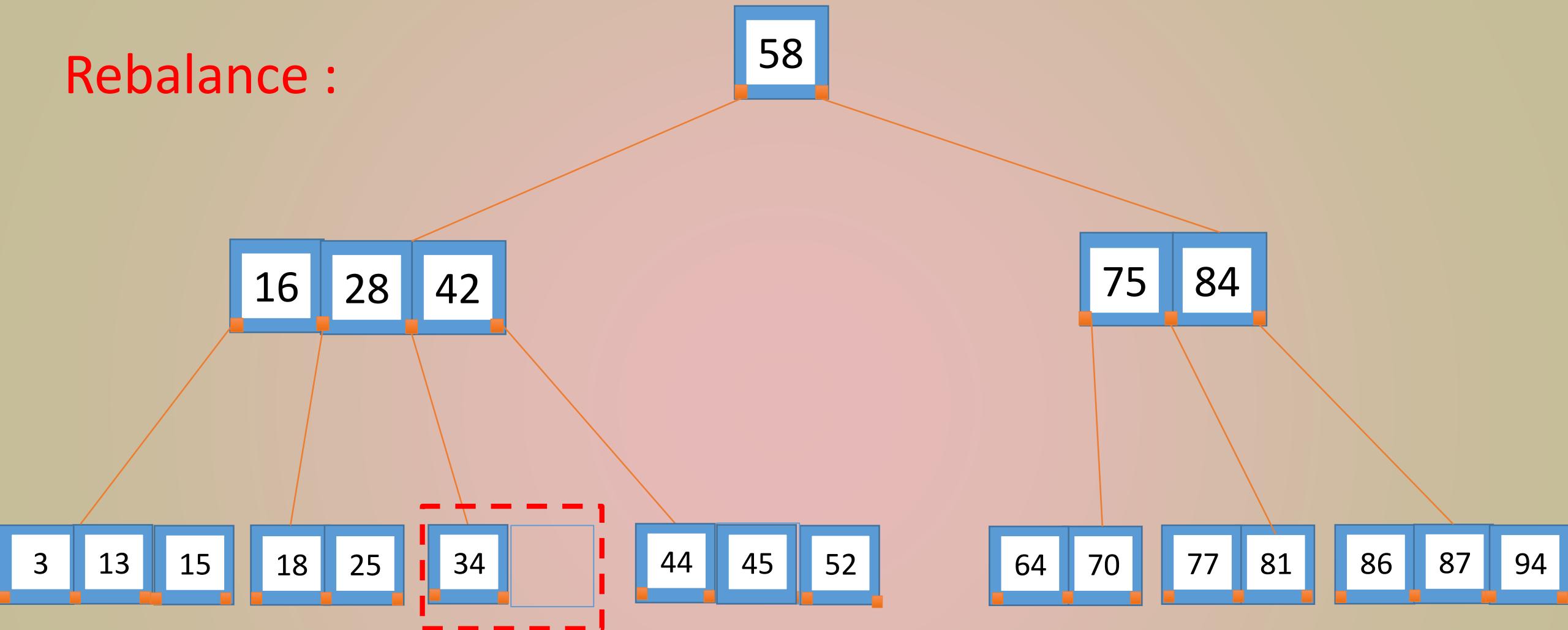
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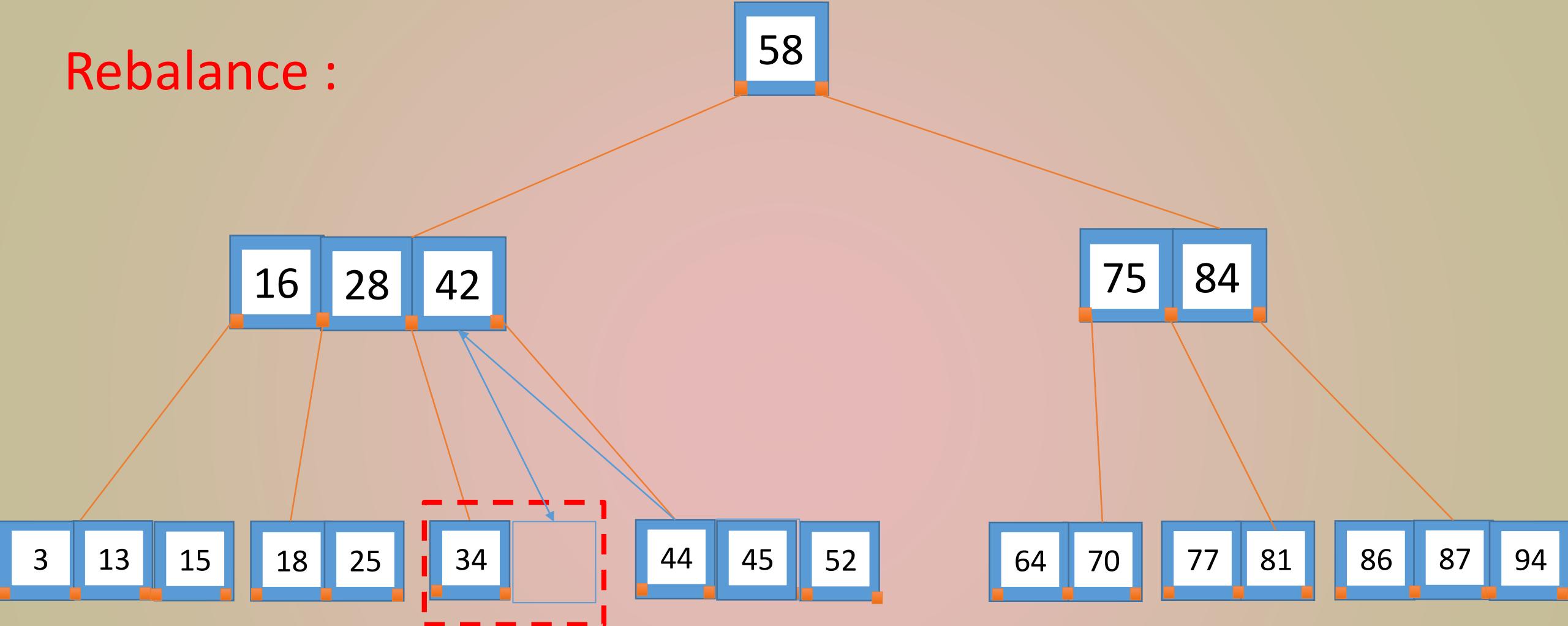
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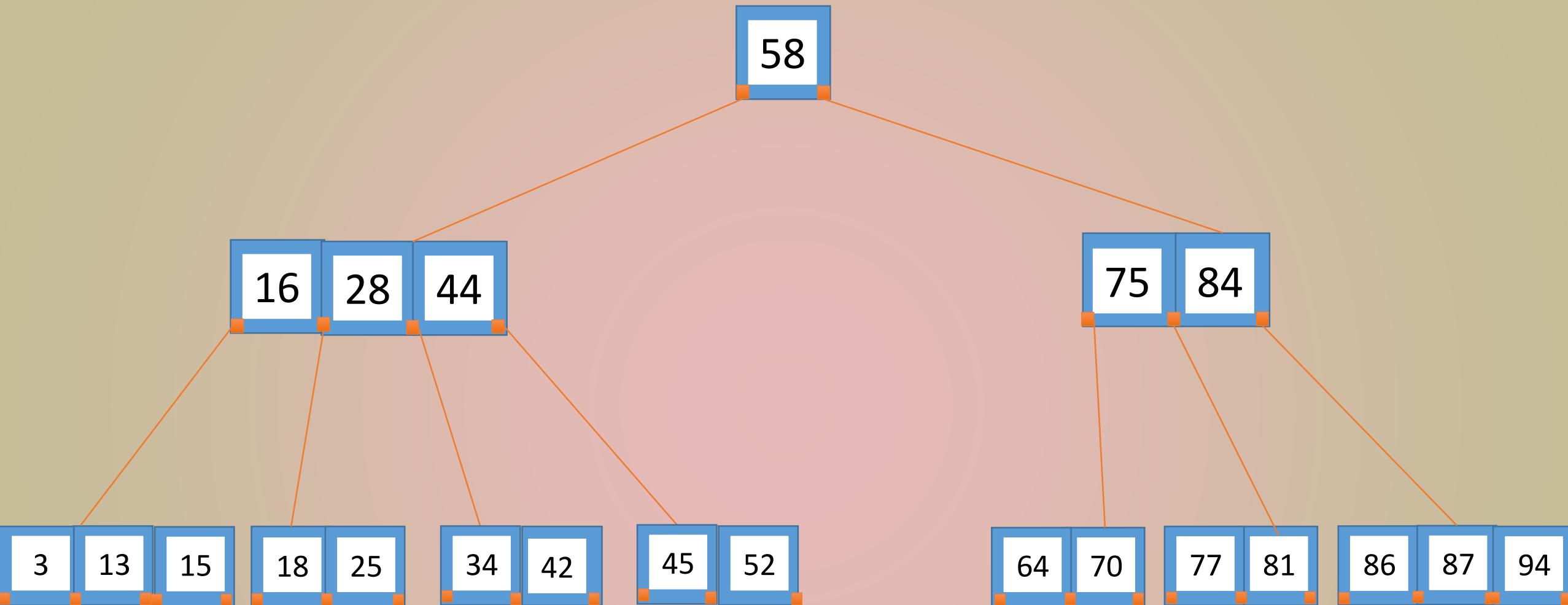


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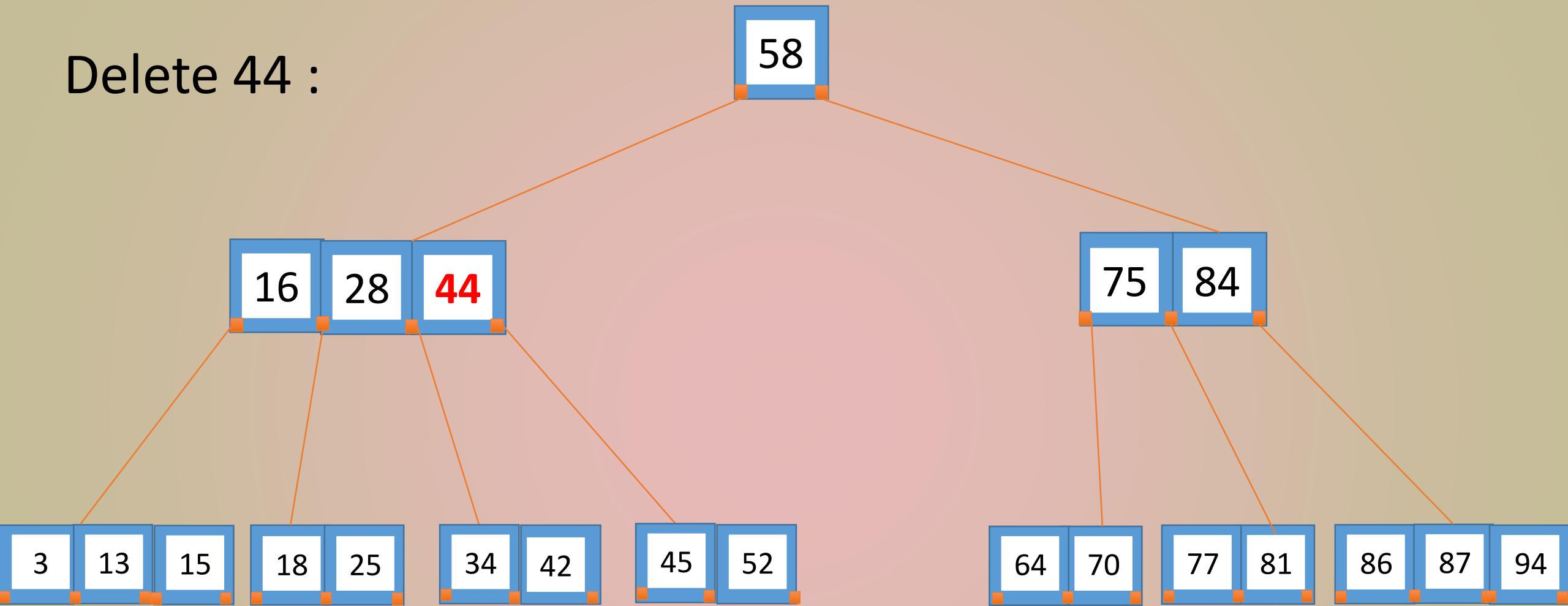


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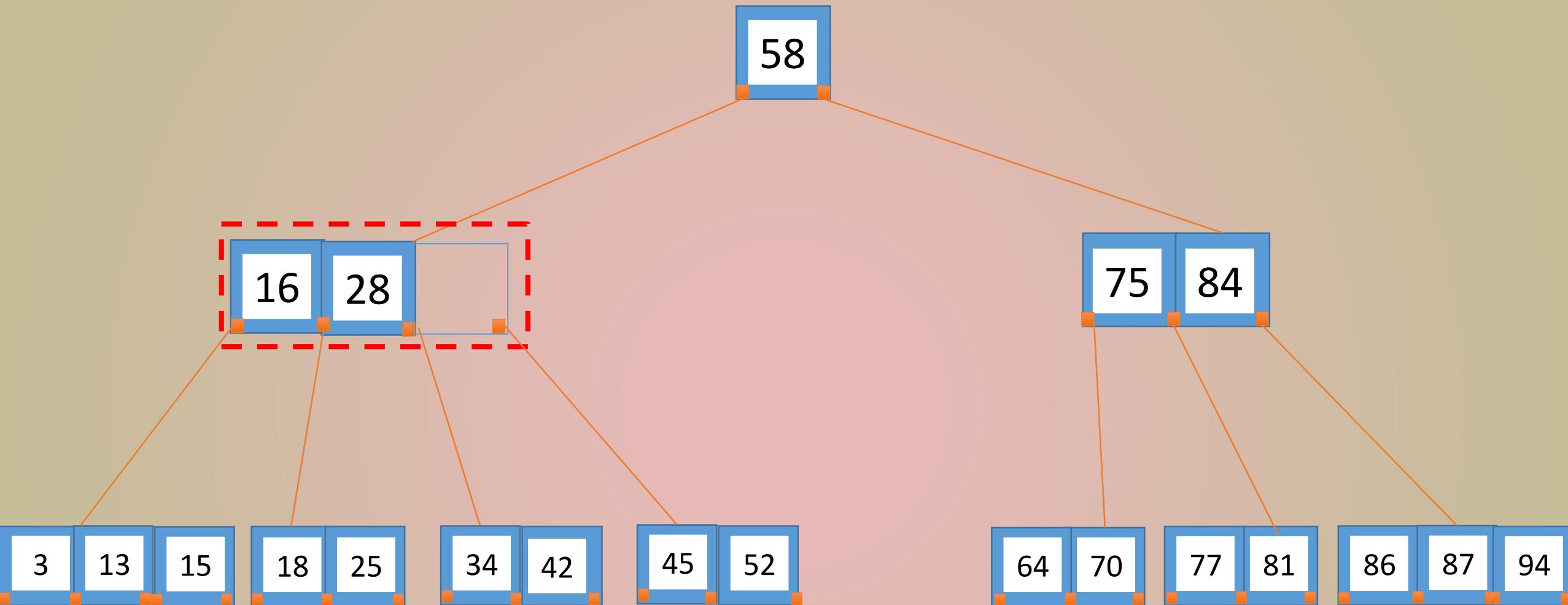


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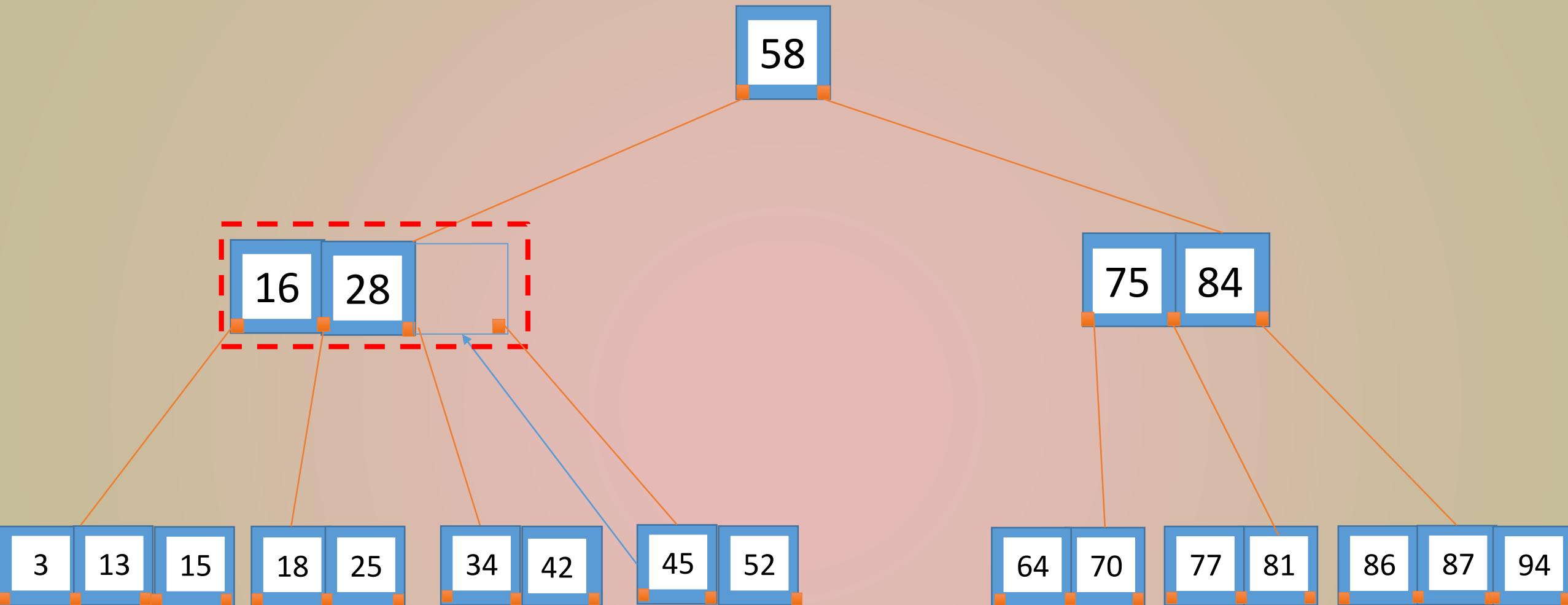
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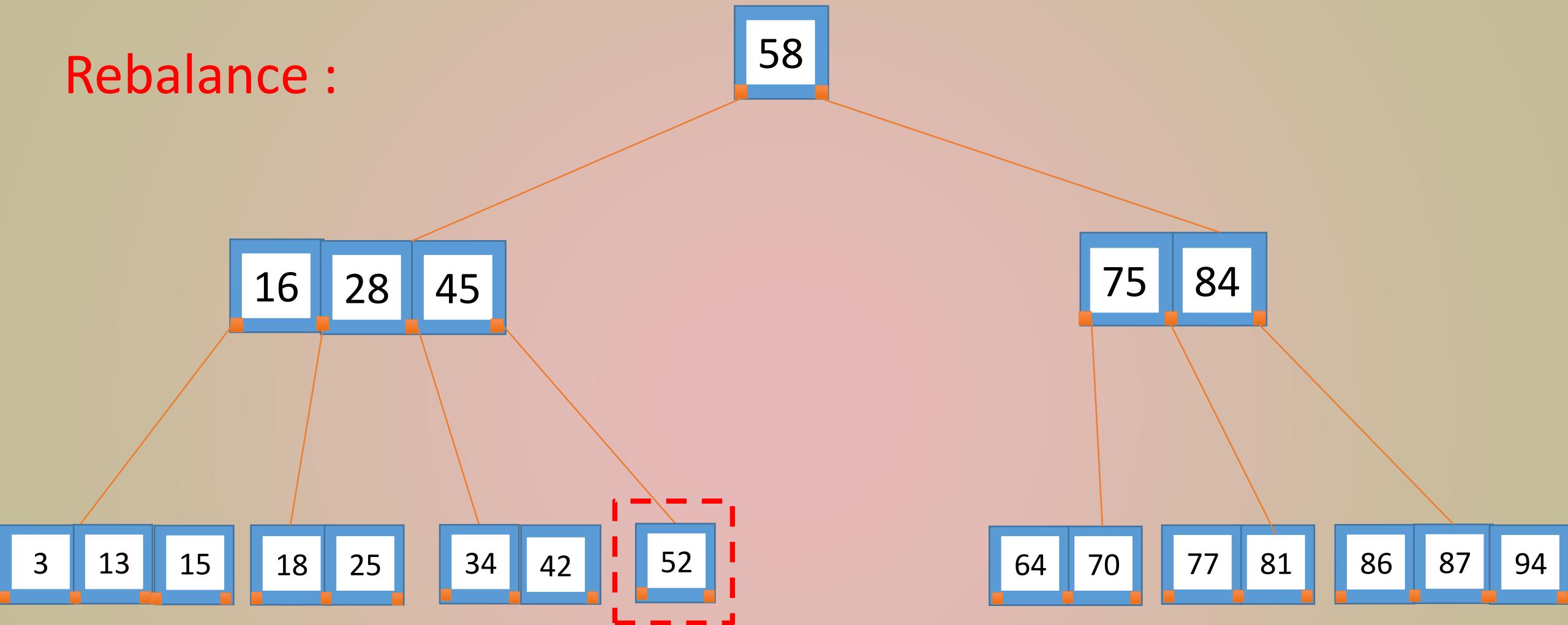


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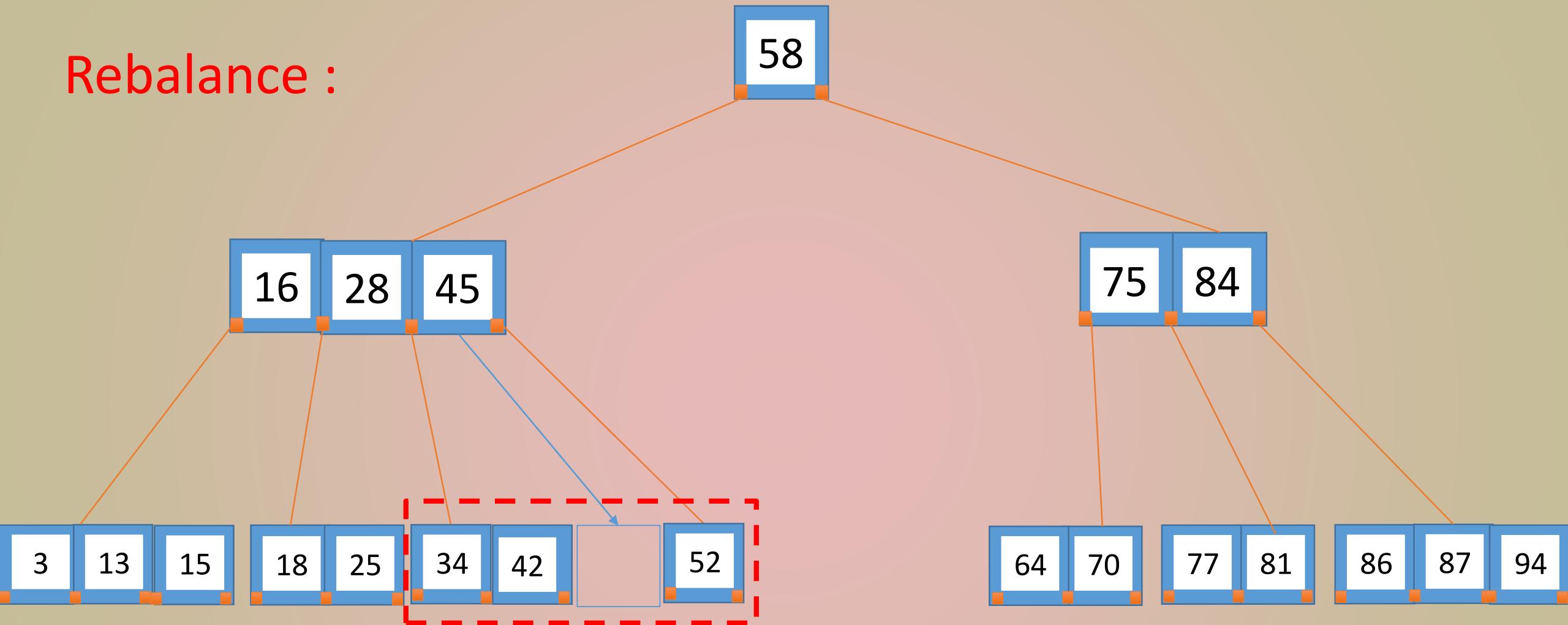
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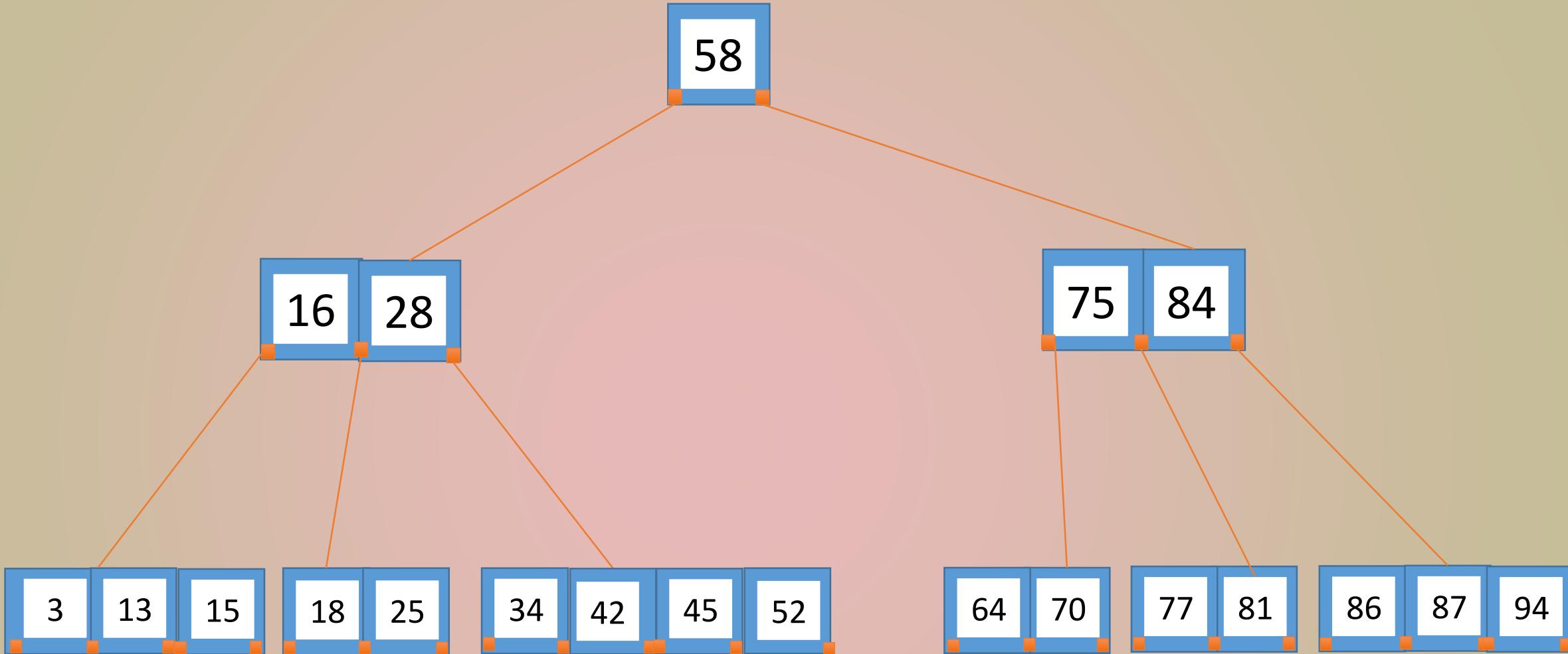


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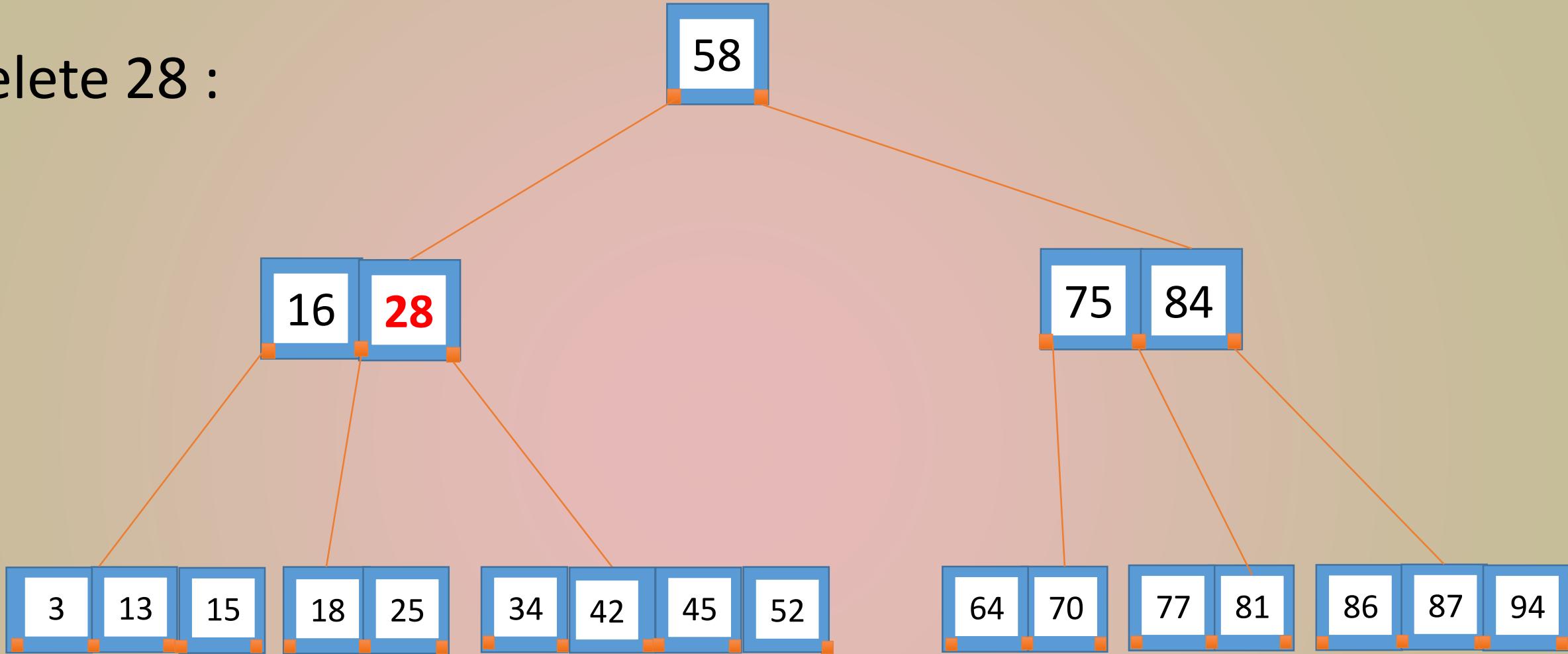


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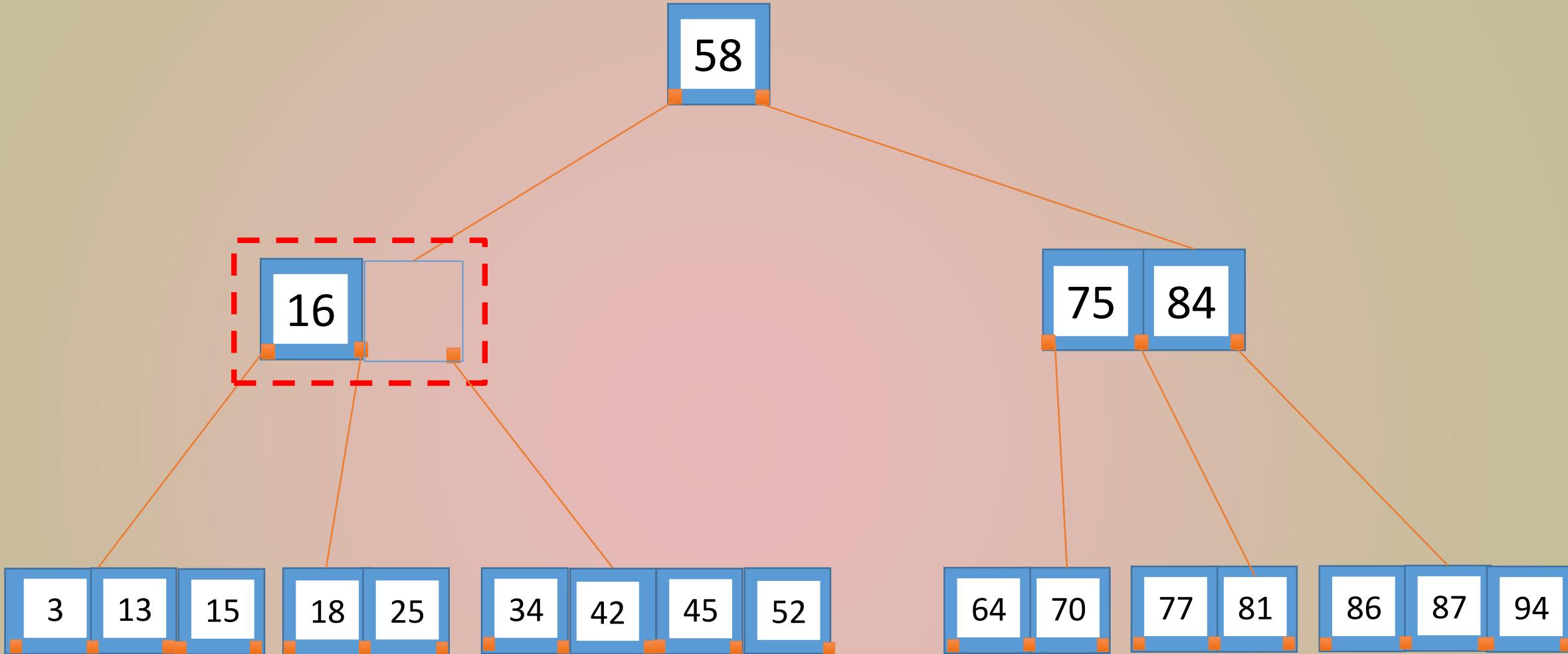


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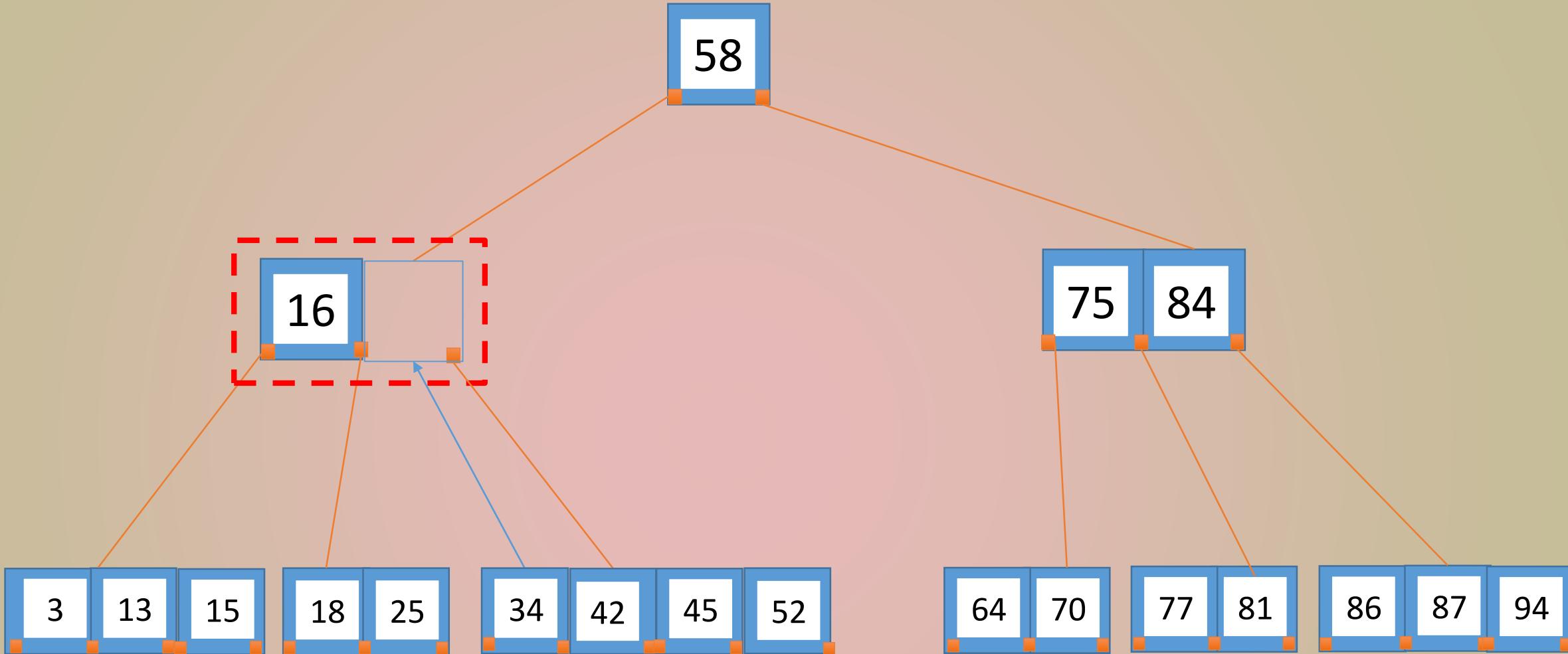
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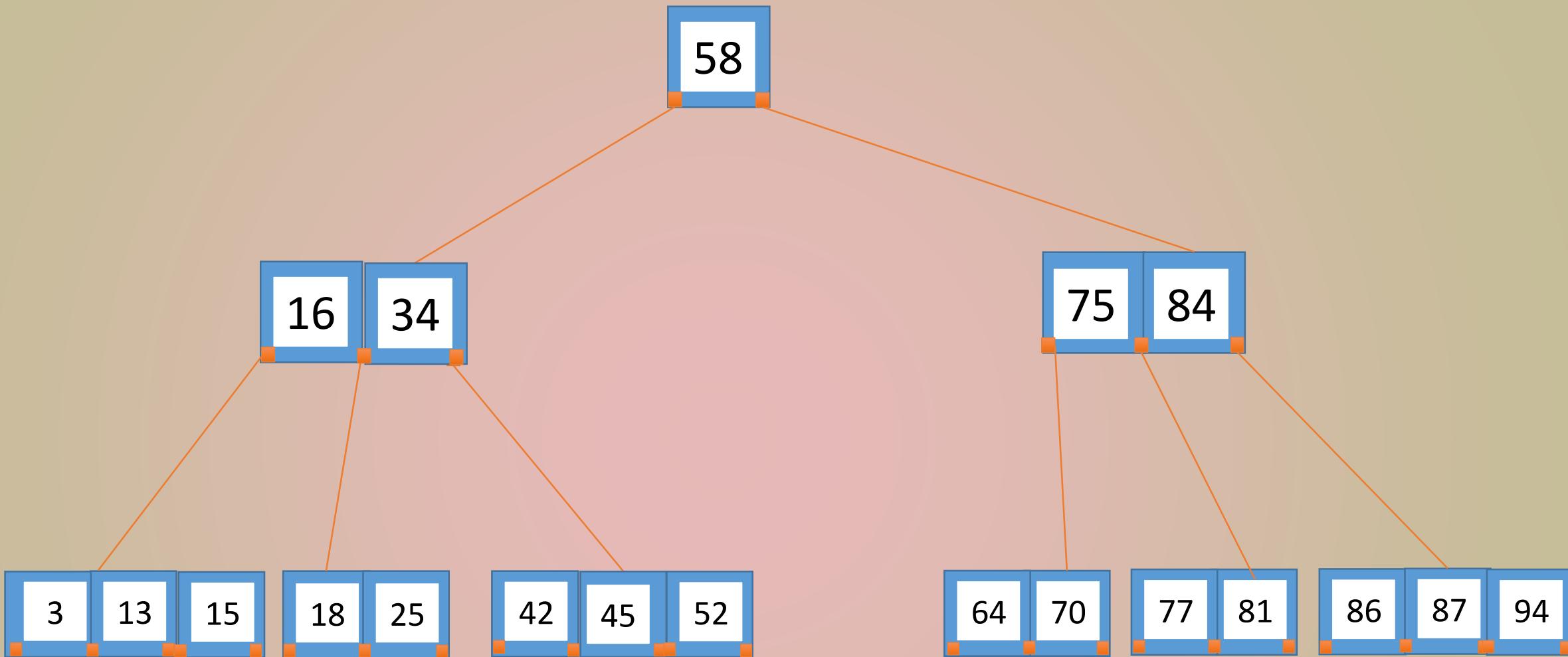
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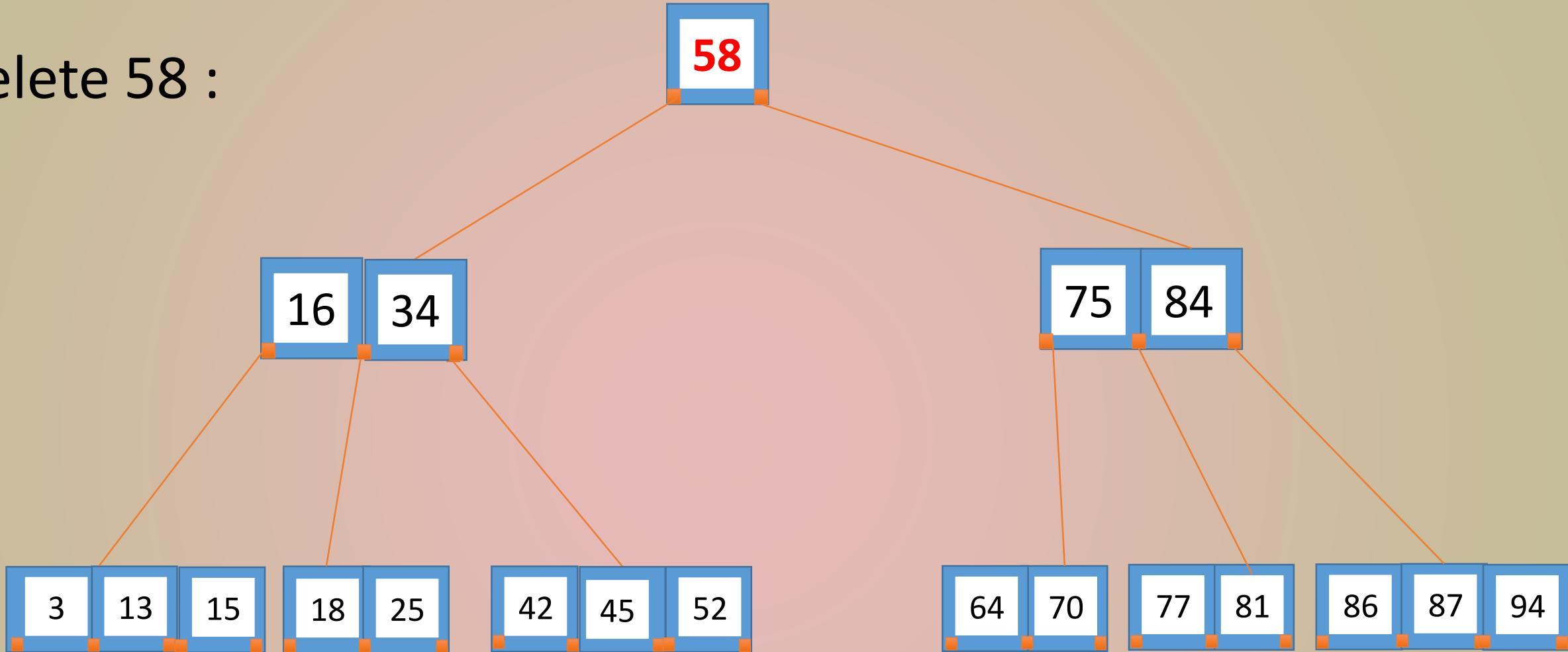


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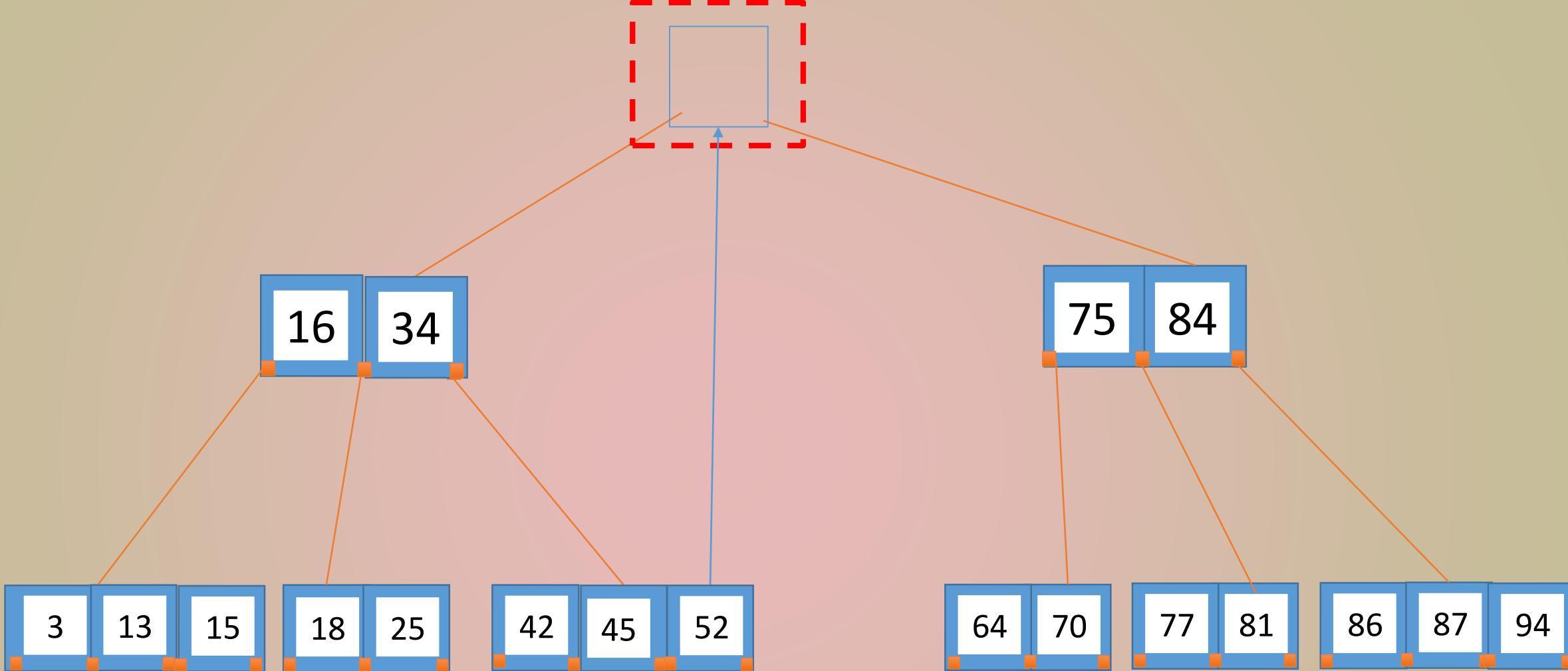
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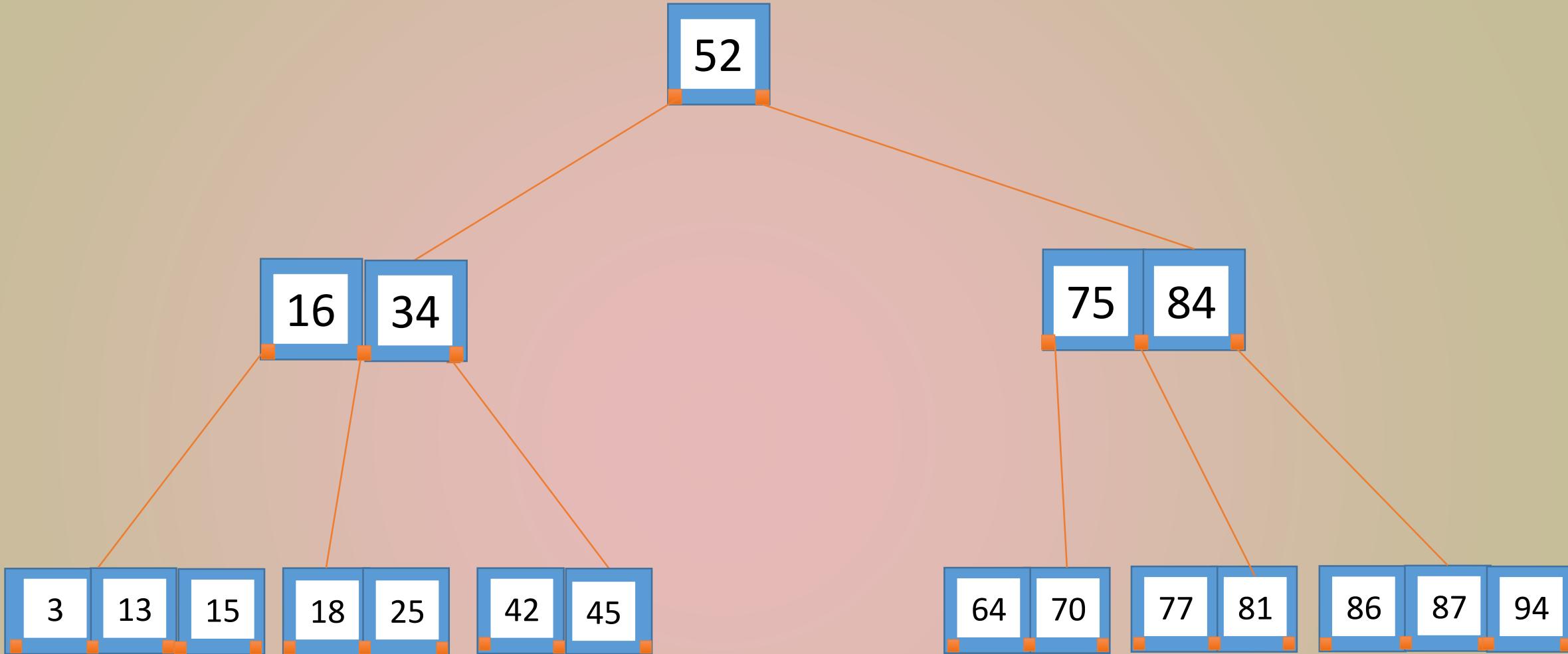
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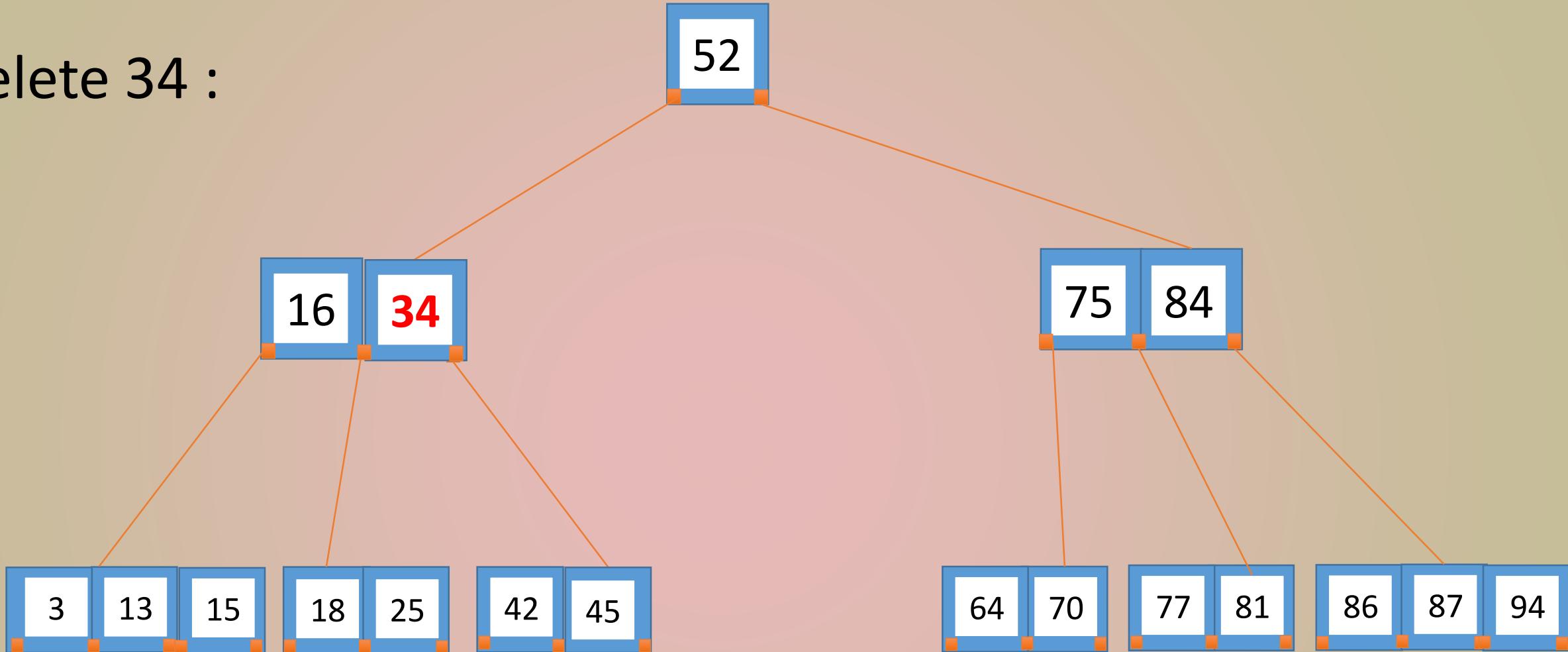


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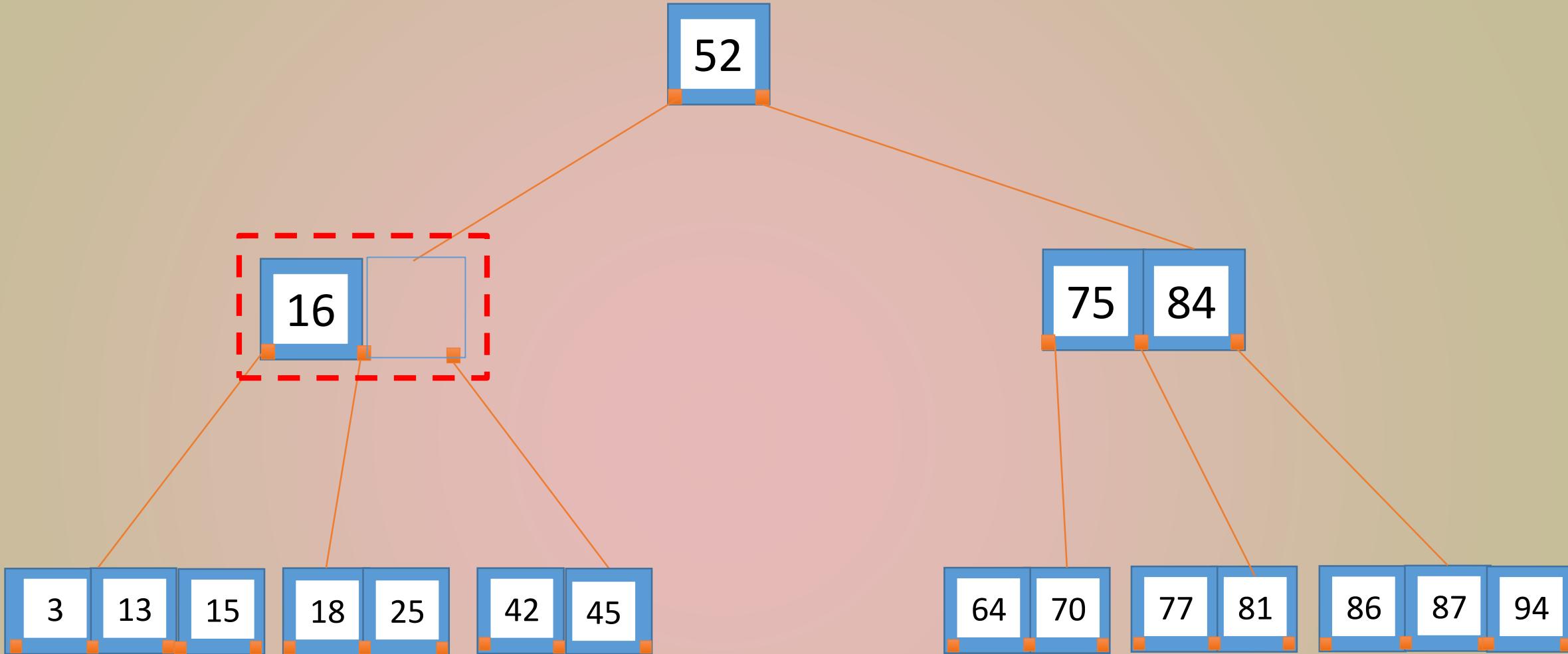


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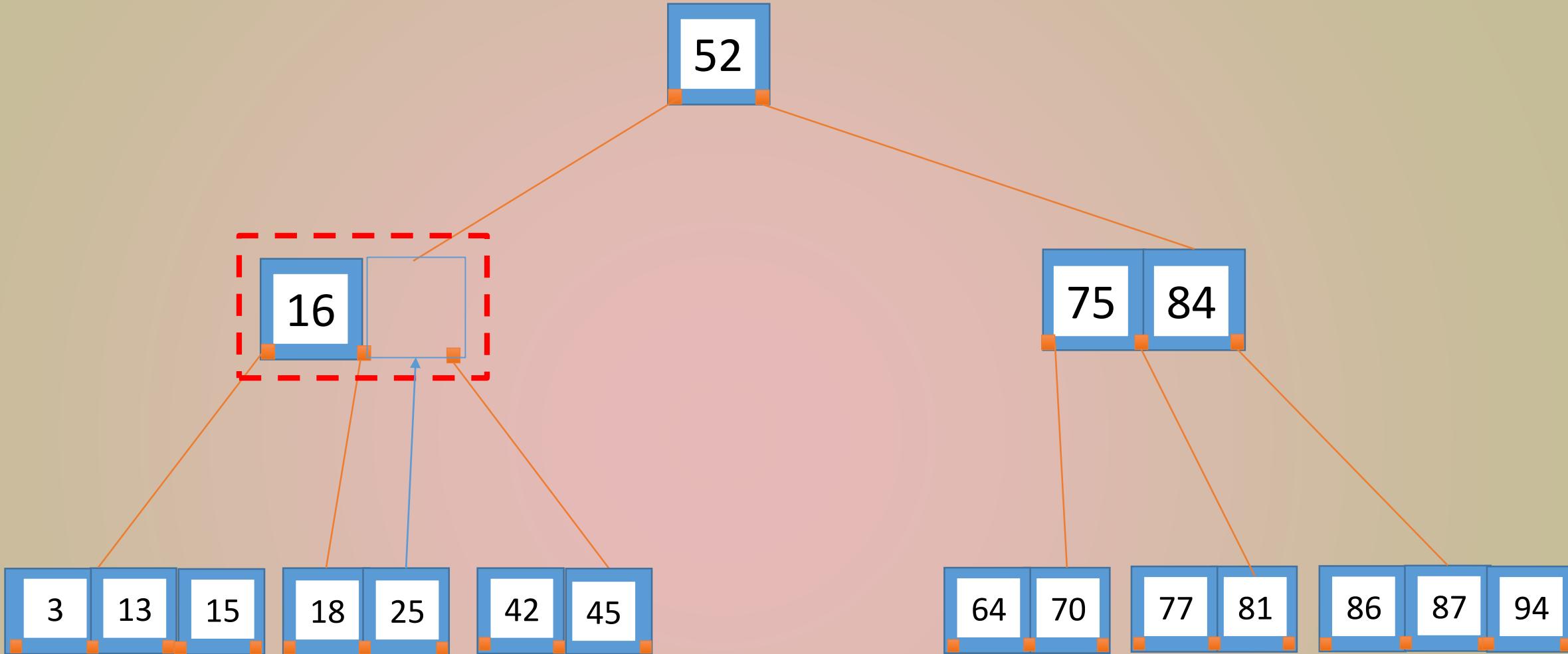
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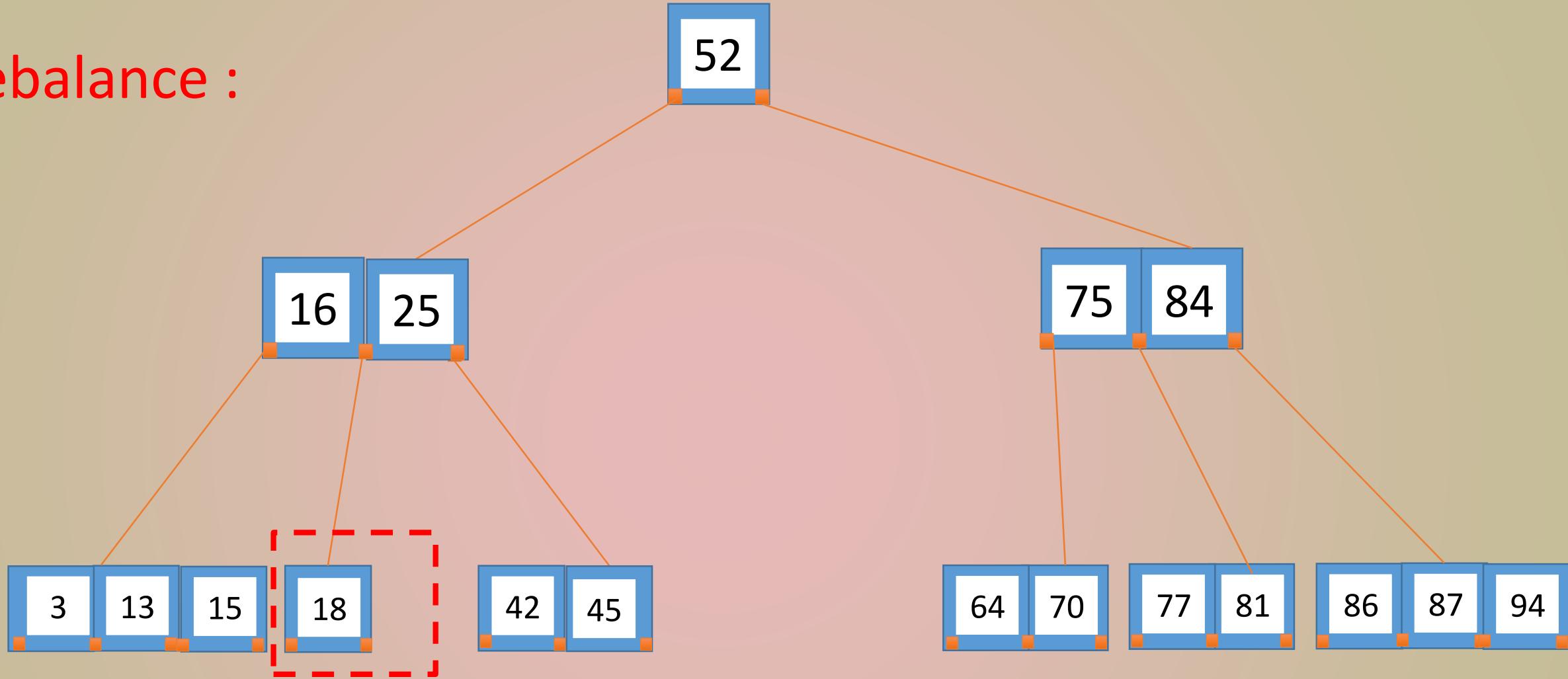


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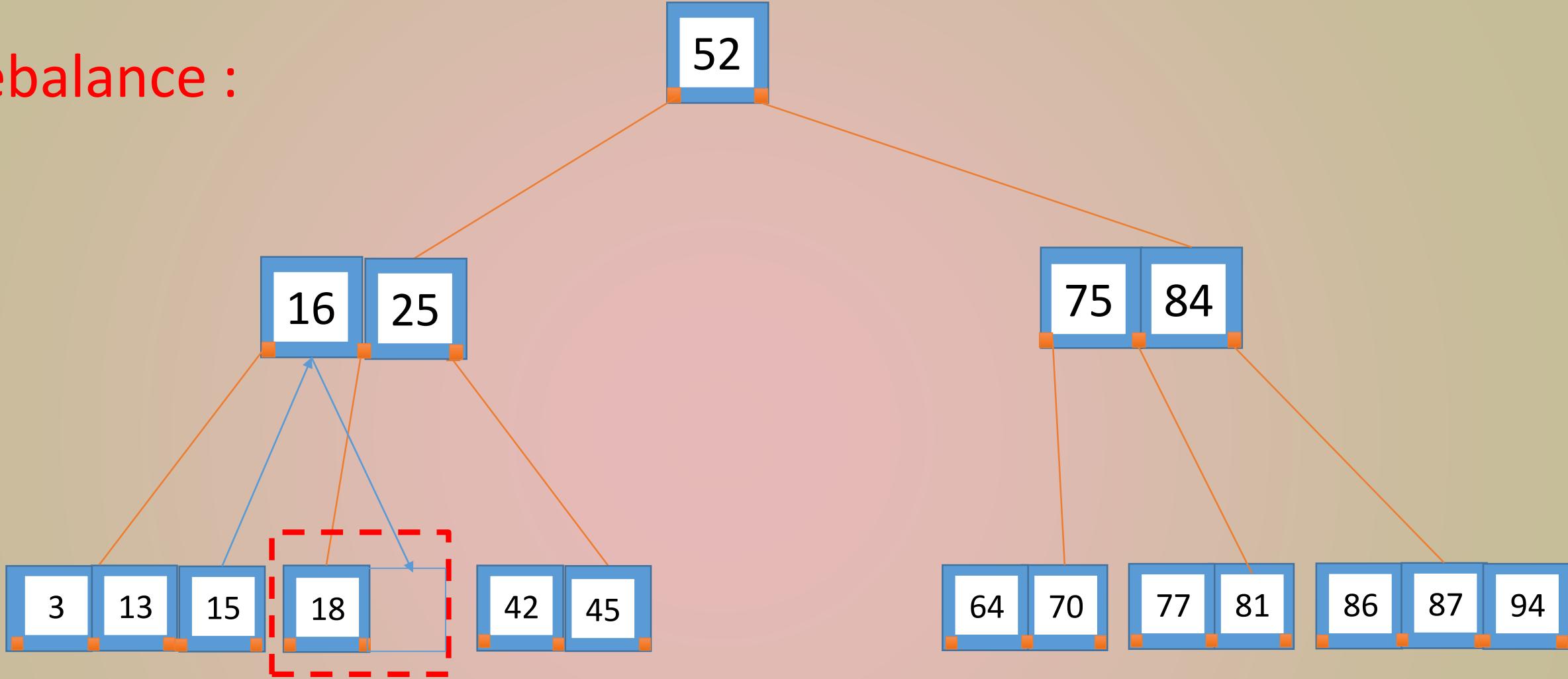
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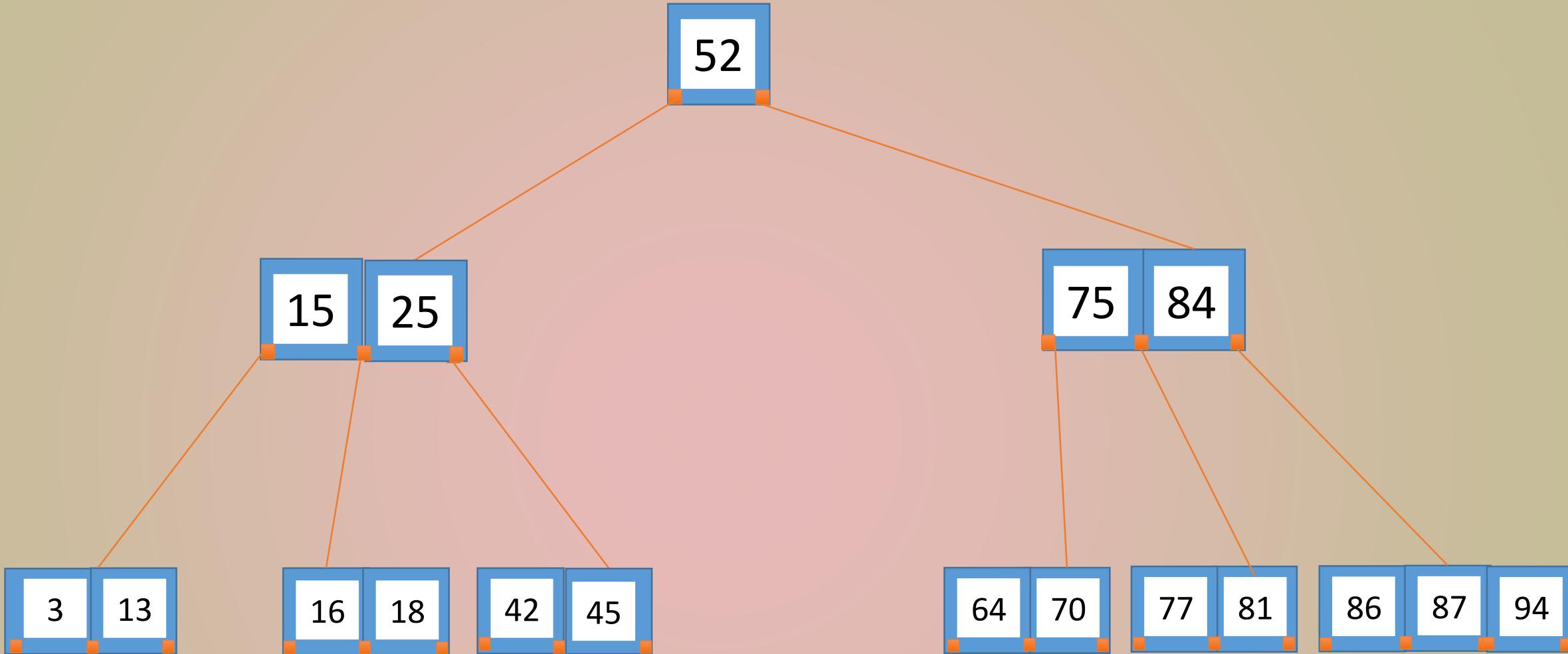


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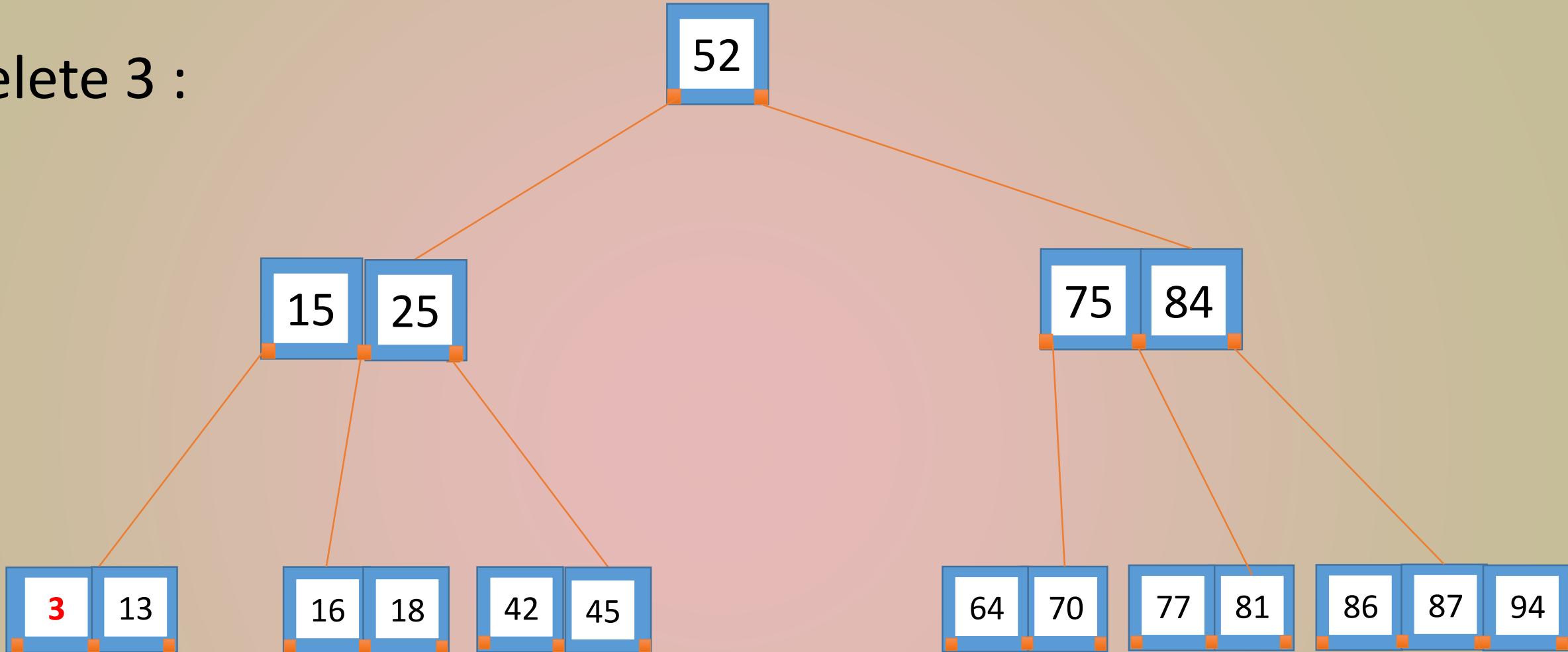


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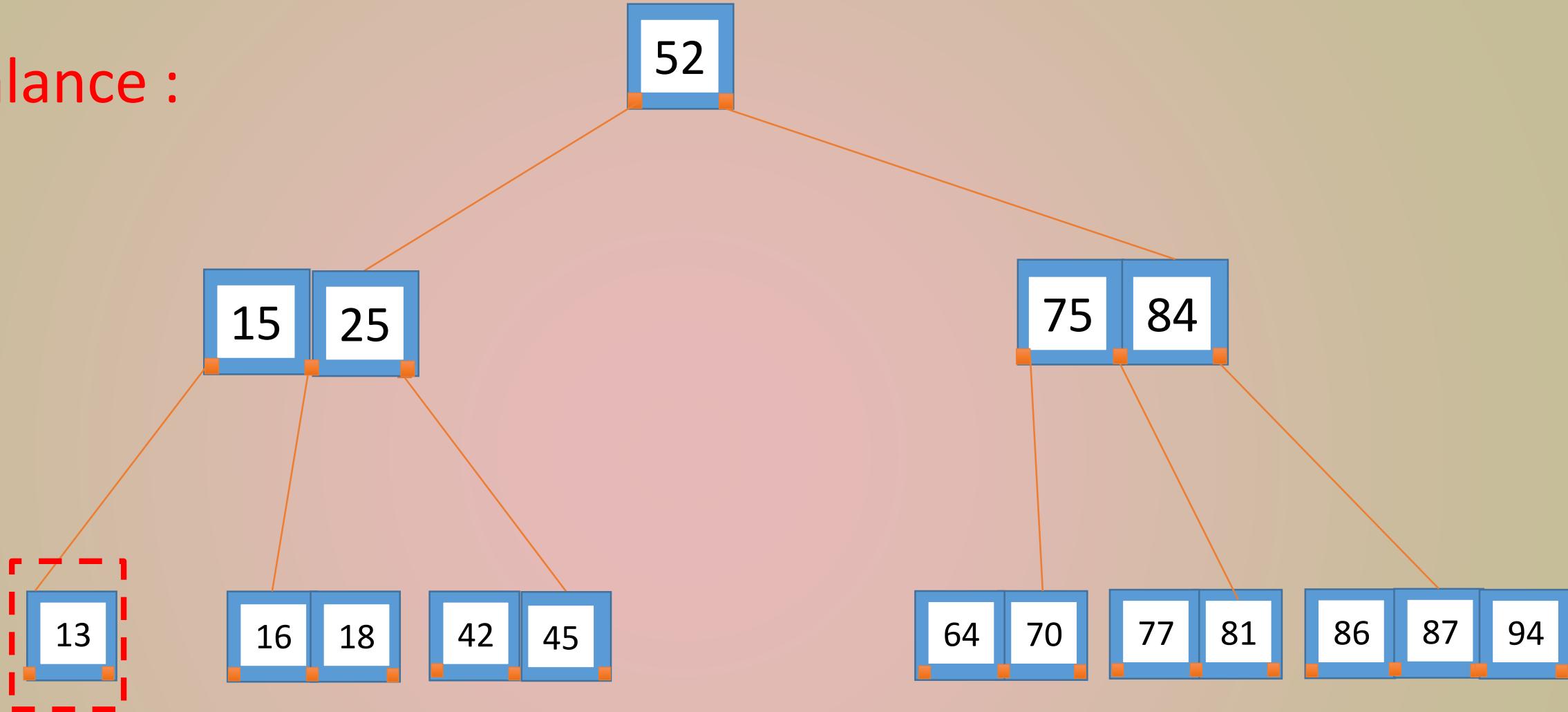
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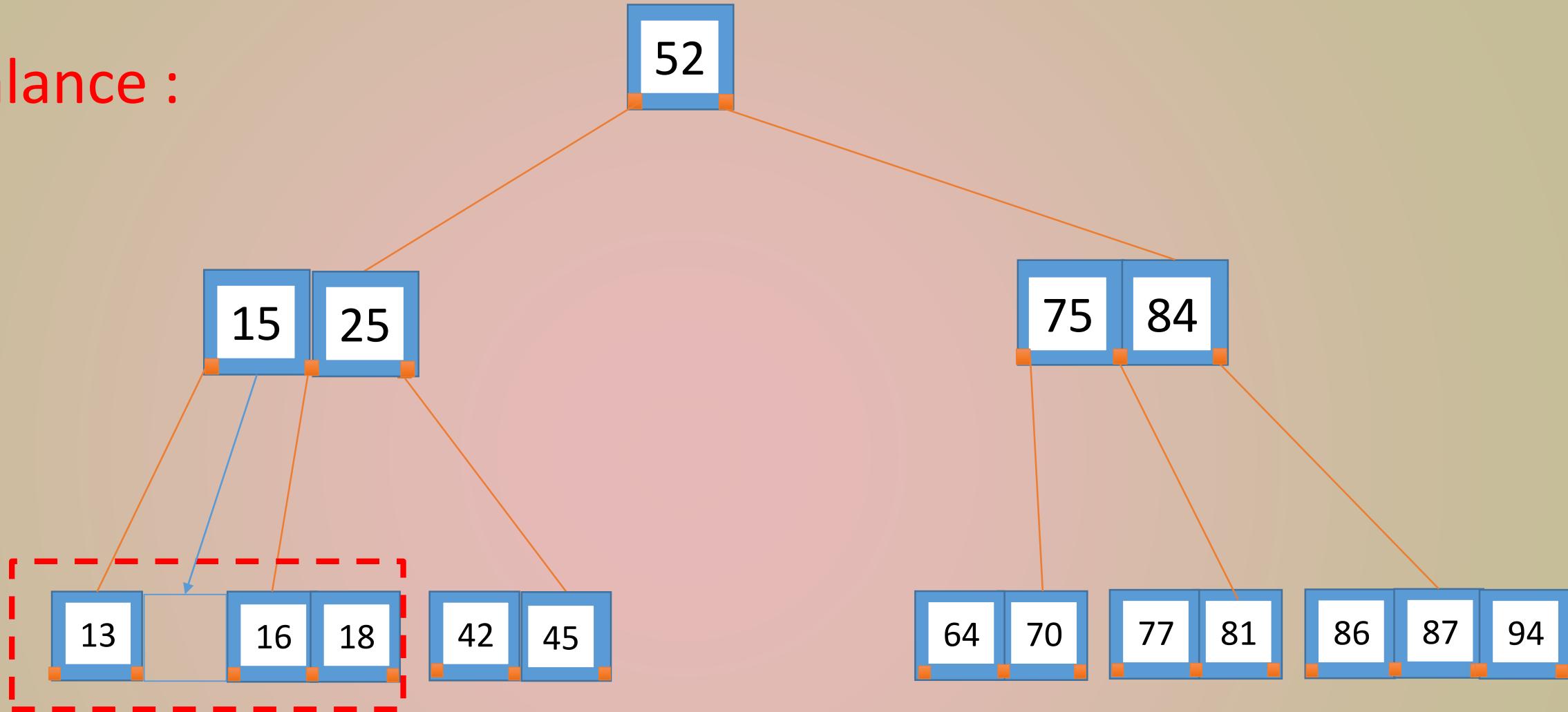
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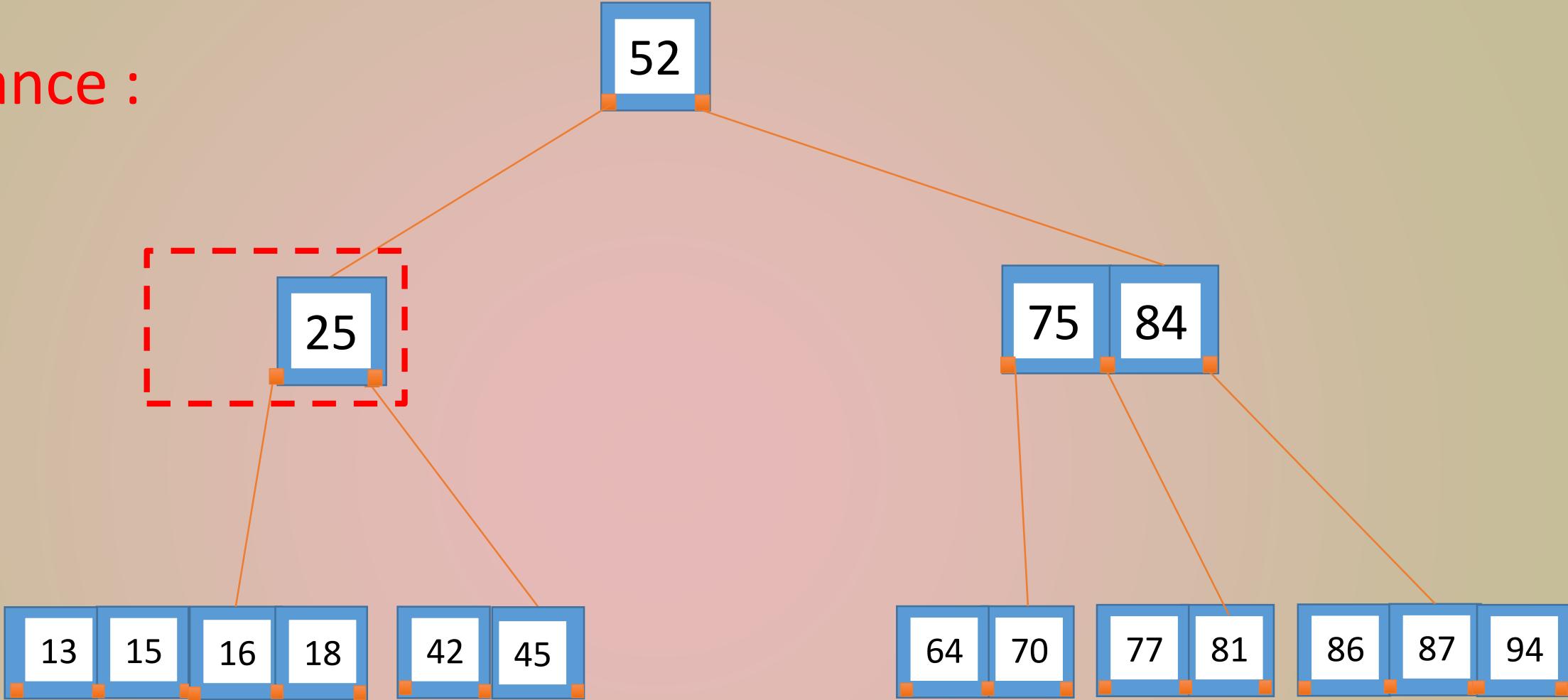
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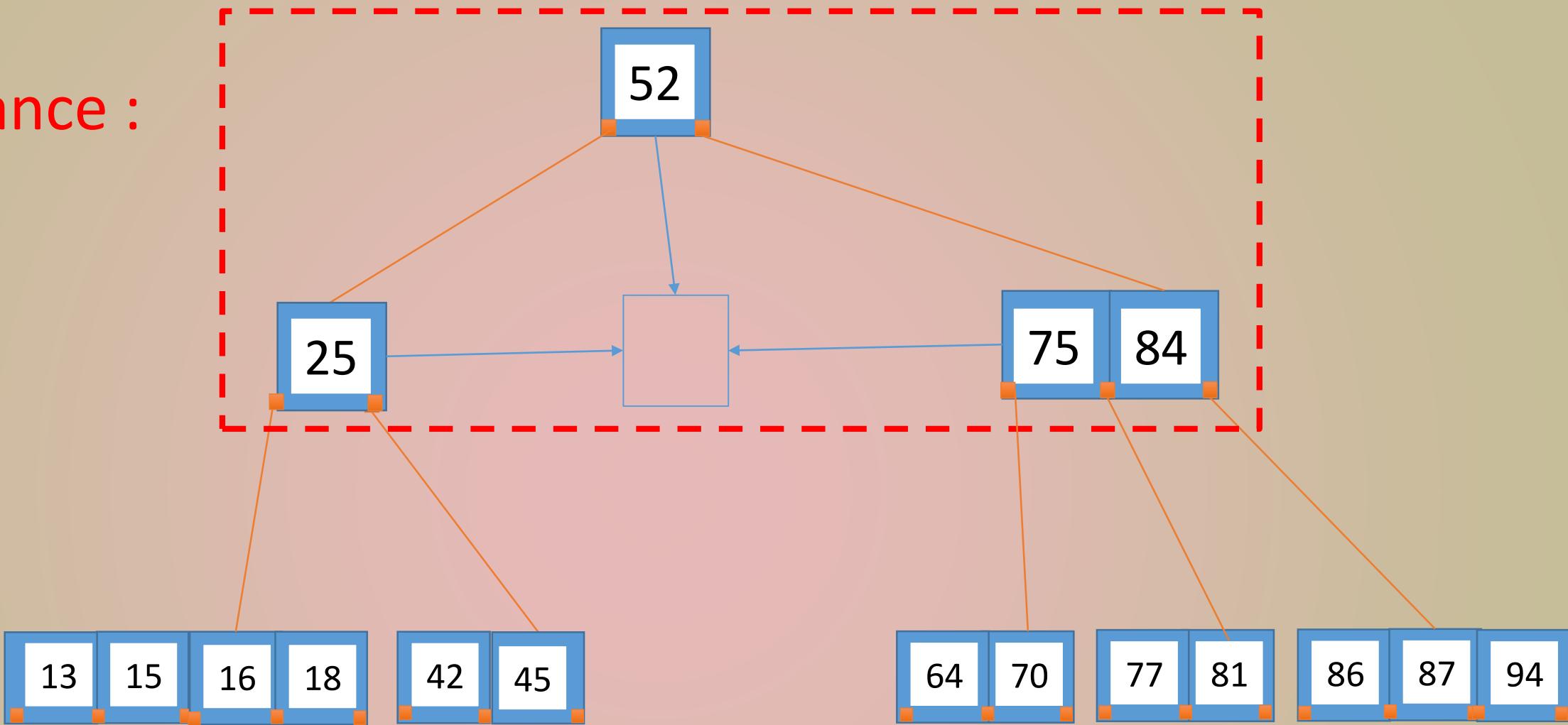
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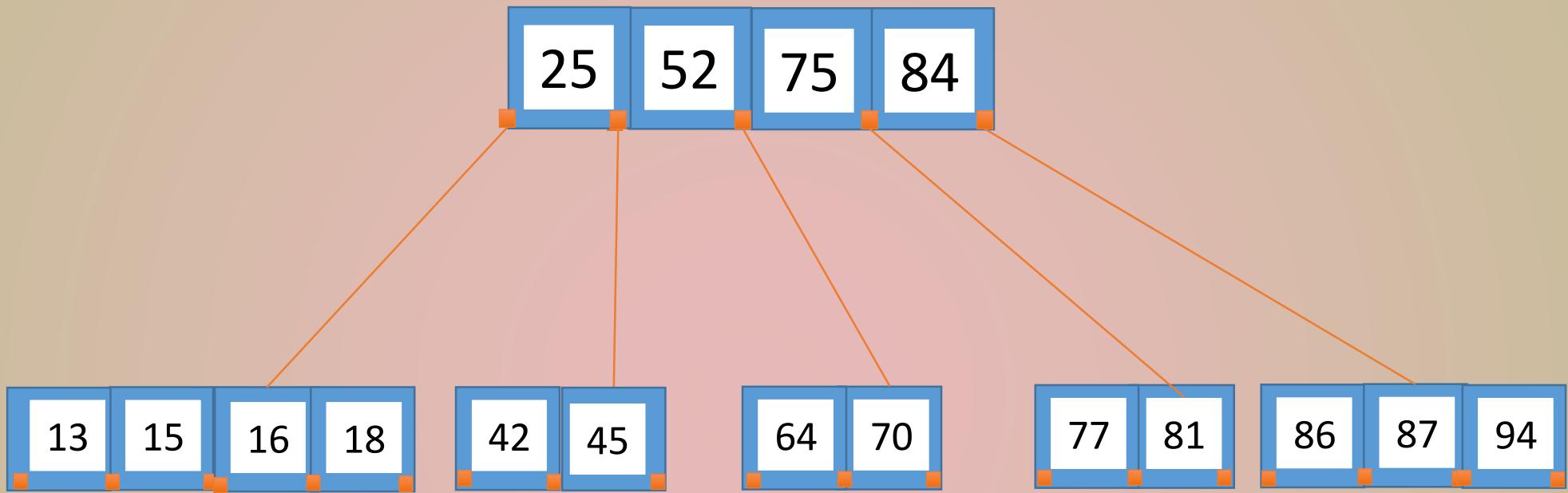


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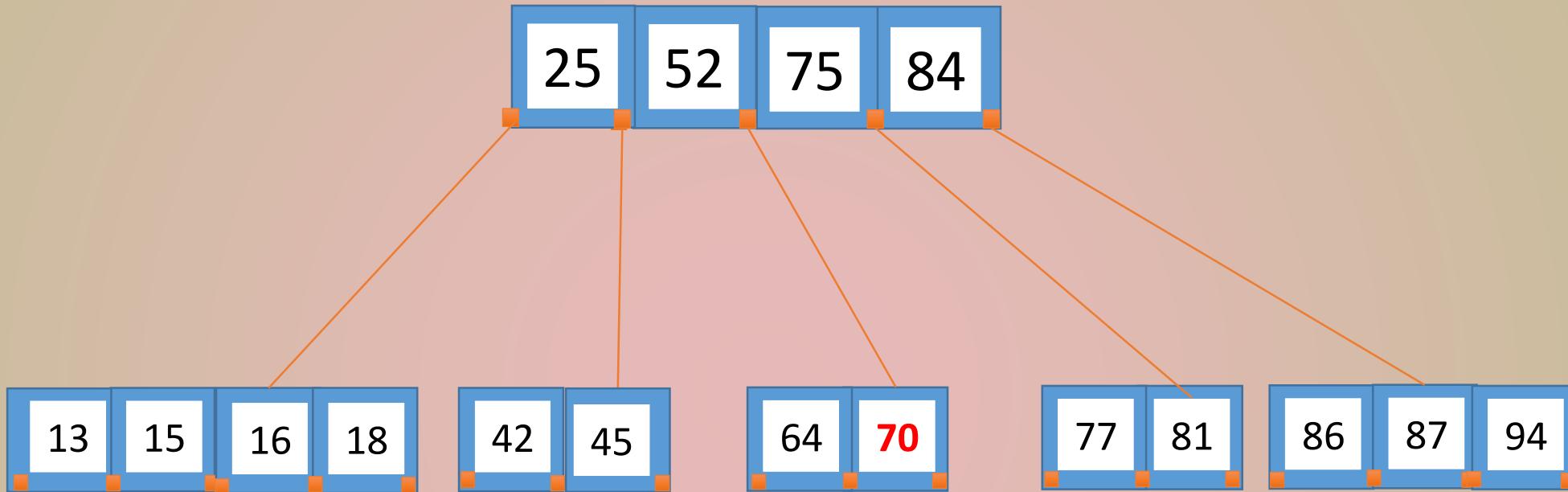


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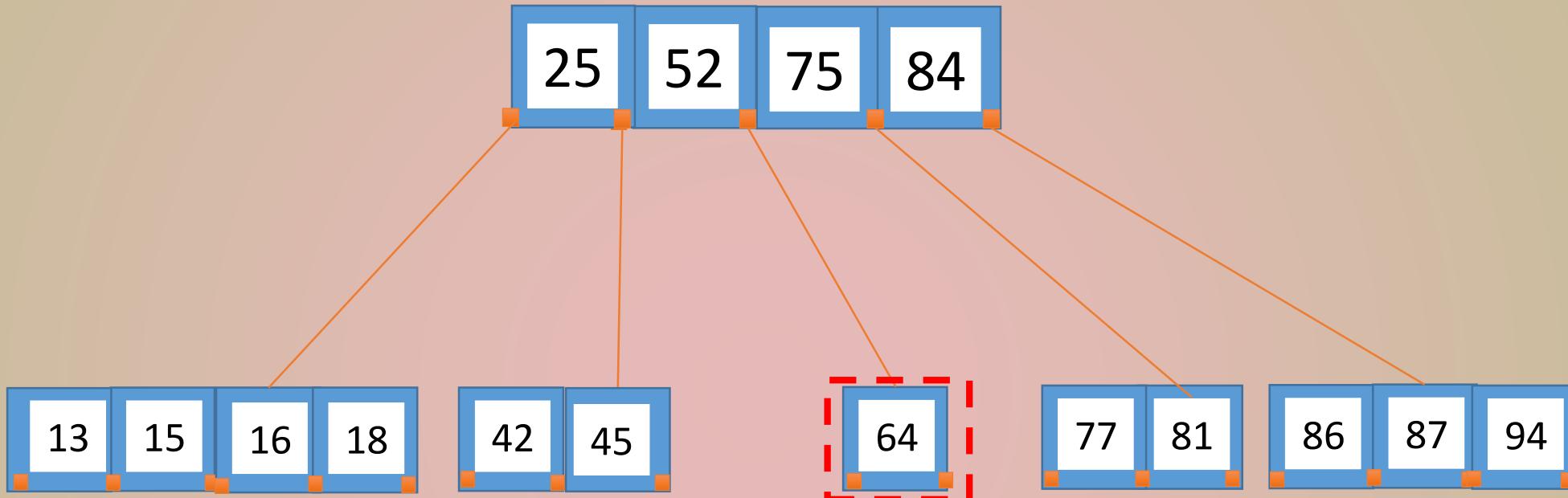
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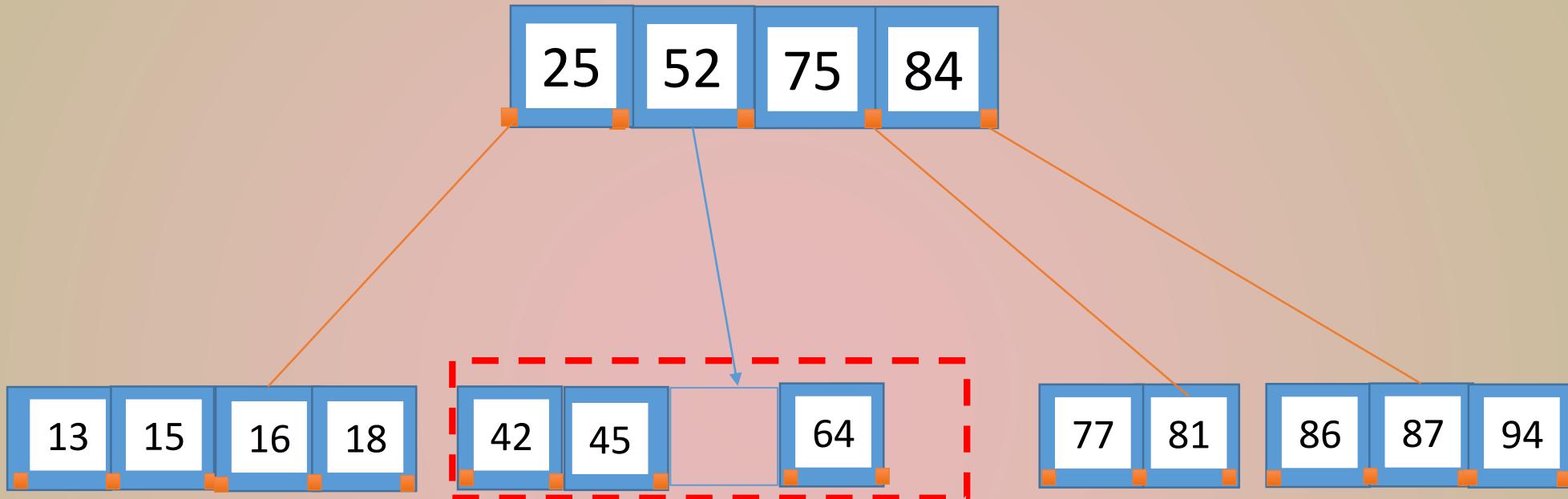
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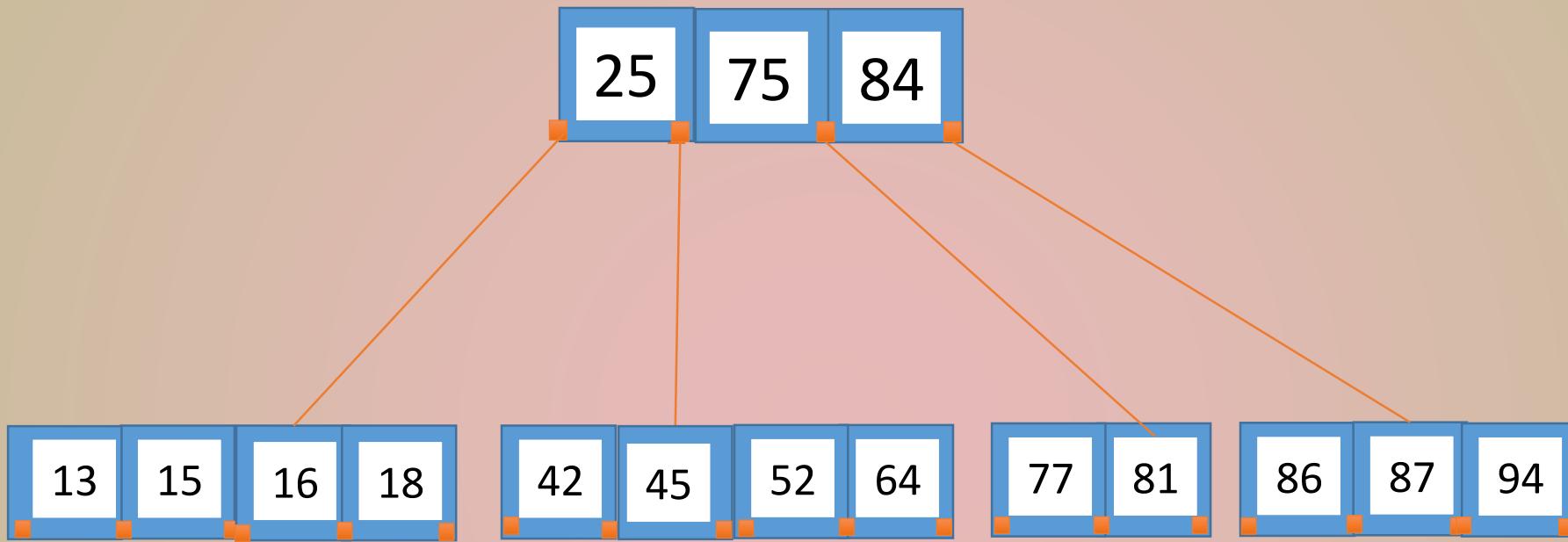


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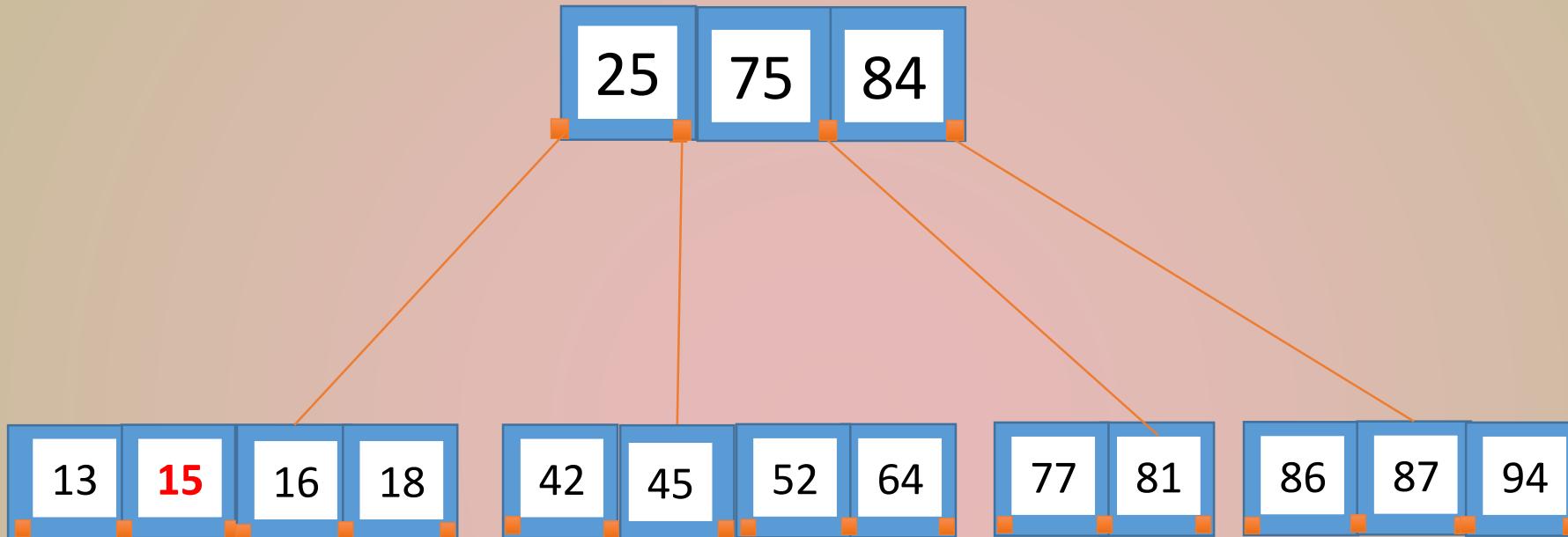


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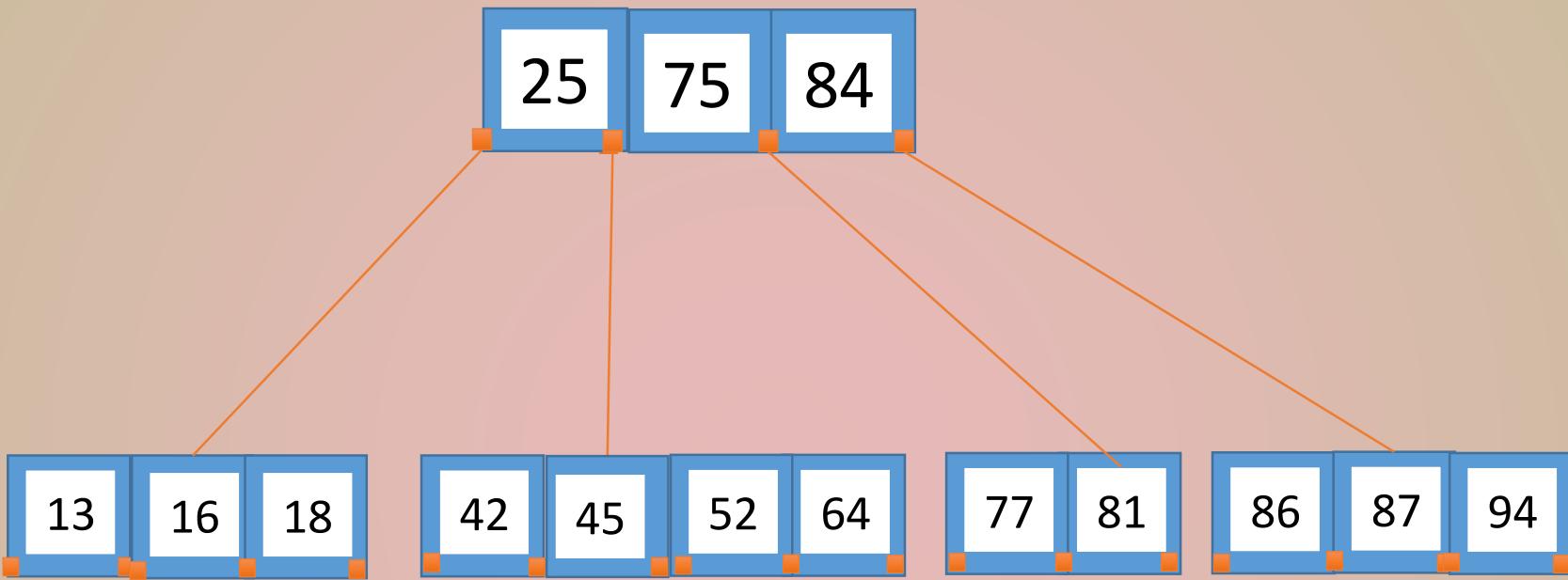


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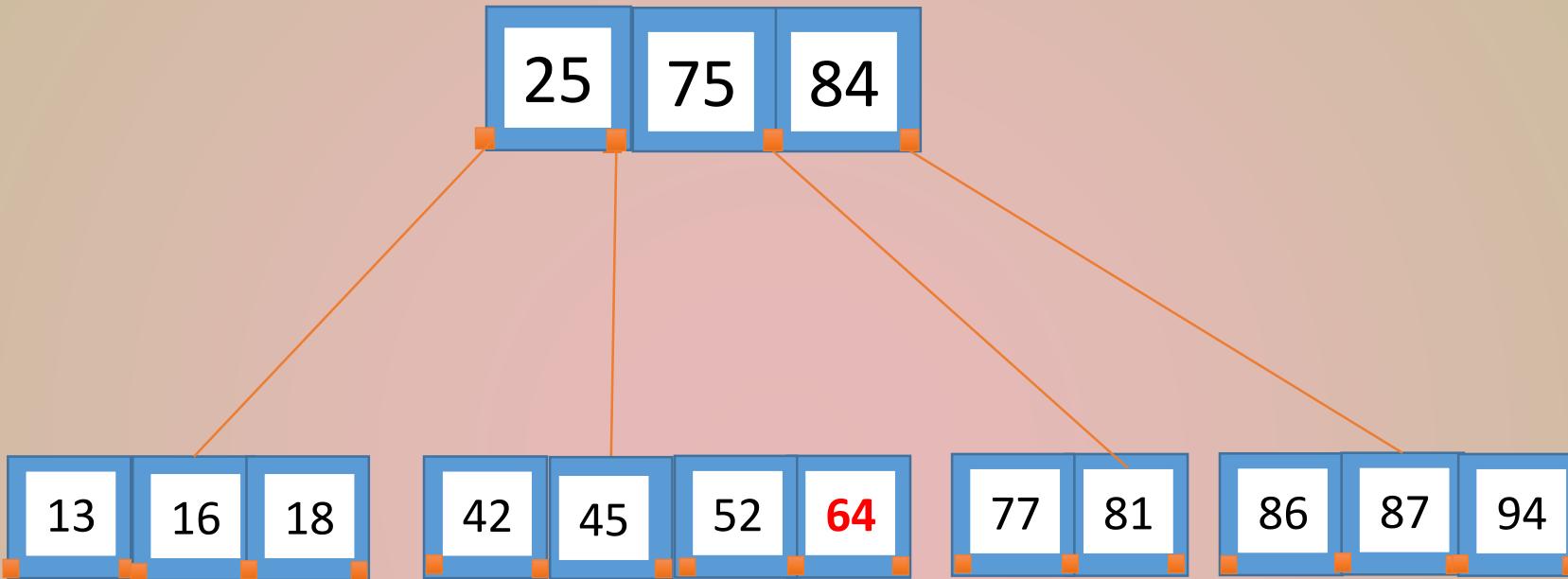


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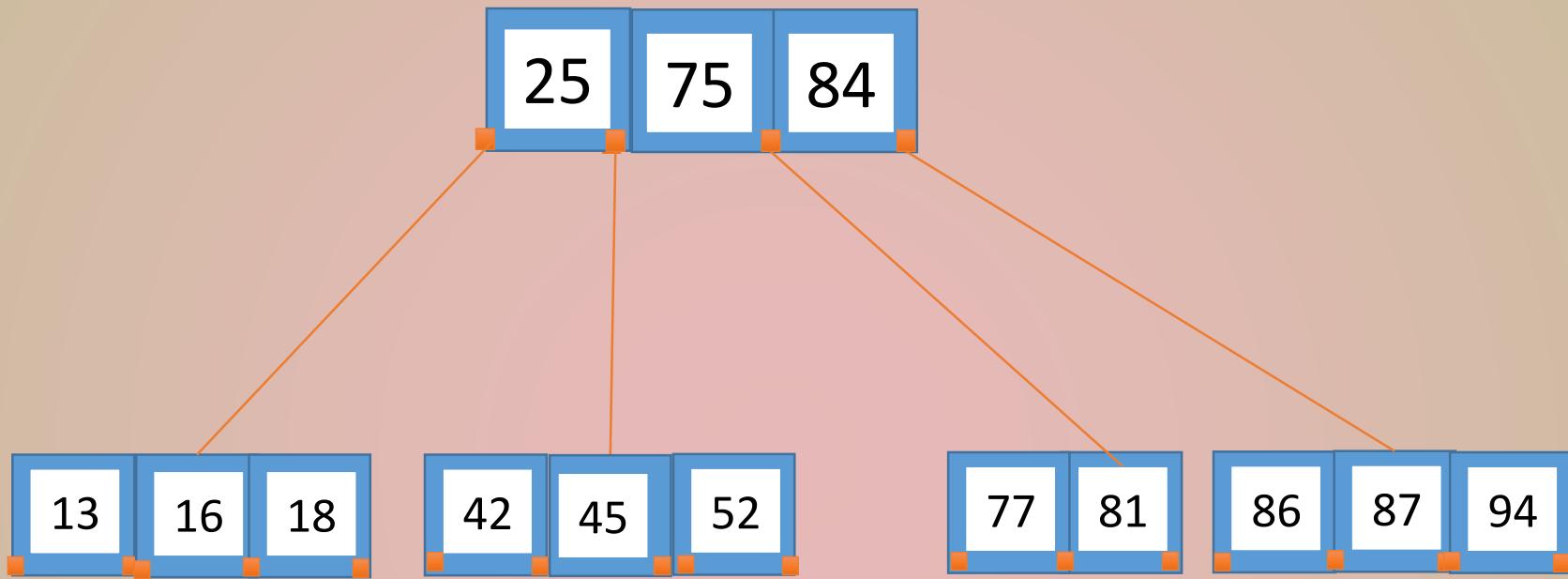


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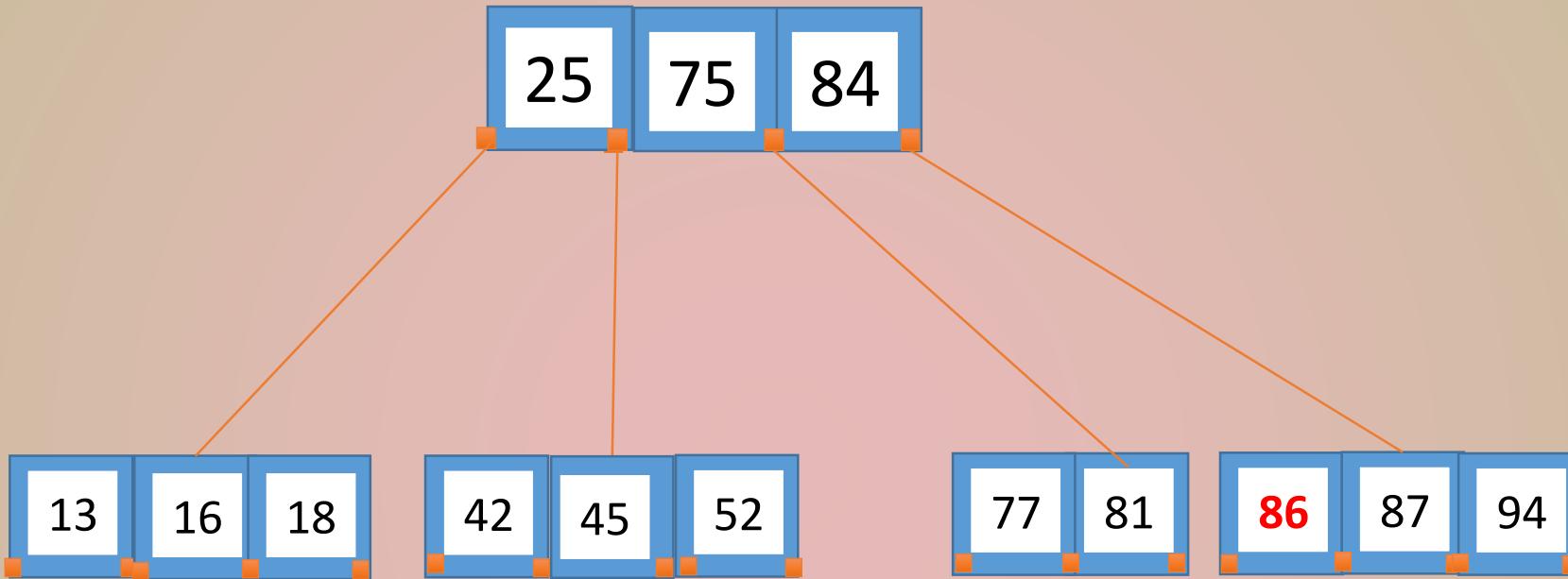


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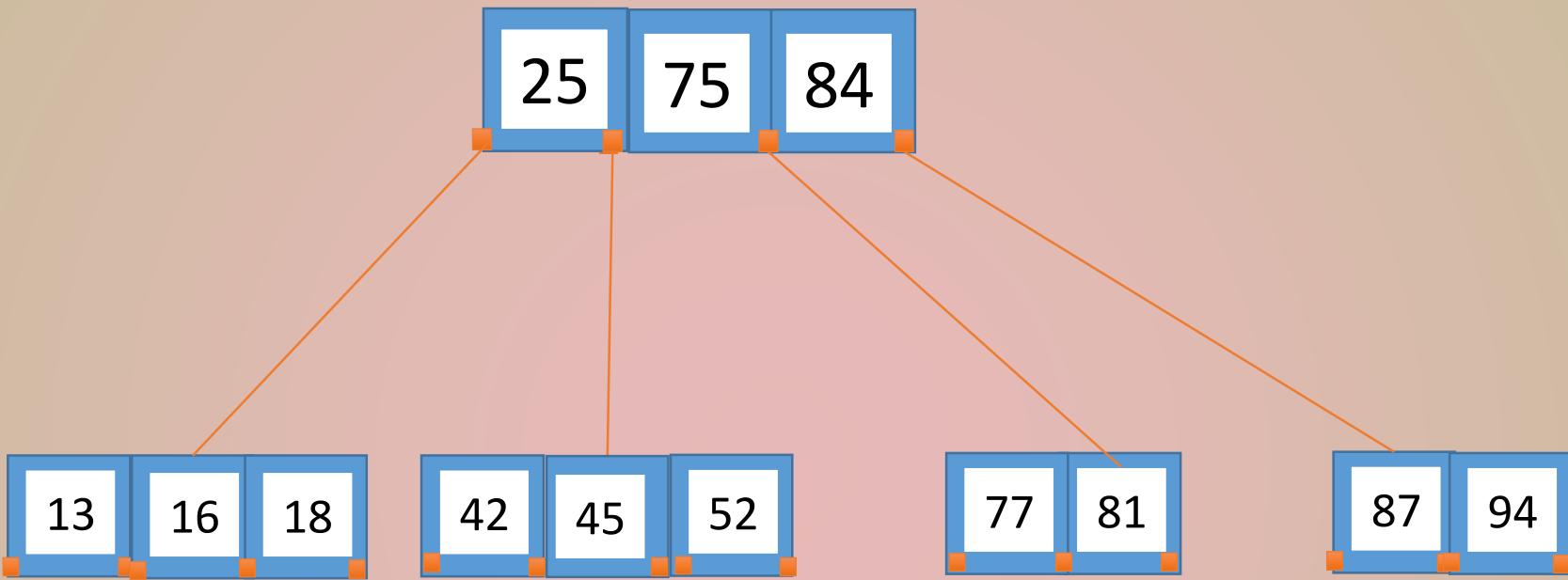


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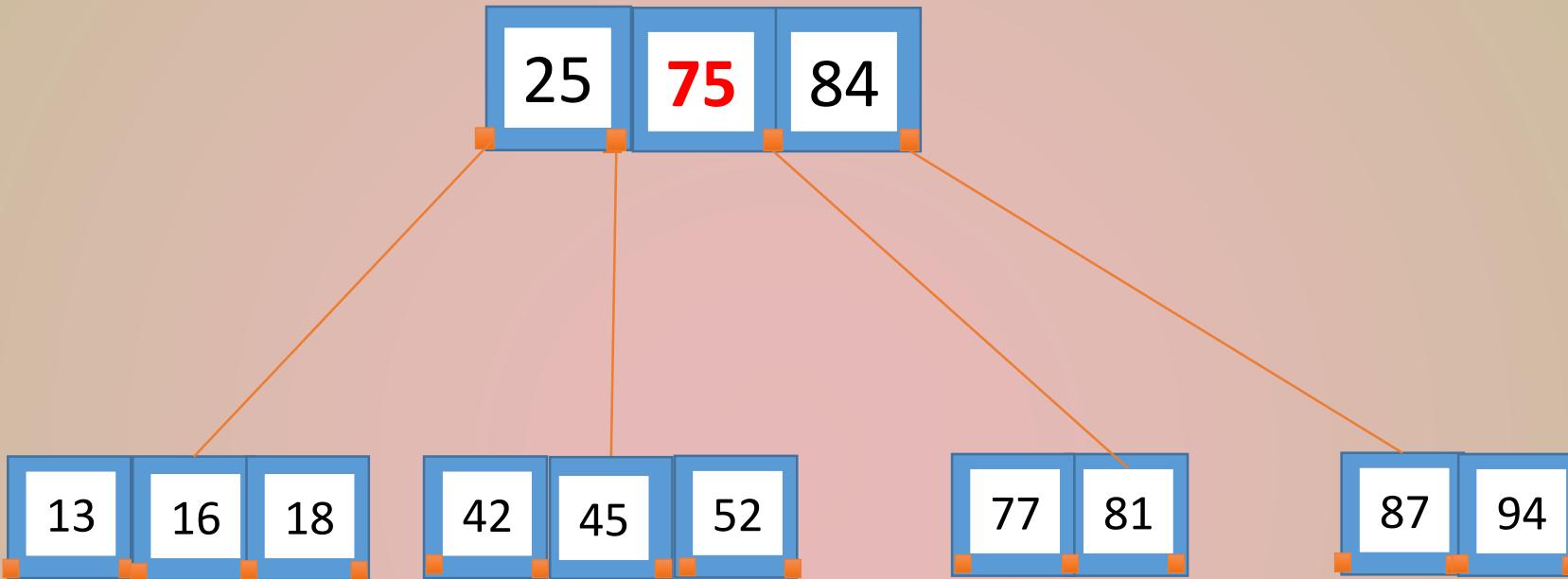


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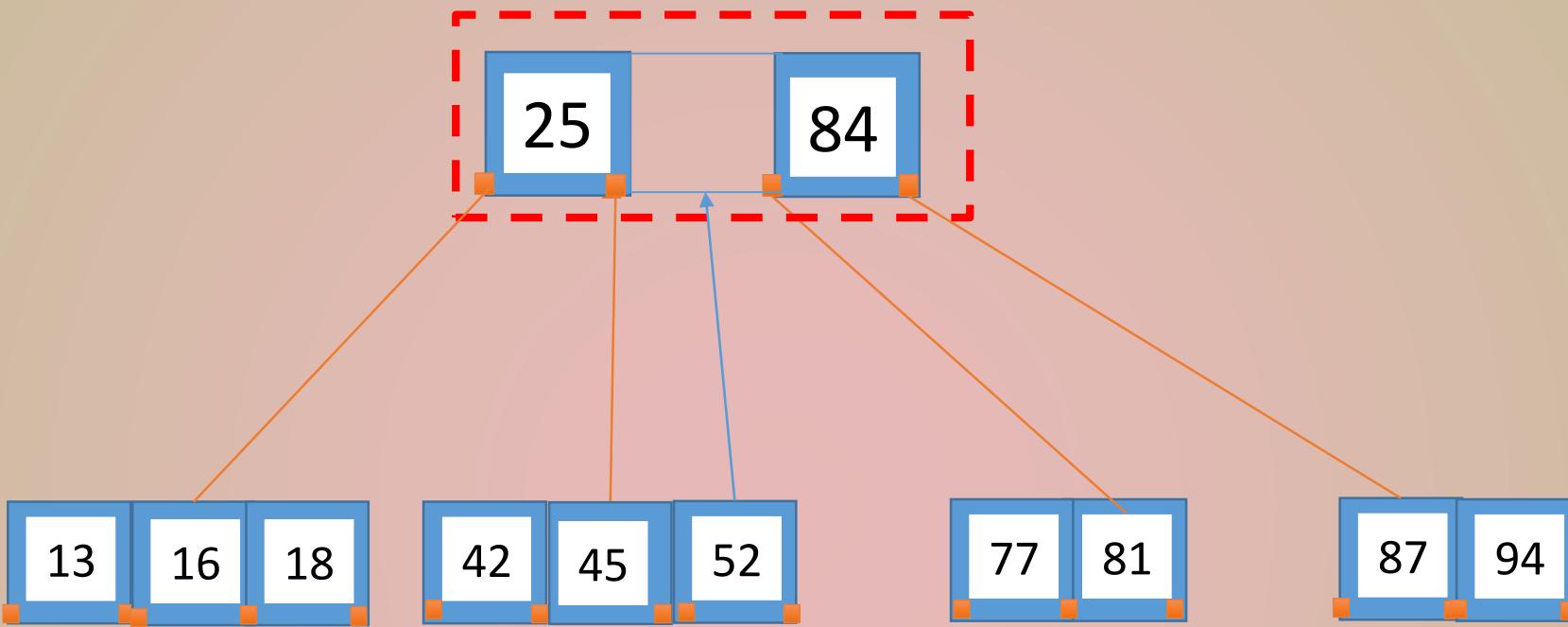


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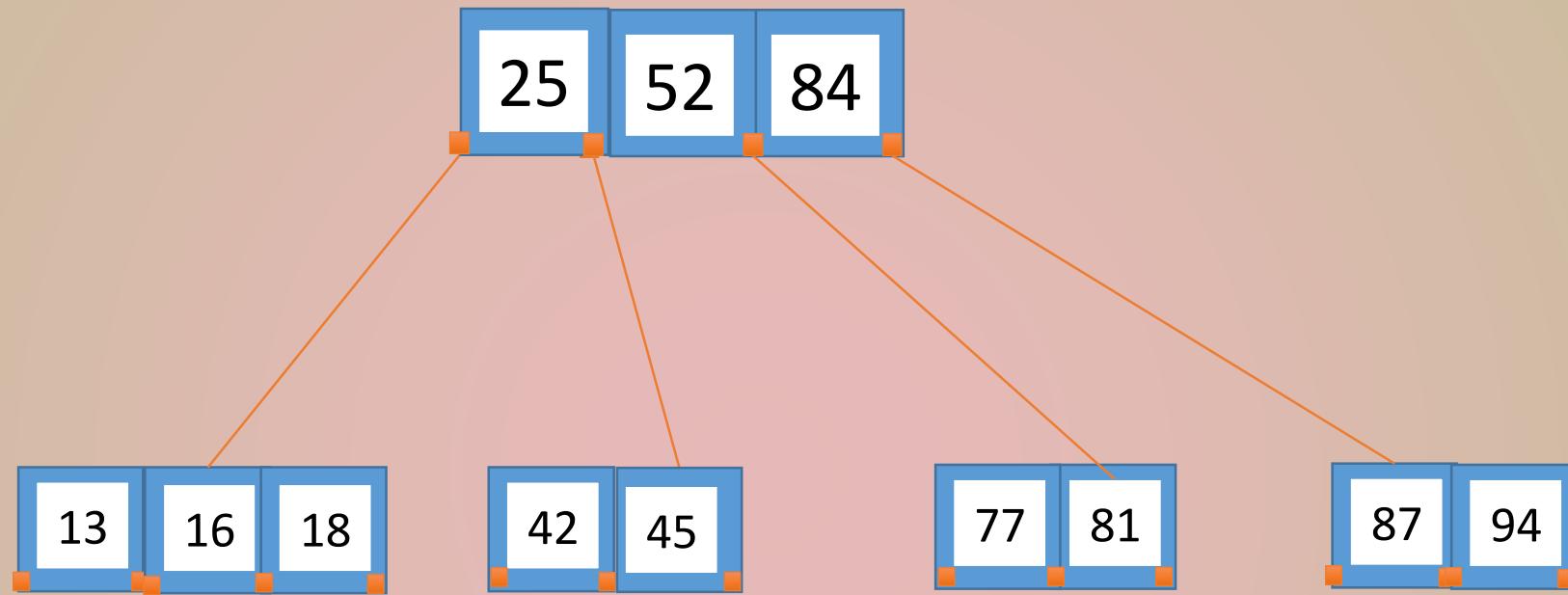
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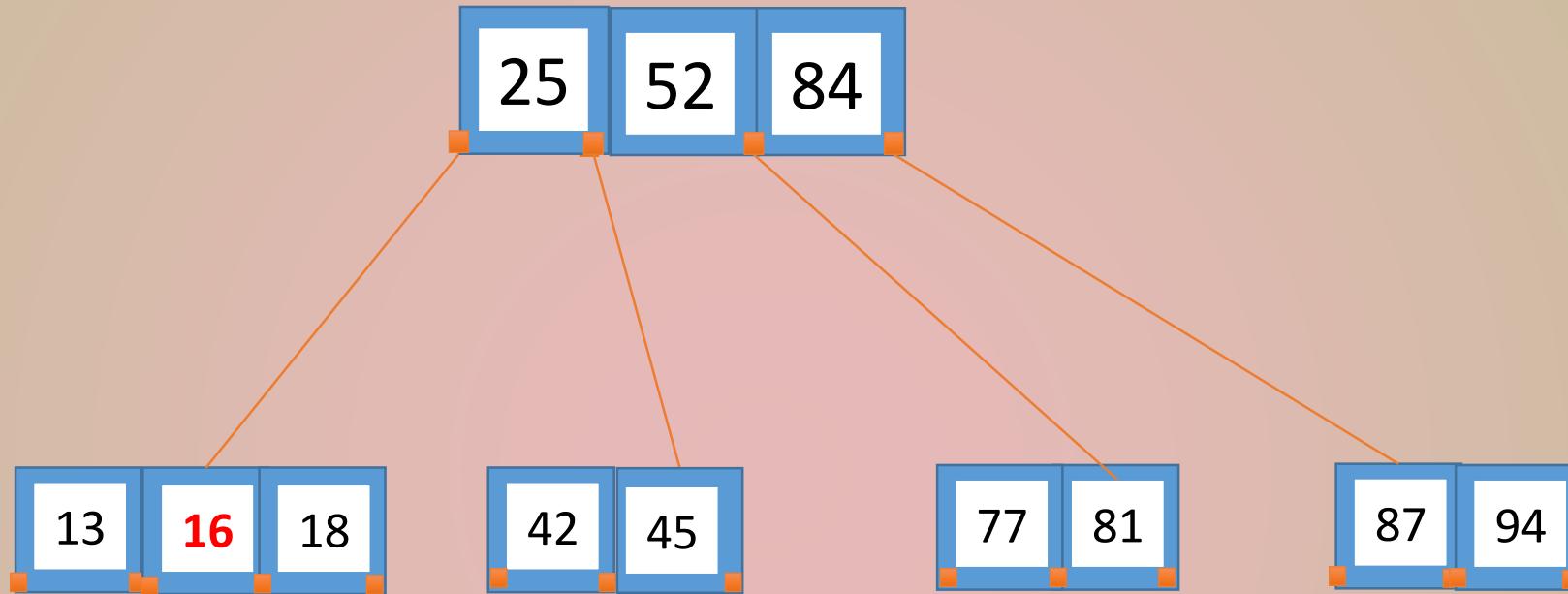


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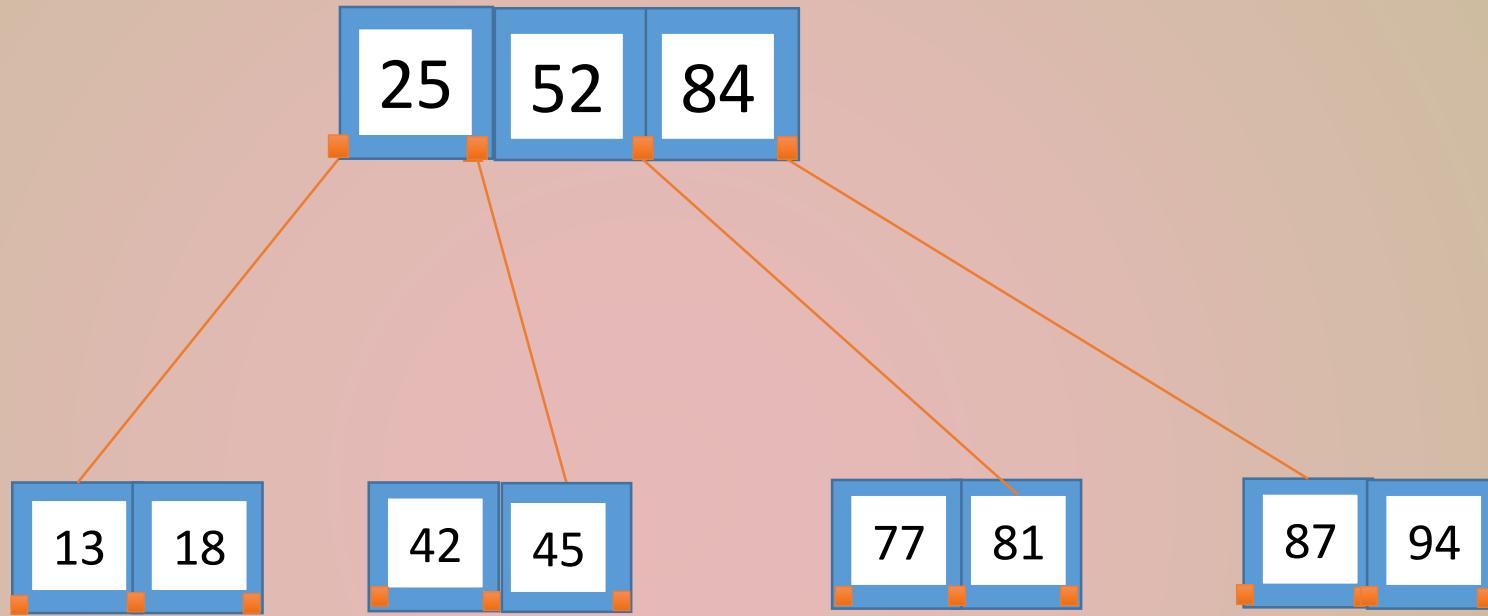


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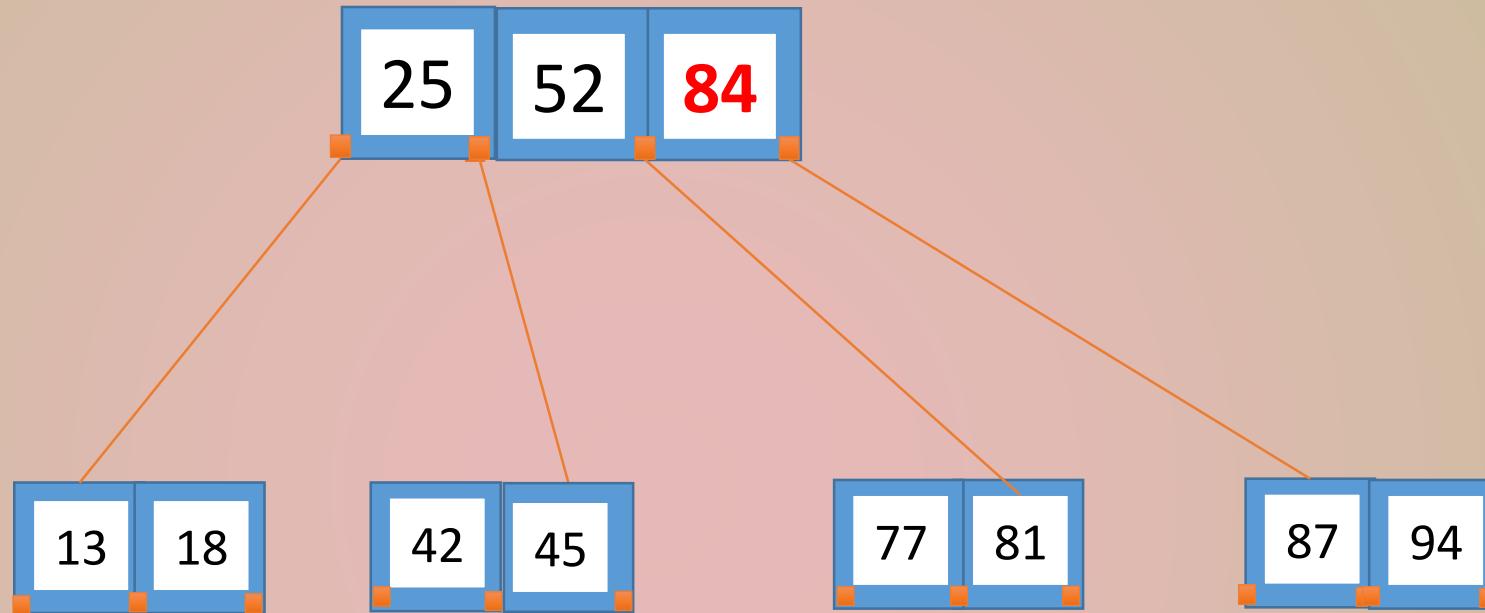


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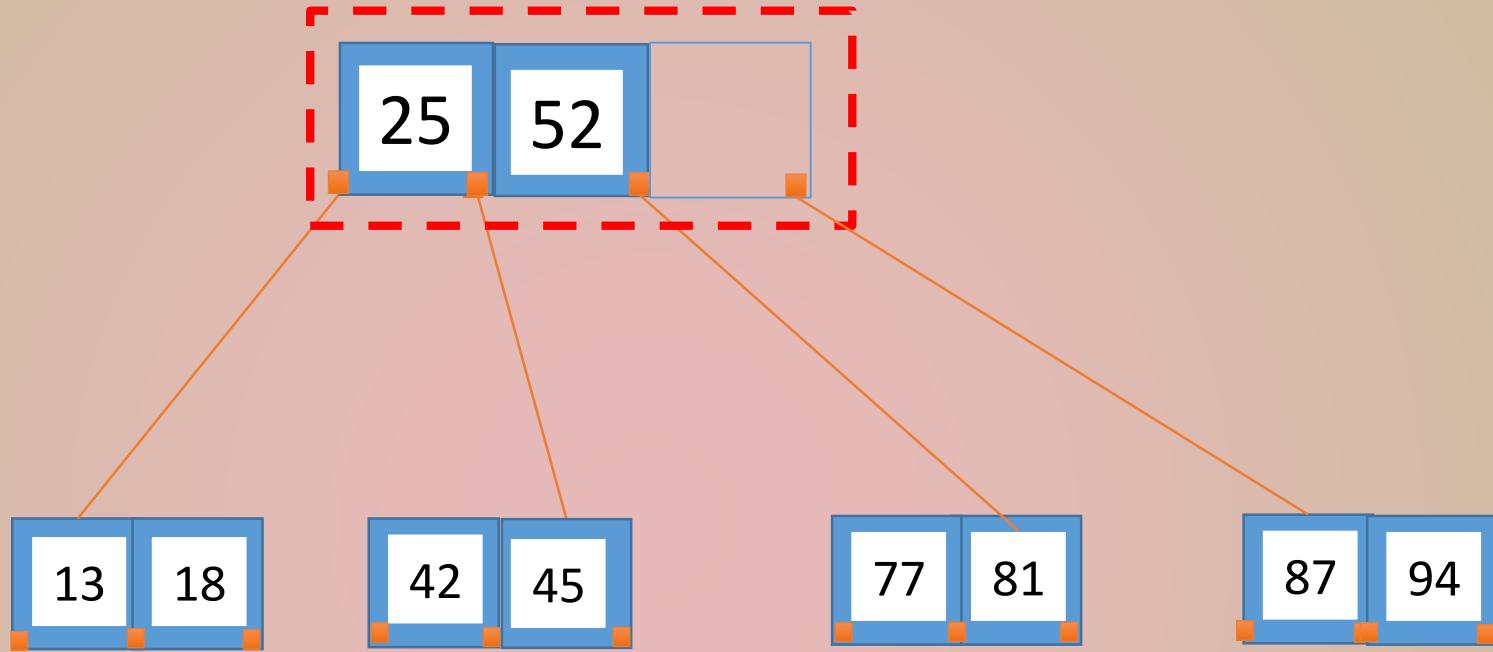


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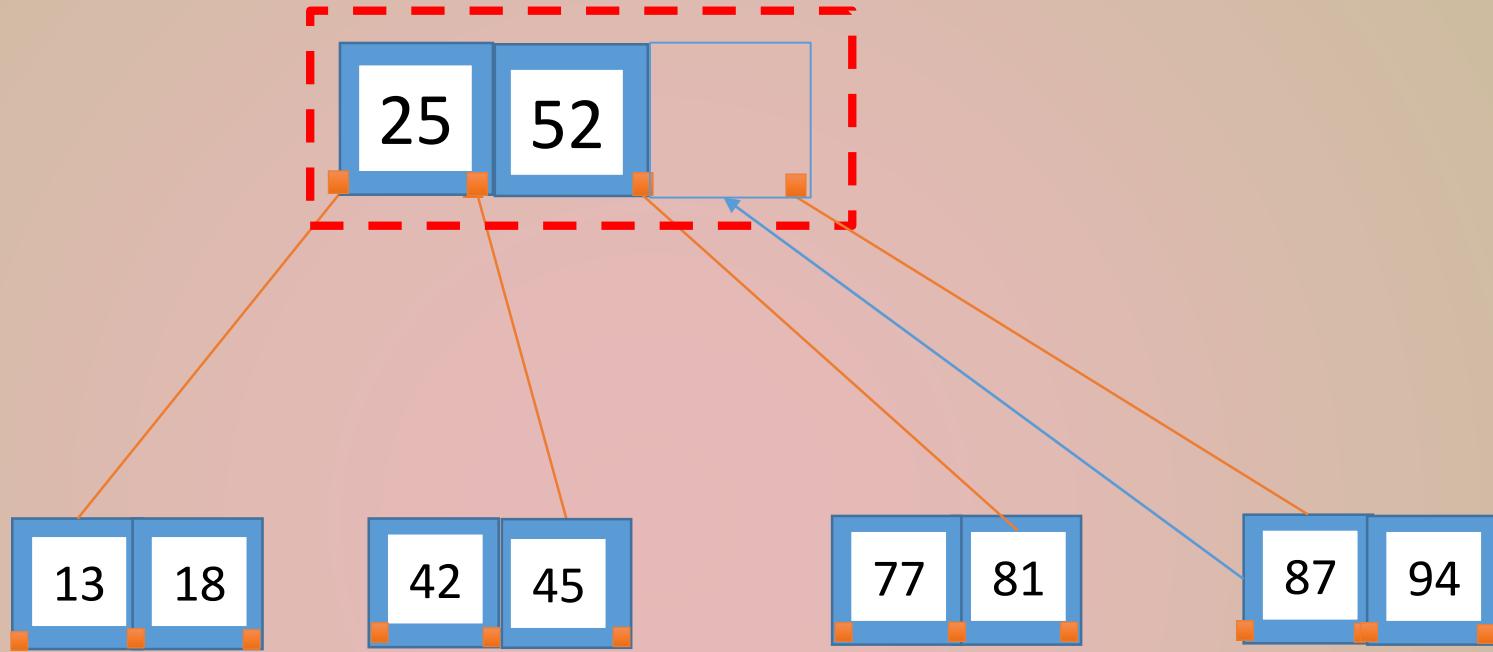
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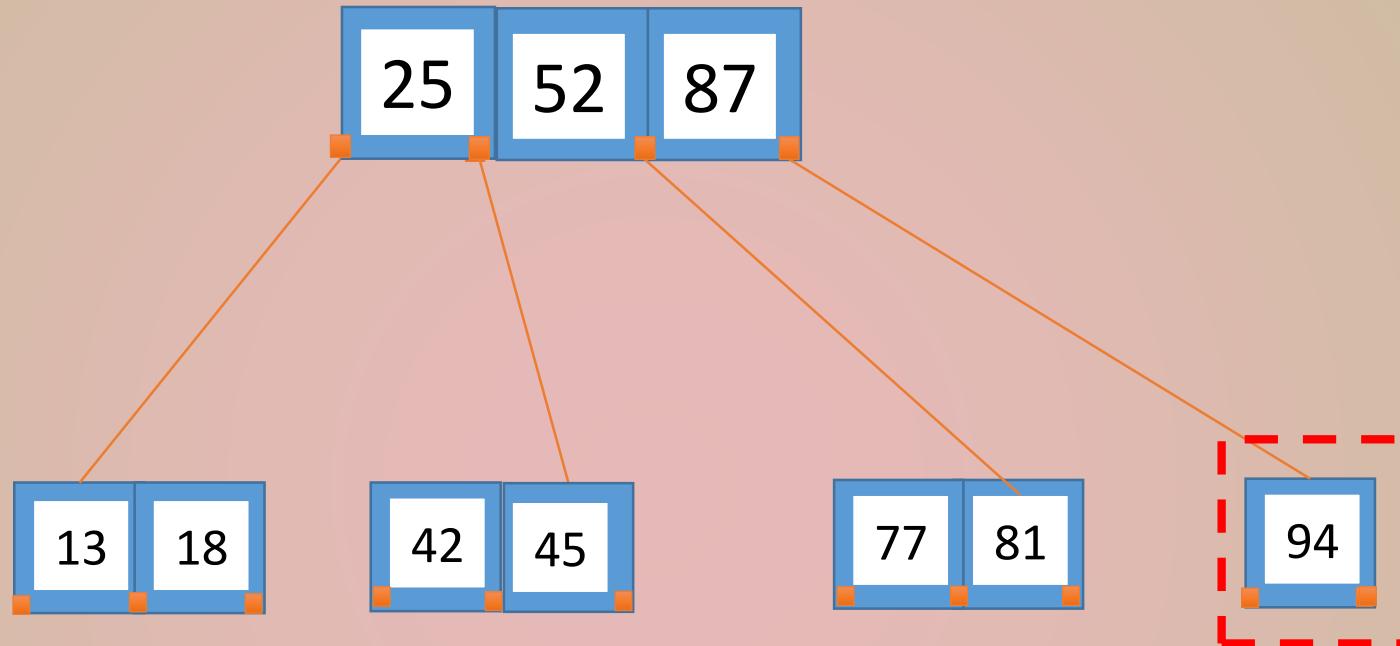


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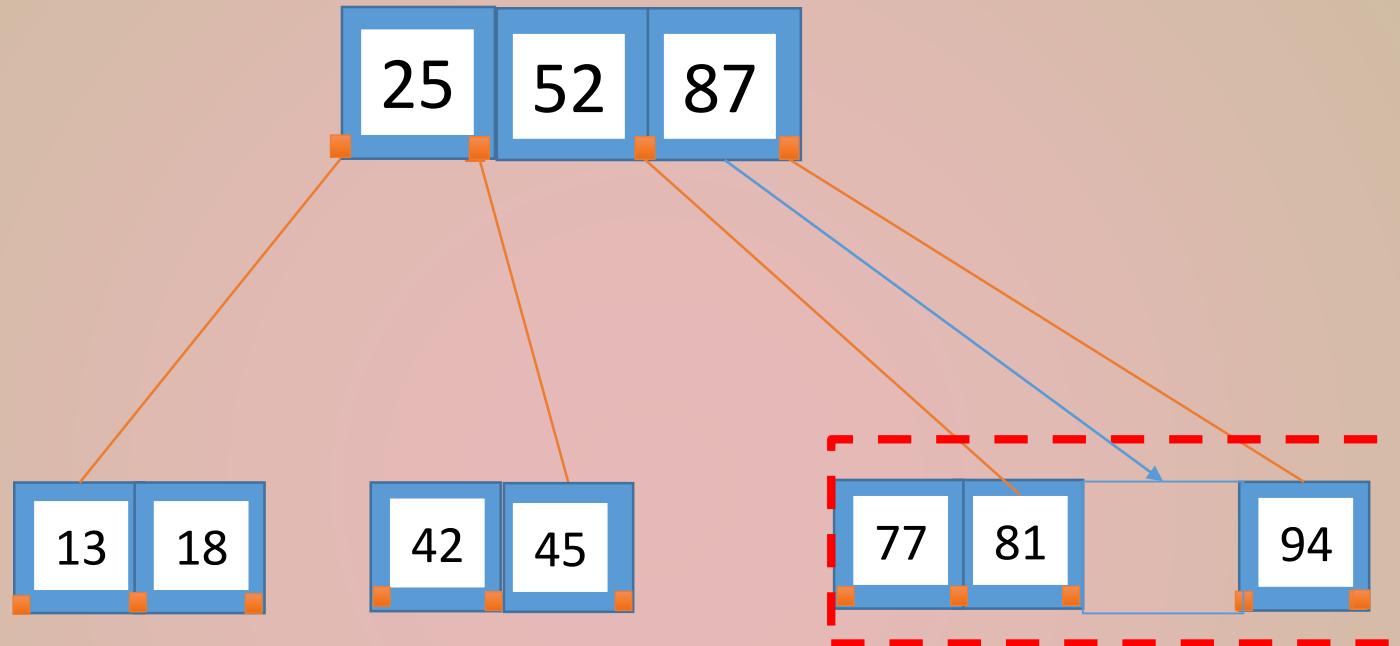
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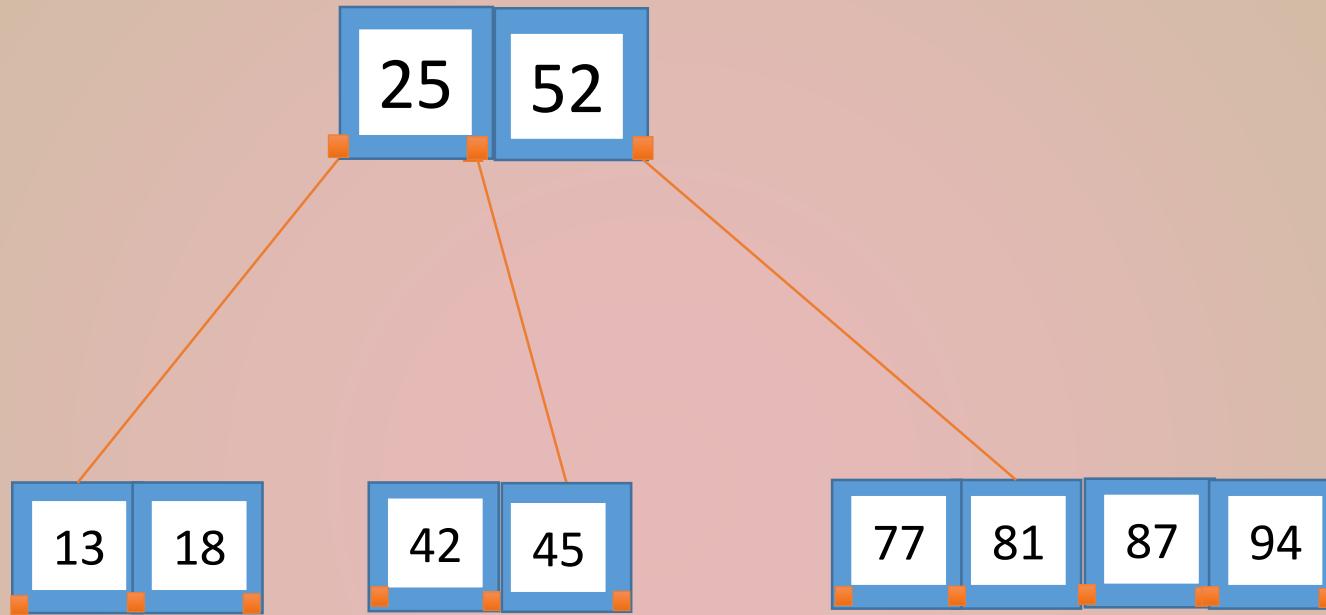


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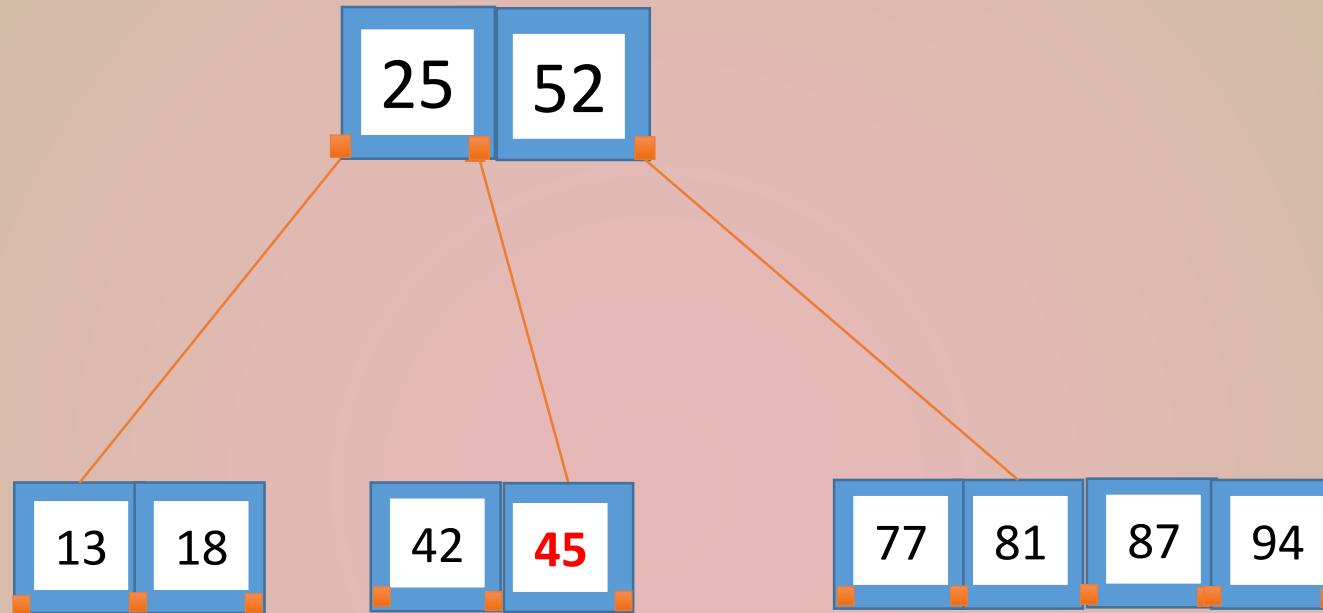


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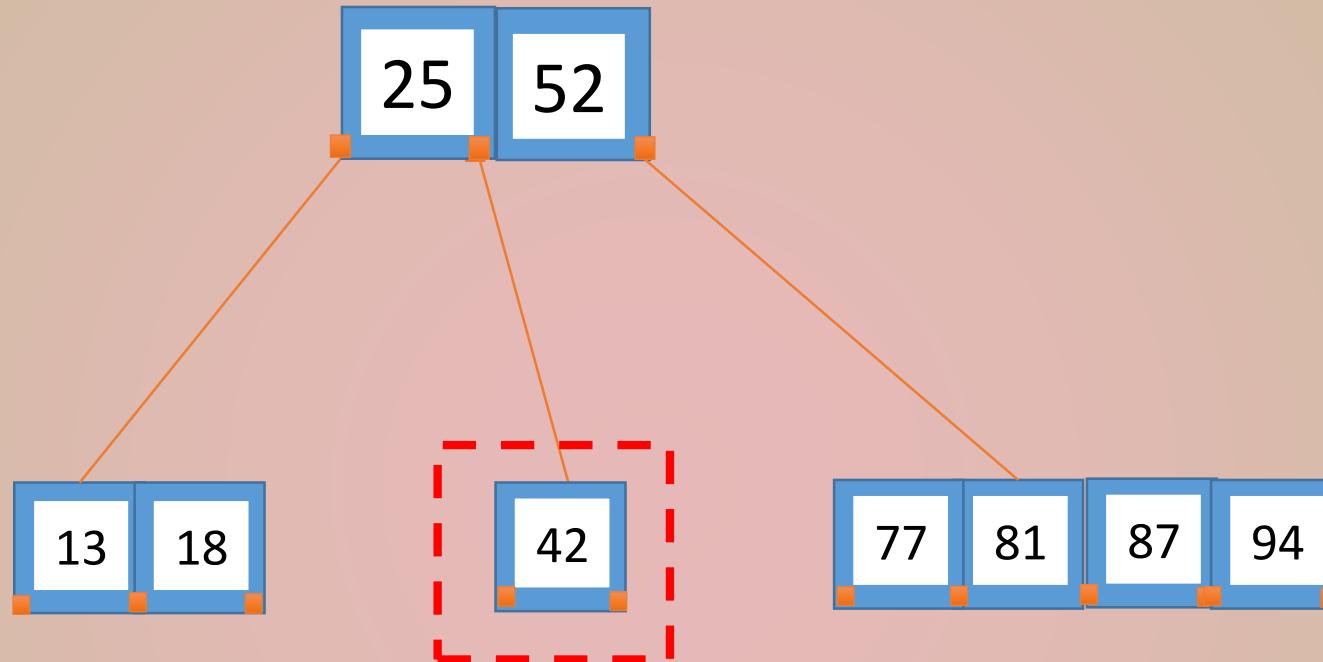
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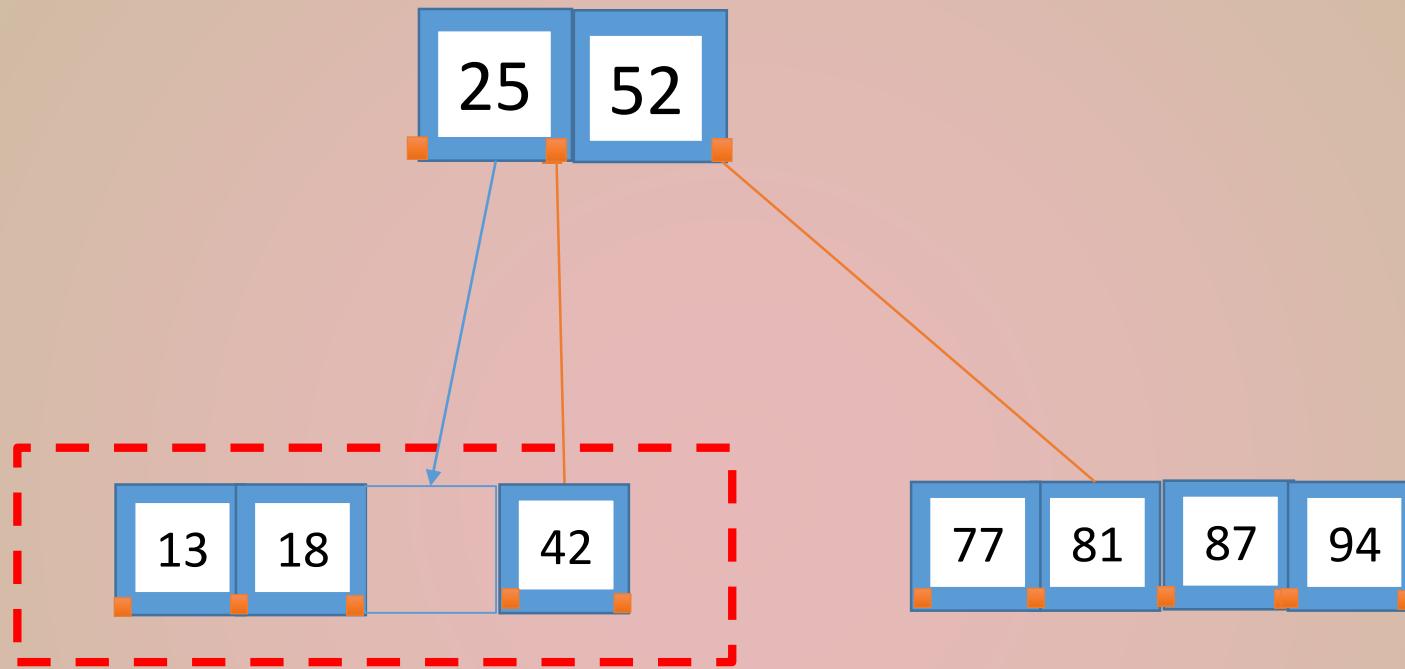
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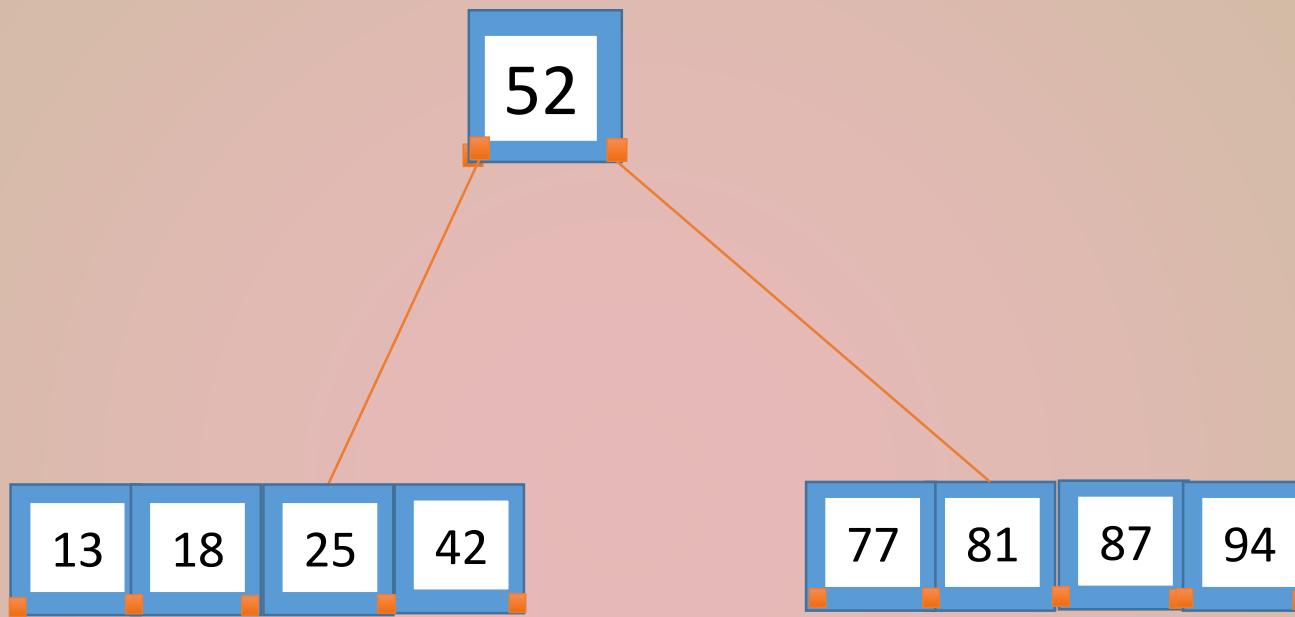


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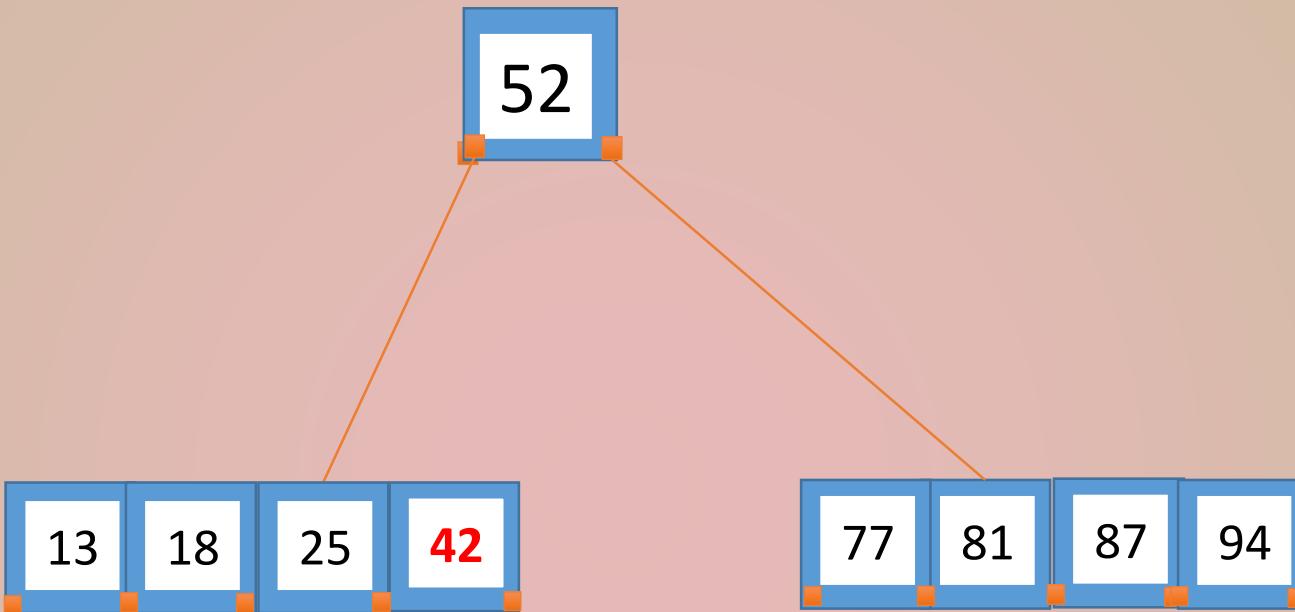


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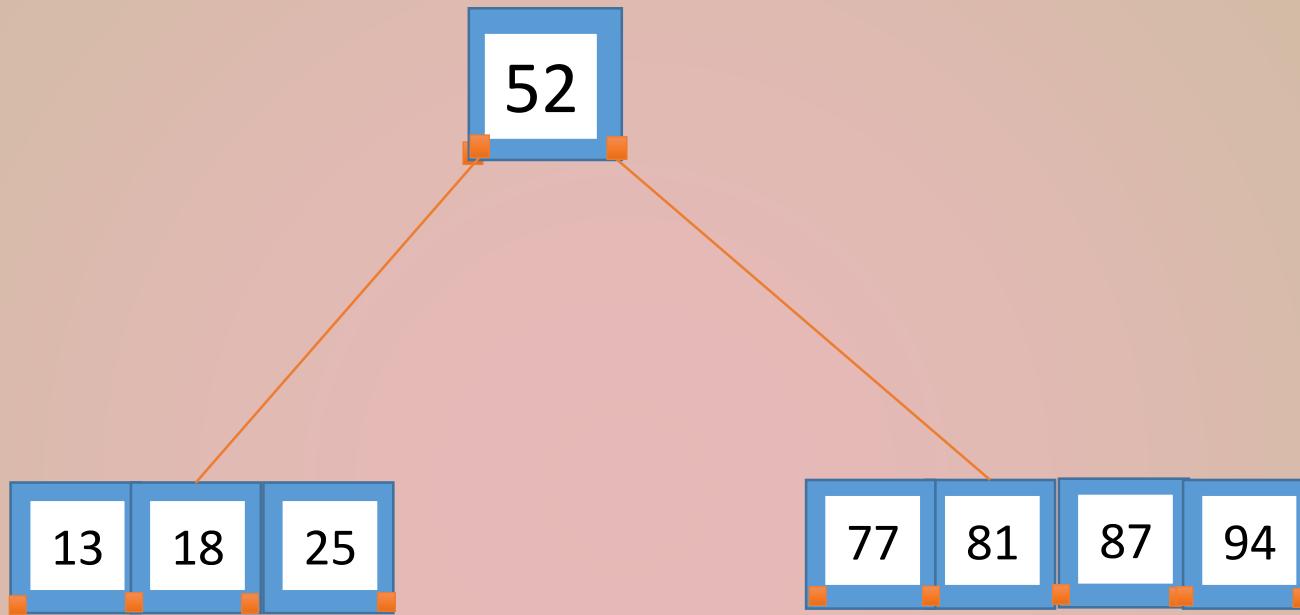


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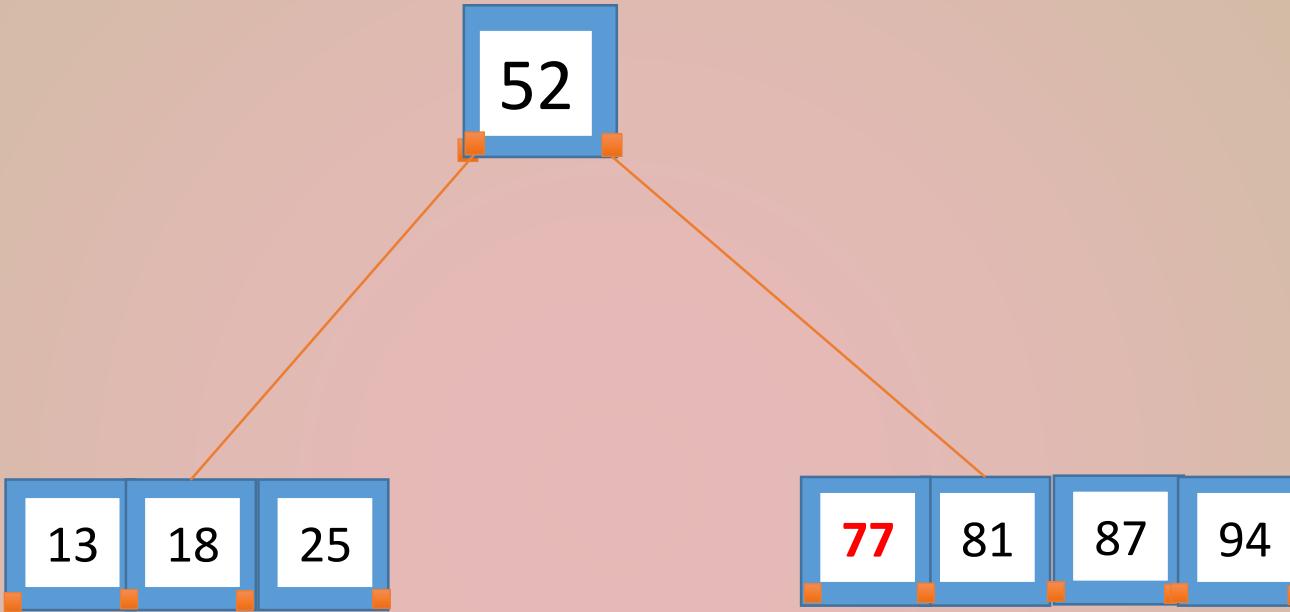


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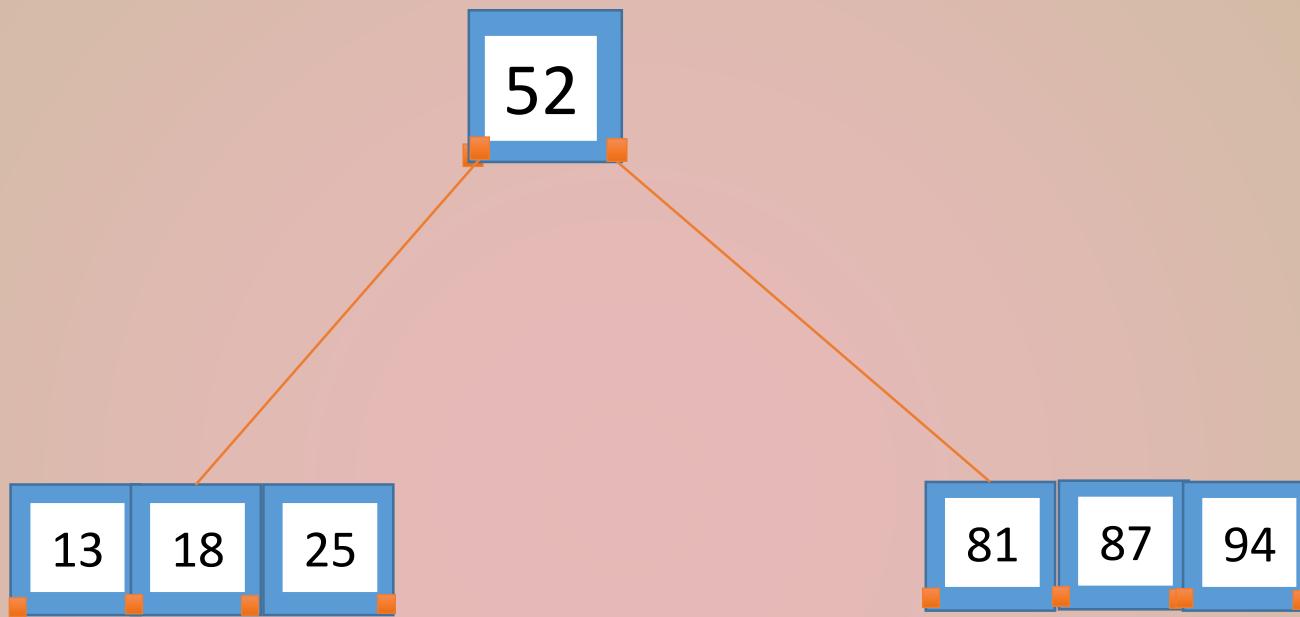


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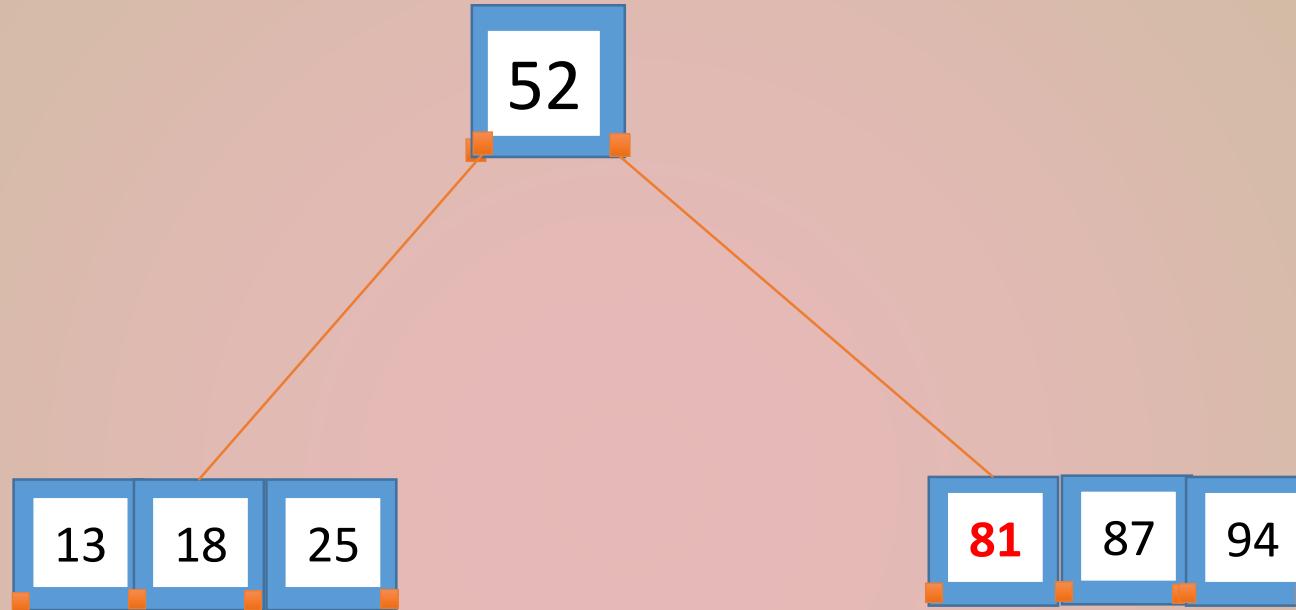


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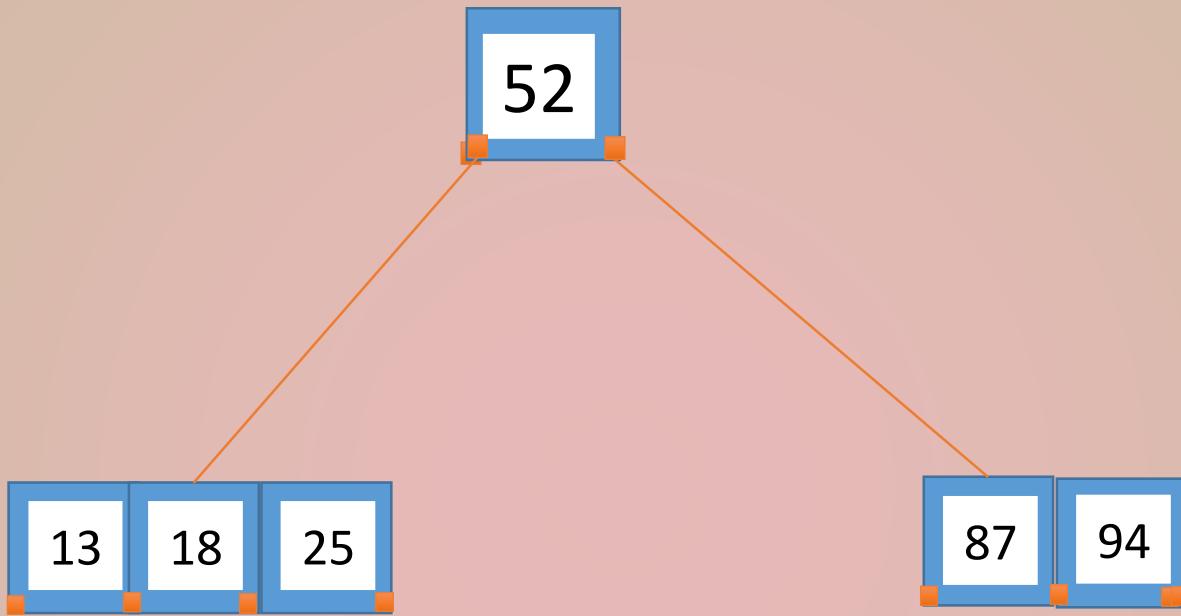


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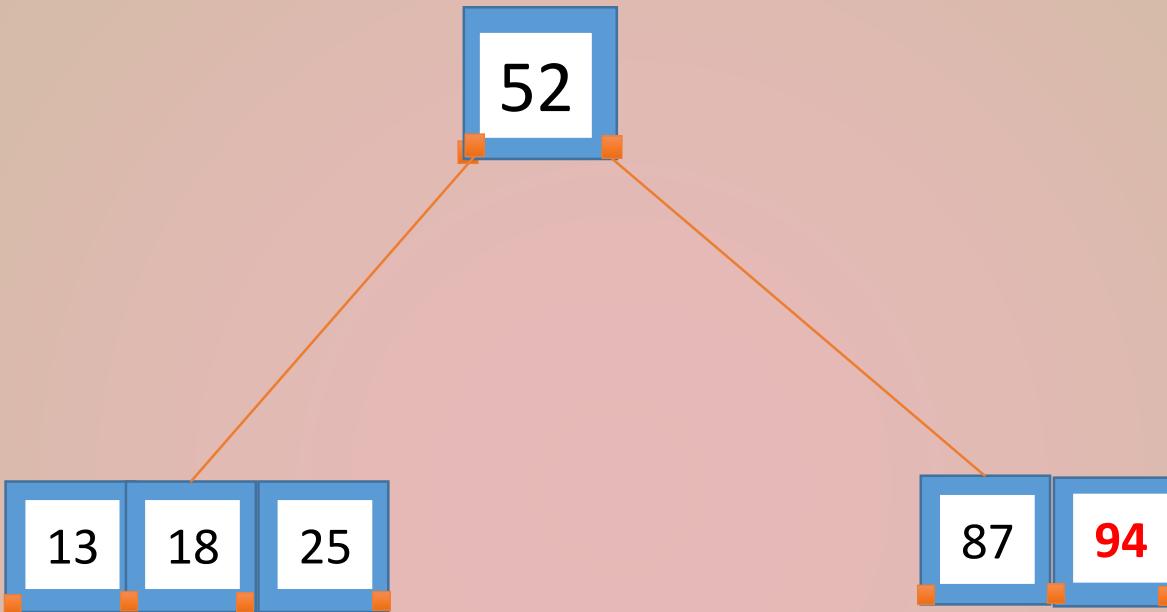


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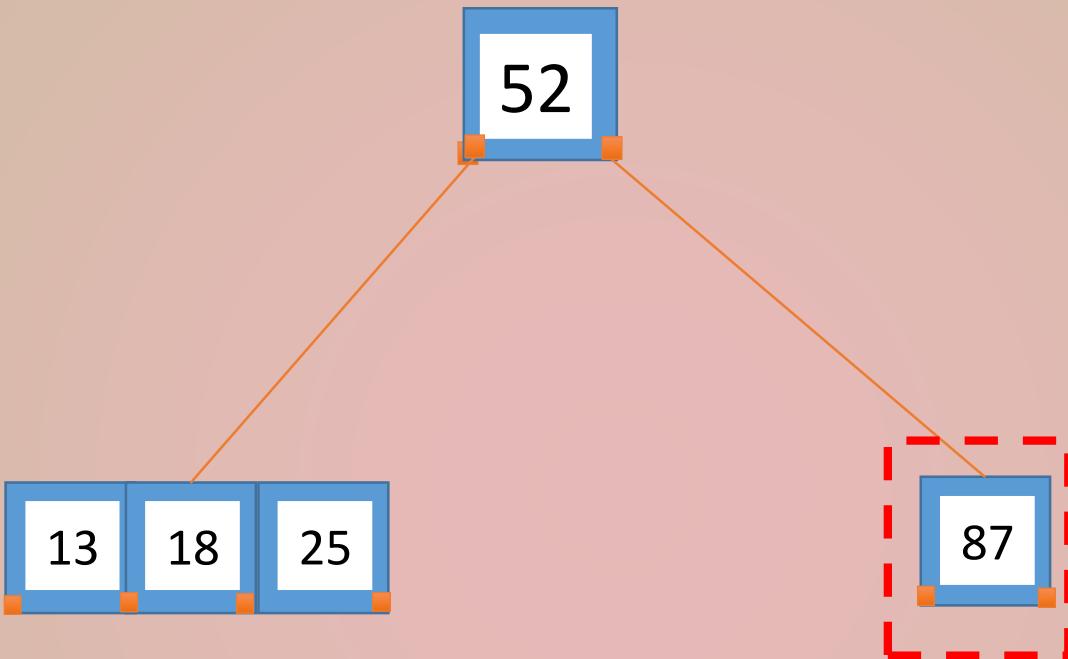
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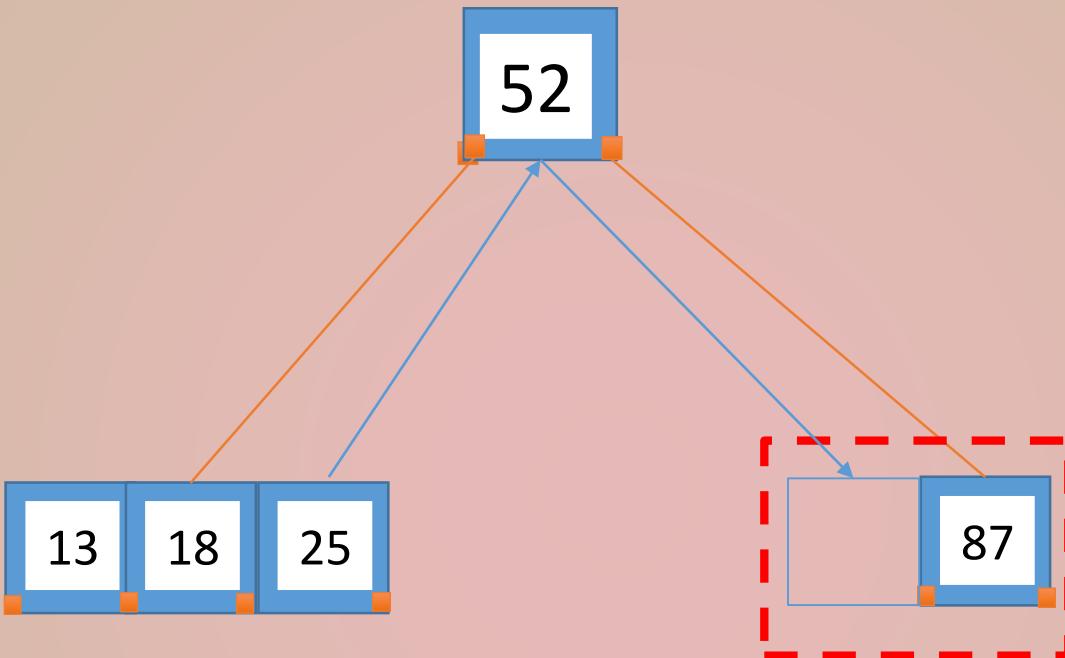
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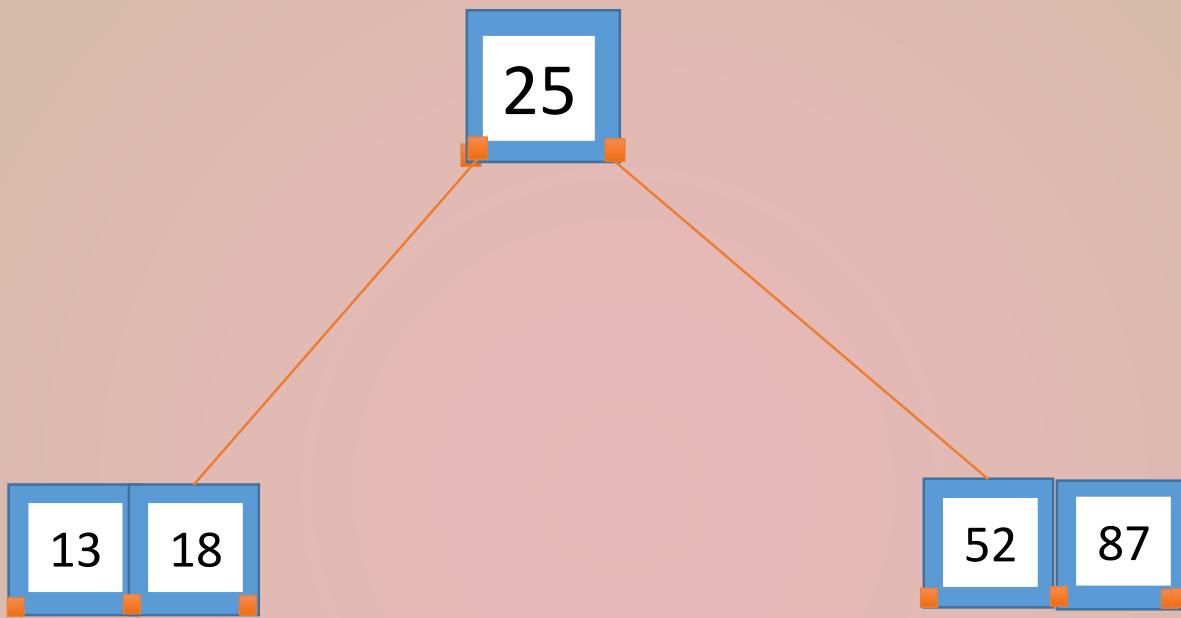


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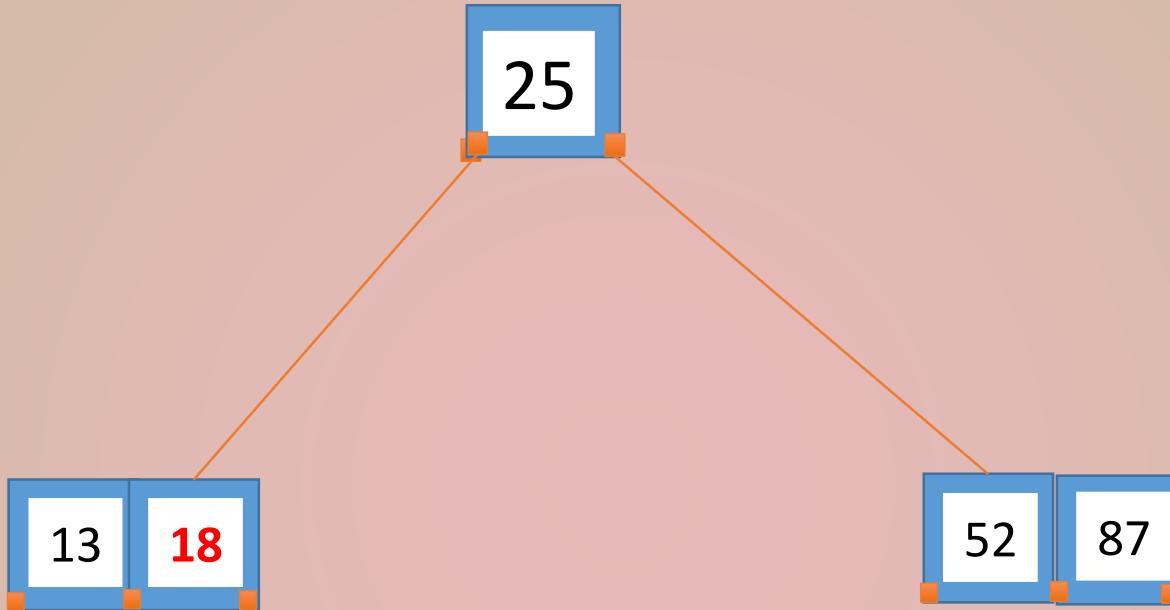


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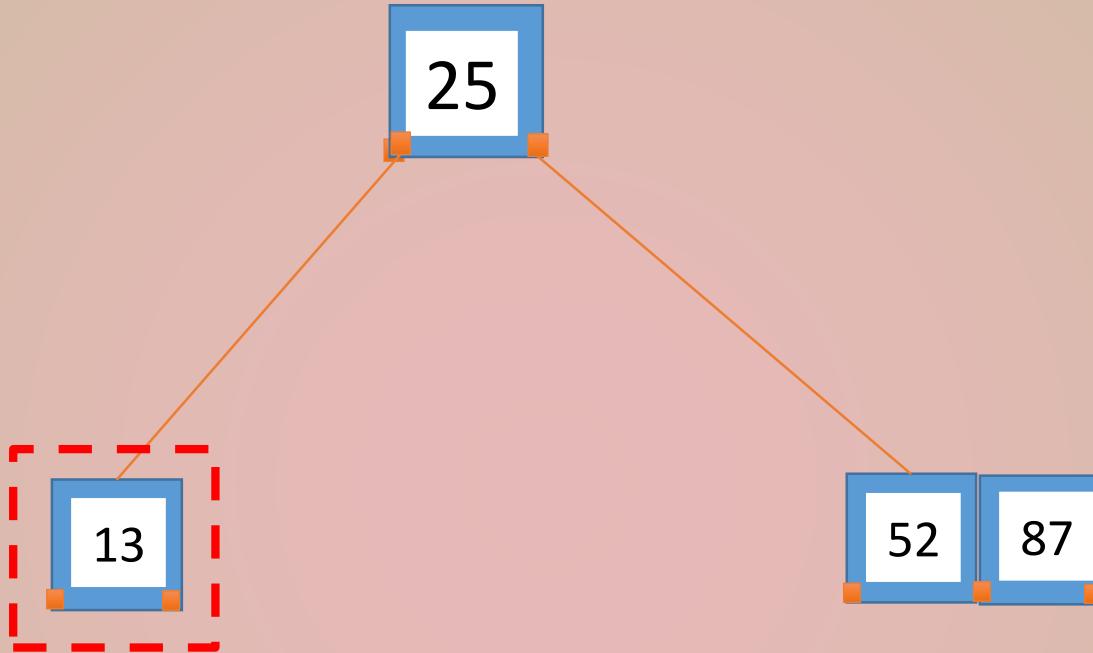
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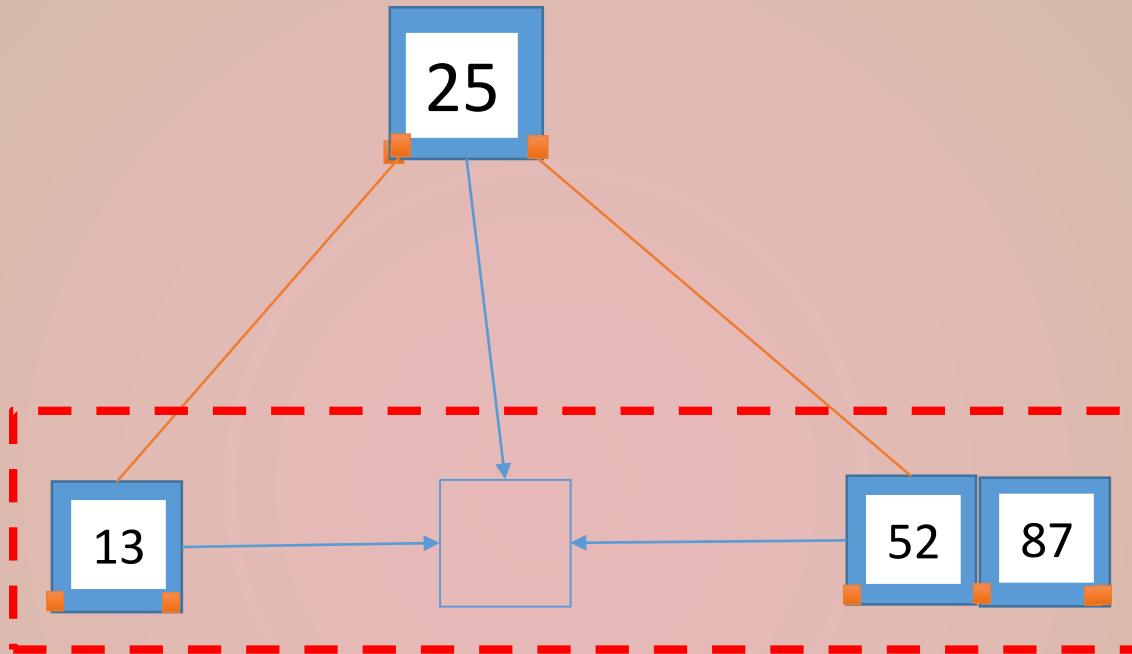
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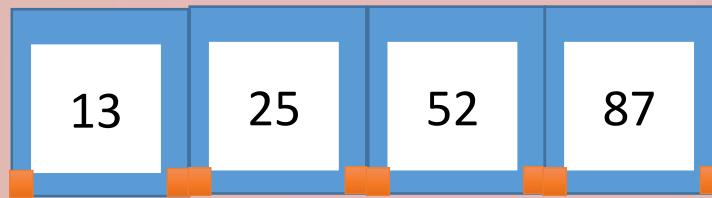


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Rebalance :



18 25 87 13 52



25 87 13 52

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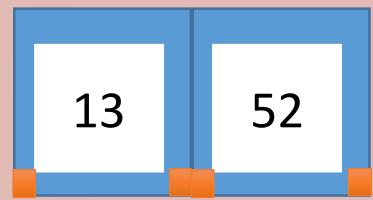


87 13 52

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87 13 52



13 52

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13 52



52

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