COMP-352 Tutorial #9

Red-Black Trees

Red-Black tree is a **self-balancing binary search tree** that balances itself through its color property denoted by an extra bit.

Rules or **Properties** of **Red-Black** trees**:**

1. **Root:** The root should be black.
2. **Leaf:** Every NULL leaf (NIL) is black.
3. **Red Nodes:** The child and parent of every red node is black.
4. **Depth:** All the leaves have the same black depth (number of black nodes).
5. **Path:** For each node, any simple path from this node to any of its descendant leaf has the same black-depth.

Attributes and Balancing Maintenance

Each node has the following attributes:

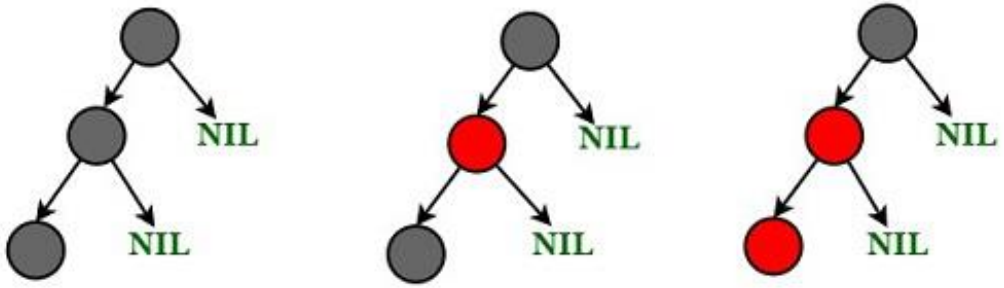
- **Color** (either red or black): *bool or int*
- **Key** or **Value**: *any type*
- **Left Child**: *Node*
- **Right Child**: *Node*
- **Parent** (except root node): *Node*

The limitations put on the node colors ensure that a simple path from the root to any leaf is not more than twice as long as any other such path. Thus the self-balancing property is maintained.

- The mechanism used is simple yet powerful.

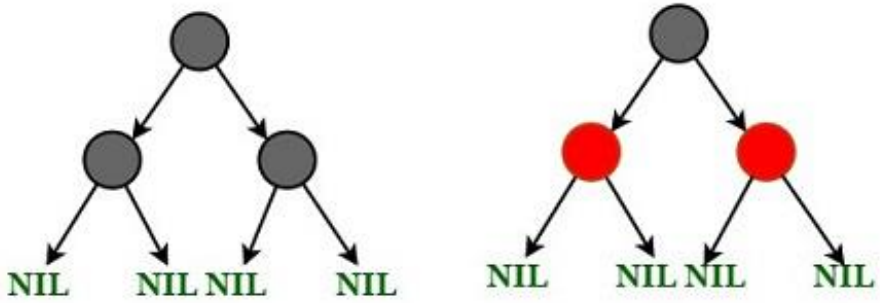
Example: Red-Black Trees

Following are NOT possible 3-noded Red-Black Trees



Violates Property 4 | Violates Property 4 | Violates Property 3

Following are possible Red-Black Trees with 3 nodes



All Possible Structure of a 3-noded Red-Black Tree

Source: https://www.geeksforgeeks.org/introduction-to-red-black-tree/

Operations on Red-Black Trees: Rotations, Transplanting, Insertion, Deletion, Traversing, Searching

Two–Three Trees

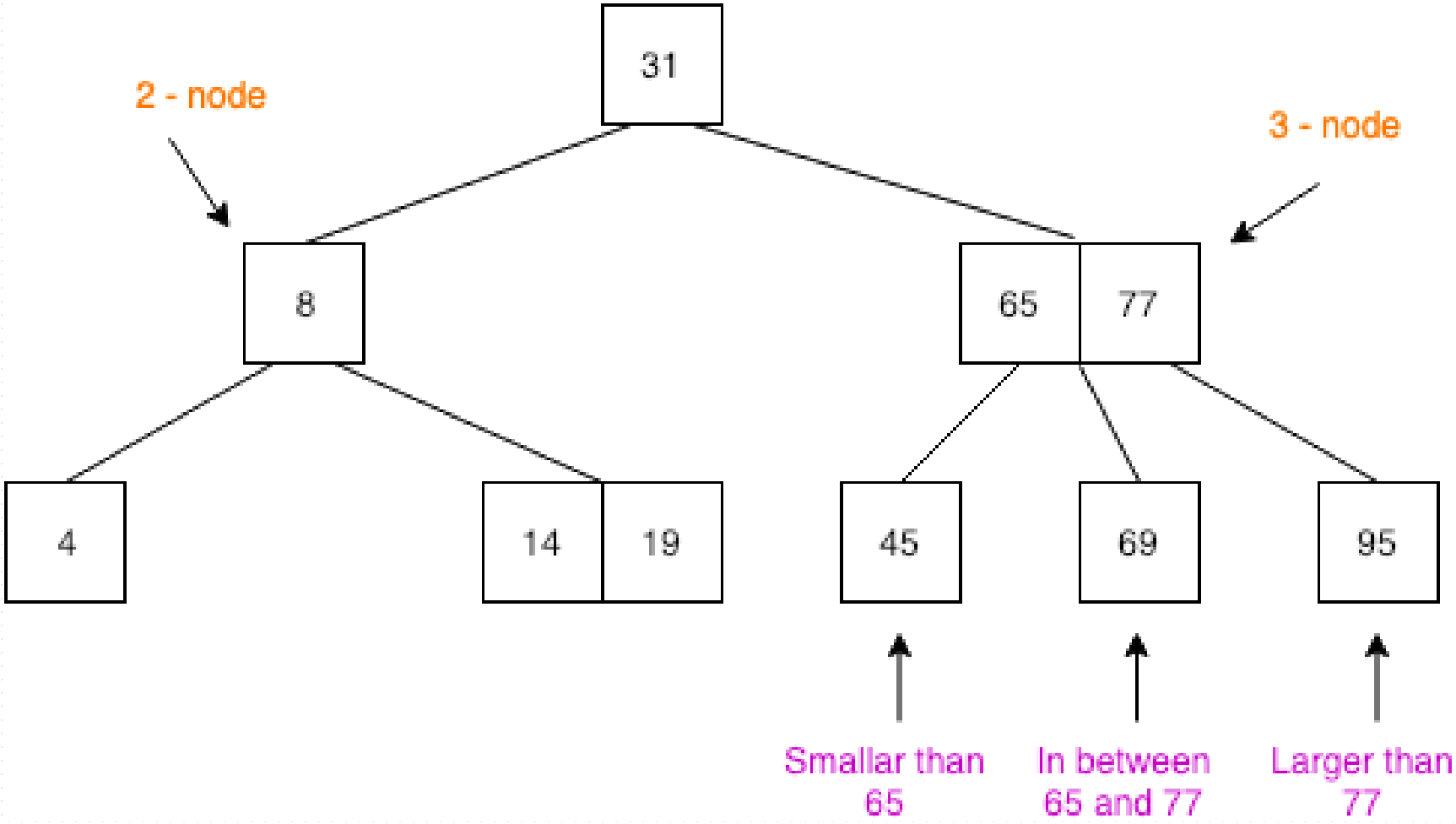
A **2-3 Tree** is a tree where a node can have 2 or 3 children nodes.

- A node with 2 children holds one key or value
- A node with 3 children holds 2 keys or values
- It follows the properties of a binary search tree
  - **For a 2-Children Node:** leftChild < Parent < RightChild
  - **For a 3-Children Node:** leftChild < min(Parent) < middleChild < max(Parent) < rightChild

A 2-3 tree maintains the following 2 properties:

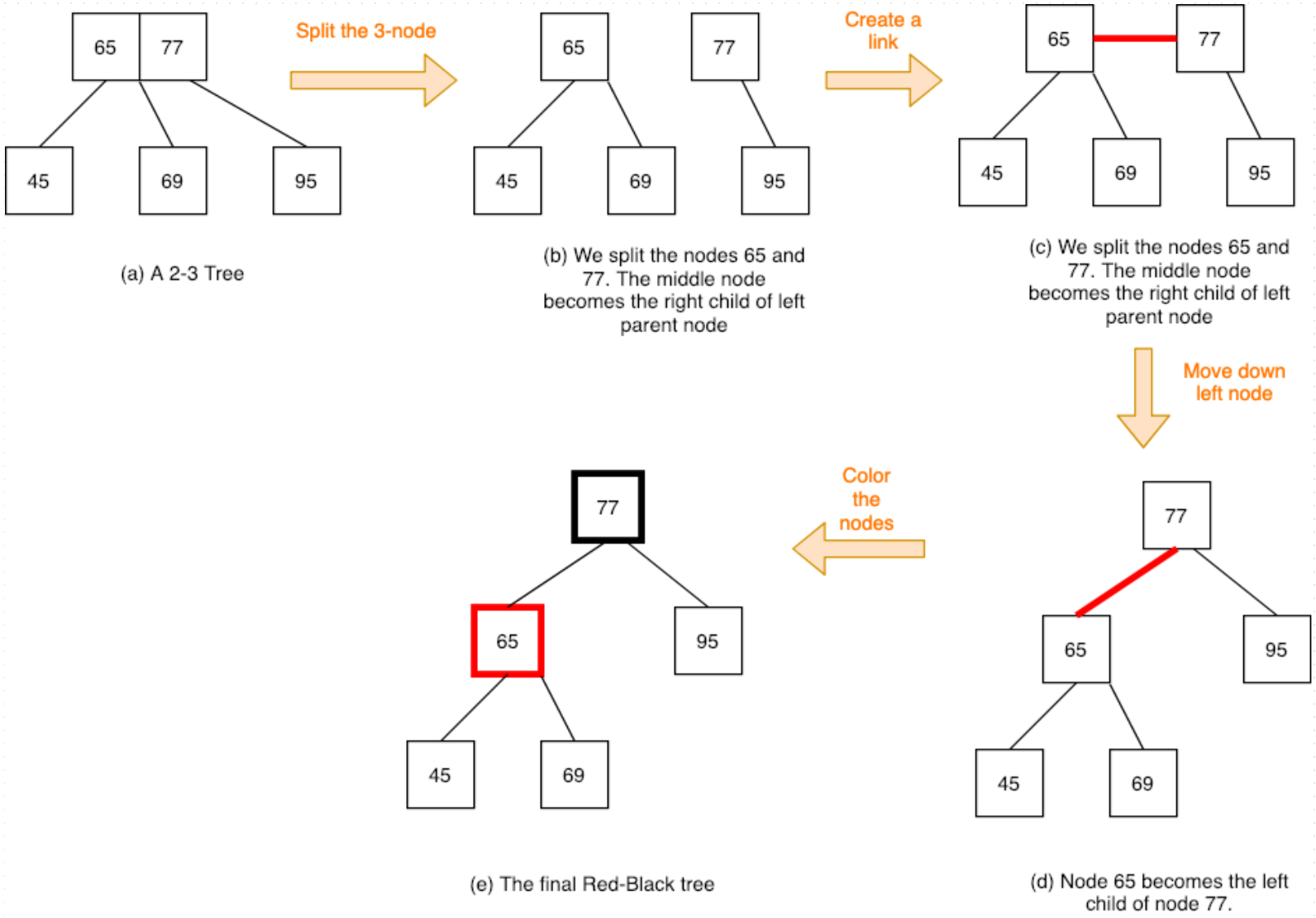
- **Perfect balance**: Every path from the root to the leaf node has the same length.
- **Symmetric order**: In-order traversal yields keys in ascending order (just like a binary search tree).

Example: Two–Three Tree



Source: https://algorithmtutor.com/Data-Structures/Tree/2-3-Trees/

Converting Red-Black Tree to 2-3 Tree



Source: https://algorithmtutor.com/Data-Structures/Tree/2-3-Trees/

EXERCISE

Red-Black Tree Search(): Implement a function that searches for a given value through a given red-black tree.

- Use the R-B Tree implementation from the GitHub Rep

THANK YOU