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CSE-461

1. We have discussed in the class the implementation of the readers-writers problem in Java. However, the read and write tasks of the **reader** thread and the **writer** thread are not given. Implement these tasks in Java as reading and writing of a file named *counter.txt*, which contains an integer counter.

A **reader** thread

- reads the counter from the file, and
- prints out its thread name and the value of the counter.

A **writer** thread

- increments the value of the counter in the file,
- prints out its thread name and the new value of the counter.

Each thread repeats its task indefinitely in a random amount of time between 0 and 3000 ms. Your **main** program should create 20 **reader** threads and 3 **writer** threads.

Source Code:
readerwriter.java

```
import java.io.File;
import java.io.FileInputStream;
import java.io.FileWriter;
import java.io.IOException;
import java.util.Random;
import java.util.Scanner;
import java.util.concurrent.locks.Condition;
import java.util.concurrent.locks.Lock;
import java.util.concurrent.locks.ReentrantLock;

public class readerwriter {
    final Lock mutex = new ReentrantLock();
    final Condition readerQueue = mutex.newCondition();
    final Condition writerQueue = mutex.newCondition();
    int nReaders = 0; // number of reader threads
    int nWriters = 0; // number of writer threads (0 or 1)
    String file = "counter.txt";
    public static Random rand = new Random();

    public void init()
    {
        FileWriter f;
        try
        {
            f = new FileWriter(new File(file)); f.write(new Integer(0).toString());
            f.close();
        }
        catch (IOException e)
        {
            e.printStackTrace();
        }
    }

    void reader() throws InterruptedException {
        mutex.lock(); // MUTUAL EXCLUSION

        while (!(nWriters == 0)) {
            readerQueue.await();
```

```
            // WAIT IN THE READER QUEUE UNTIL WRITERS BECOME ZERO
        }

        nReaders++; // ONE MORE READER

        if (--nReaders == 0) {
            writerQueue.signal(); // WAKE UP A WRITING THREAD
        }
        mutex.unlock();
    }
    void writer() throws InterruptedException {
        mutex.lock();

        while (!((nReaders == 0) && (nWriters == 0)))
        {
            writerQueue.await(); // WAIT IN WRITER QUEUE
        } // until no more writer & readers nWriters++; //one writer
        // ONLY ONE WRITER AT A TIME
        writerQueue.signal(); // wake up a waiting writer
        // readerQueue.signalAll(); //wake up all
        // waiting readers mutex.unlock();
    }
    void readToFile(String path) {
        try {
            Scanner reader = new Scanner(new FileInputStream(path));
            int x = reader.nextInt();
            System.out.printf(" Counter: %d\n", x);
        }
        catch (IOException ex) {
            ex.printStackTrace();
        }
    }
    void writeToFile(String path) {
        int counterToWrite;
        try {
            Scanner reader = new Scanner(new FileInputStream(path));
            counterToWrite = (int) reader.nextInt();
            counterToWrite++;
            FileWriter f = new FileWriter(new File(path));
            f.write(new Integer(counterToWrite).toString());
            f.close();
            System.out.printf("WRITER: " + Thread.currentThread().getName() + "
Writing... ");
            System.out.printf(" Counter: %d\n", counterToWrite);
        } catch (IOException ex) {
            ex.printStackTrace();
        }
    }
}
```

Main.java

```
import java.util.Random;

public class main {
    public final static int NUMBER_READ_THREAD = 20;
    public final static int NUMBER_WRITE_THREAD = 3;
    public static readerwriter readerWriterClass = new readerwriter();
    public static Random rand = new Random();
    static class readerThread extends Thread {
    @Override
    public void run() {
        System.out.print("Reader " + getName() + ":Started\n");
```

```
        while (true) {
            try {
                    readerWriterClass.reader();
                    Thread.sleep(rand.nextInt(3000));
                } catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        }
    }
    static class writerThread extends Thread {
        @Override
        public void run() {
            System.out.print("Writer " + getName() + ": Started\n");
                while (true) {
                try {
                readerWriterClass.writer();
                Thread.sleep(rand.nextInt(3000));
                } catch (InterruptedException ex) {
                ex.printStackTrace();
                }
            }
        }
    }
    public static void main(String[] args) {
            readerWriterClass.init(); readerThread readerThreads[] = new
readerThread[NUMBER_READ_THREAD];
            writerThread writerThreads[] = new writerThread[NUMBER_WRITE_THREAD];
            System.out.print("Create/start the thread\n");
            for (int i = 0; i < NUMBER_WRITE_THREAD; ++i) {
                writerThreads[i] = new writerThread();
                writerThreads[i].start();
            } for (int i = 0; i < NUMBER_READ_THREAD; ++i) {
                readerThreads[i] = new readerThread();
                readerThreads[i].start();
        }
    }
}
```

Output:

Create/start the thread

Writer Thread-0: Started
Writer Thread-1: Started
Writer Thread-2: Started
Reader Thread-3:Started
Reader Thread-4:Started
Reader Thread-5:Started
Reader Thread-6:Started
Reader Thread-7:Started
Reader Thread-8:Started
Reader Thread-9:Started
Reader Thread-10:Started
Reader Thread-11:Started
Reader Thread-12:Started
Reader Thread-13:Started
Reader Thread-14:Started
Reader Thread-15:Started

Reader Thread-16:Started
Reader Thread-17:Started
Reader Thread-18:Started
Reader Thread-19:Started
Reader Thread-20:Started
Reader Thread-21:Started
Reader Thread-22:Started

2. We discussed in class the readers-writers problem with **writers priority**, which can be solved in guarded commands:

Source Code:

Readerwriterpriority.java

```
import java.io.File;
import java.io.FileInputStream;
import java.io.FileWriter;
import java.io.IOException;
import java.util.Random;
import java.util.Scanner;
import java.util.concurrent.locks.Condition;
import java.util.concurrent.locks.Lock;
import java.util.concurrent.locks.ReentrantLock;

public class readerwriterpriority {
    final Lock mutex = new ReentrantLock();
    final Condition readerQueue = mutex.newCondition(); // CONDITION VARIABLE
    final Condition writerQueue = mutex.newCondition(); // CONDITION //VARIABLE
    int nReaders = 0; // NUMBER OF READER THREADS
    int nWriters = 0; // NUMBER OF WRITER THREADS 0 OR 1
    int nActiveWriters = 0;
    // NUMBER OF THREADS CURRENTLY WRITING
    String file = "counter.txt";
    public static Random rand = new Random();
    public void init() {
        FileWriter f;
        try {
            f = new FileWriter(new File(file)); f.write(new Integer(0).toString());
f.close();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }

    void reader() throws InterruptedException {
        mutex.lock(); // MUTUAL EXCLUSION
        while (!(nWriters == 0)) {
            readerQueue.await();
            // WAIT IN THE READER QUEUE UNTIL WRITERS BECOME ZERO
        }
        nReaders++; // ONE MORE READER

        mutex.unlock();
        readToFile(file);

        mutex.lock();
        if (--nReaders == 0) {
            writerQueue.signal(); // WAKE UP A WRITING THREAD
        }
        mutex.unlock();
```

```
    }

    void writer() throws InterruptedException {
        mutex.lock();
        nWriters++; // WRITER ARRIVED
        while (!((nReaders == 0) && (nActiveWriters == 0)))
        // IF THERE ARE ANY ACTIVE READERS OR WRITERS
        {
            writerQueue.await(); // WAIT IN WRITER QUEUE
        }
        // UNTIL NO MORE READERS OR WRITERS
        nActiveWriters++; // ONE ACTIVE WRITER
        mutex.unlock();
        writeToFile(file);
        mutex.lock();
        // MUTUAL EXCLUSION NEEDED
         nActiveWriters--;
        // ONLY ONE WRITER AT A TIME
        if (--nWriters == 0)
        // NO MORE WAITING WRITERS
        {
            readerQueue.signalAll();
        } else // HAVING WAITING WRITER
        {
            writerQueue.signal(); // WAKE UP ONE WAITING WRITER
        }
        mutex.unlock();
    }
    public void readToFile(String path) {
        try {
            Scanner reader = new Scanner(new FileInputStream(path));
            int x = reader.nextInt();
            System.out.printf("Reader: " + Thread.currentThread().getName() + "
Reading...");
            System.out.printf(" Counter: %d\n", x);
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
    public void writeToFile(String path) {
        int counterToWrite;
        try {
            Scanner reader = new Scanner(new FileInputStream(path));
            counterToWrite = (int) reader.nextInt();
            counterToWrite++;
            FileWriter f = new FileWriter(new File(path));
            f.write(new Integer(counterToWrite).toString());
            f.close();
            System.out.printf("WRITER: " + Thread.currentThread().getName() + "
Writing... ");
            System.out.printf(" Counter: %d\n", counterToWrite);
        } catch (IOException e) {
            e.printStackTrace();
        }
    }

    void readerQueue() {
        throw new UnsupportedOperationException("Not supported yet."); //To change body
of generated methods, choose Tools | Templates.
    }
}
```

Main.java

```
import java.util.Random;

public class main {
public final static int NUMBER_READ_THREAD = 1;
public final static int NUMBER_WRITE_THREAD = 1;
public static readerwriterpriority readerWriterClass = new readerwriterpriority();
public static Random rand = new Random();

static class readerThread extends Thread {
        public void run() {
        System.out.print("Reader " + getName() + ": Started\n");
        while (true) {
            try {
                readerWriterClass.reader();
                int time = rand.nextInt(3000);
                Thread.sleep(time);
                } catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        }
    }

    static class writerThread extends Thread {
        public void run() {
            System.out.print("Writer " + getName() + ": Started\n");
            while (true) {
                try {
                    readerWriterClass.writer();
                    int time = rand.nextInt(3000);
                    Thread.sleep(time);
                } catch (InterruptedException e) {
                    e.printStackTrace();
                }
            }
        }
    }
    public static void main(String[] args) {
        readerWriterClass.init();
        readerThread readerThreads[] = new readerThread[NUMBER_READ_THREAD];
        writerThread writerThreads[] = new writerThread[NUMBER_WRITE_THREAD];
        System.out.print("Create/start the thread\n");

        for (int i = 0; i < NUMBER_READ_THREAD; ++i) {
            readerThreads[i] = new readerThread();
            readerThreads[i].start();
        }

        for (int i = 0; i < NUMBER_WRITE_THREAD; ++i) {
            writerThreads[i] = new writerThread();
            writerThreads[i].start();
        }
    }
}
```

Output:

Writer Thread-0: Started
Writer Thread-1: Started
Reader Thread-3: Started

Writer Thread-2: Started
Reader Thread-4: Started
Reader Thread-8: Started
Reader Thread-7: Started
Reader Thread-6: Started
Reader Thread-9: Started
Reader Thread-11: Started
Reader Thread-5: Started
Reader Thread-12: Started
Reader Thread-10: Started
Reader Thread-15: Started
Reader Thread-14: Started
Reader Thread-13: Started
Reader Thread 16: Started
Reader Thread-18: Started
Reader Thread-19: Started
Reader Thread-17: Started
Reader Thread-20: Started
Reader Thread-21: Started
Reader Thread-22: Started
WRITER: Thread-0 Writing... Counter: 1
WRITER: Thread-1 Writing... Counter: 2
WRITER: Thread-2 Writing... Counter: 3
Reader: Thread-3 Reading...
Reader: Thread-5 Reading...
Reader: Thread-11 Reading...
Reader: Thread-4 Reading... Counter: 3
Reader: Thread-8 Reading... Counter: 3
Counter: 3
Reader: Thread-9 Reading... Counter: 3
Counter: 3
Counter: 3
Reader: Thread-12 Reading... Counter: 3
Reader: Thread-6 Reading... Counter: 3
Reader: Thread-19 Reading... Counter: 3
Reader: Thread-10 Reading...
Reader: Thread-15 Reading...
Reader: Thread-7 Reading... Counter: 3
Counter: 3
Reader: Thread-22 Reading... Counter: 3
Reader: Thread-13 Reading... Counter: 3

Reader: Thread-16 Reading... Counter: 3
Reader: Thread-20 Reading... Counter: 3
Reader: Thread-14 Reading... Counter: 3
Reader: Thread-17 Reading... Counter: 3
Reader: Thread-18 Reading... Counter: 3
Reader: Thread-21 Reading... Counter: 3
Counter: 3
Reader: Thread-18 Reading... Counter: 3
WRITER: Thread-2 Writing... Counter: 4
Reader: Thread-8 Reading... Counter: 4
Reader: Thread-21 Reading... Counter: 4
Reader: Thread-15 Reading... Counter: 4
Reader: Thread-20 Reading... Counter: 4
Reader: Thread-6 Reading... Counter: 4
Reader: Thread-22 Reading... Counter: 4
Reader: Thread-11 Reading... Counter: 4
Reader: Thread-6 Reading... Counter: 4
Reader: Thread-8 Reading... Counter: 4
WRITER: Thread-0 Writing... Counter: 5
Reader: Thread-9 Reading... Counter: 5
Reader: Thread-3 Reading... Counter: 5
Reader: Thread-7 Reading... Counter: 5
Reader: Thread-21 Reading... Counter: 5
Reader: Thread-21 Reading... Counter: 5
WRITER: Thread-0 Writing... Counter: 6
Reader: Thread 5 Reading... Counter: 6
WRITER: Thread-1 Writing... Counter: 7
Reader: Thread-16 Reading... Counter: 7
Reader: Thread-12 Reading... Counter: 7
Reader: Thread-22 Reading... Counter: 7
WRITER: Thread-2 Writing... Counter: 8
Reader: Thread-5 Reading... Counter: 8
WRITER: Thread-1 Writing... Counter: 9
Reader: Thread-18 Reading... Counter: 9
Reader: Thread-18 Reading... Counter: 9
Reader: Thread-19 Reading... Counter: 9
Reader: Thread-4 Reading... Counter: 9
Reader: Thread-10 Reading... Counter: 9
Reader: Thread-11 Reading... Counter: 9
Reader: Thread-5 Reading... Counter: 9
Reader: Thread-17 Reading... Counter: 9
Reader: Thread-15 Reading... Counter: 9
Reader: Thread-3 Reading... Counter: 9
Reader: Thread-12 Reading... Counter: 9
Reader: Thread-22 Reading... Counter: 9
Reader: Thread-20 Reading... Counter: 9
Reader: Thread-7 Reading... Counter: 9
Reader: Thread-14 Reading... Counter: 9
Reader: Thread-8 Reading... Counter: 9

Reader: Thread-6 Reading... Counter: 9
Reader: Thread-7 Reading... Counter: 9
Reader: Thread-13 Reading... Counter: 9
Reader: Thread-17 Reading... Counter: 9
Reader: Thread-14 Reading... Counter: 9
WRITER: Thread-0 Writing... Counter: 10
Reader: Thread-8 Reading... Counter: 10
Reader: Thread-10 Reading... Counter: 10
Reader: Thread-9 Reading... Counter: 10
Reader: Thread-4 Reading... Counter: 10
Reader: Thread-20 Reading... Counter: 10
Reader: Thread-16 Reading... Counter: 10
Reader: Thread-19 Reading... Counter: 10
Reader: Thread-18 Reading... Counter: 10
Reader: Thread-13 Reading... Counter: 10
Reader: Thread-16 Reading... Counter: 10
Reader: Thread-21 Reading... Counter: 10
Reader: Thread-15 Reading... Counter: 10
Reader: Thread-8 Reading... Counter: 10
Reader: Thread-5 Reading... Counter: 10
Reader: Thread-10 Reading... Counter: 10
WRITER: Thread-2 Writing... Counter: 11
WRITER: Thread-1 Writing... Counter: 12
Reader: Thread-3 Reading... Counter: 12
Reader: Thread-8 Reading... Counter: 12
Reader: Thread 9 Reading... Counter: 12
Reader: Thread-13 Reading... Counter: 12
Reader: Thread-12 Reading... Counter: 12
WRITER: Thread-1 Writing... Counter: 13
Reader: Thread-17 Reading... Counter: 13
Reader: Thread-20 Reading... Counter: 13
Reader: Thread-11 Reading... Counter: 13
Reader: Thread-22 Reading... Counter: 13
Reader: Thread-6 Reading... Counter: 13
Reader: Thread-21 Reading... Counter: 13
Reader: Thread-5 Reading... Counter: 13
Reader: Thread-14 Reading... Counter: 13
Reader: Thread-4 Reading... Counter: 13
Reader: Thread-7 Reading... Counter: 13
Reader: Thread-18 Reading... Counter: 13
WRITER: Thread-0 Writing... Counter: 14
WRITER: Thread-1 Writing... Counter: 15
WRITER: Thread-2 Writing... Counter: 16
Reader: Thread-16 Reading... Counter: 16
Reader: Thread-17 Reading... Counter: 16
Reader: Thread-13 Reading... Counter: 16
Reader: Thread-17 Reading... Counter: 16
Reader: Thread-11 Reading... Counter: 16
Reader: Thread-19 Reading... Counter: 16

3. Consider a chain of processes P_1, P_2, ..., P_n implementing a multitiered client-server architecture. Process P_i is client of process P_{i+1}, and P_i will return a reply to P_{i-1} only after receiving a reply from P_{i+1}. What are the main problems with this organization when taking a look at the request-reply performance at process P_1?

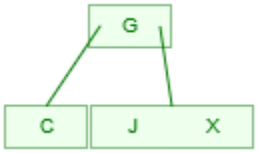
Answer: The larger *n* becomes the performance is expected to degrade. This is because the process relies on two different machines communicating with each other, so if one machine is performing badly or can't be reached for some reason this immediately degrades the performance for all machines within the chain and at the highest level. Wherefore the performance between P_1 and P_2 could also be determined by n-2 request-reply interactions between other layers.

4. Show the B-trees of order four resulted from loading the following sets of keys (each letter is a key) in order:

a. C G J X
   I. Inserting C:
   - 

   II. Inserting G:
   - 

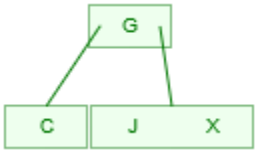
   III. Inserting J:
   - 

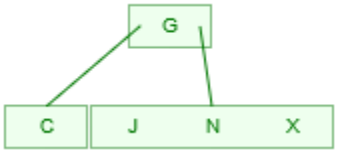
   IV. Inserting X:
   - 

b. C G J X N S U O A E B H I
   I. Inserting C:
   - 

   II. Inserting G:
   - 

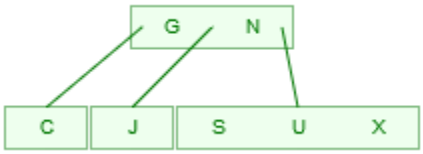
   III. Inserting J:
   - 

   IV. Inserting X:
   - 

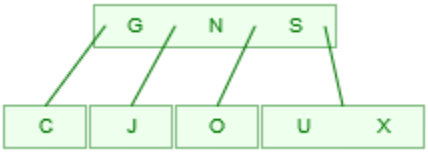
   V. Inserting N:
   - 

   VI. Inserting S:

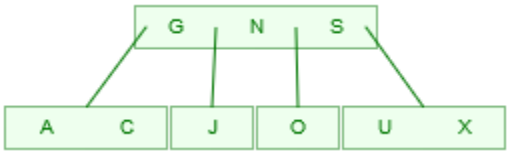
VII. Inserting U:



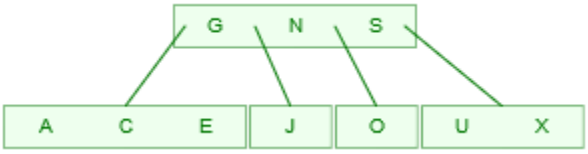
VIII. Inserting O:



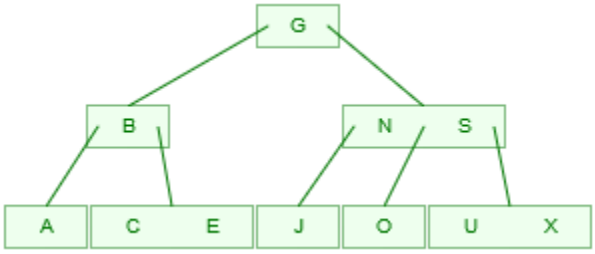
IX. Inserting A:



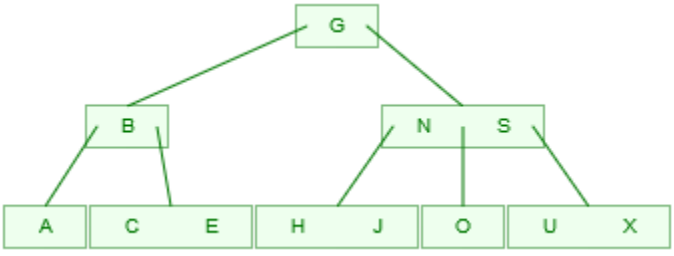
X. Inserting E:



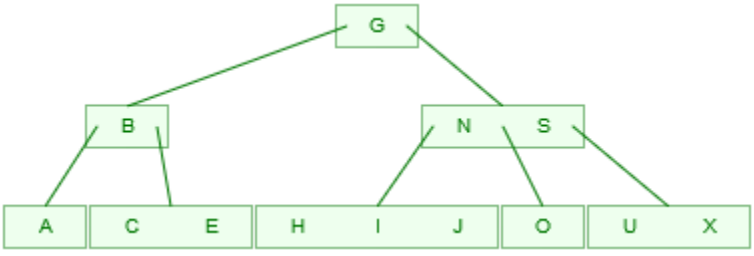
XI. Inserting B:



XII. Inserting H:



XIII. Inserting I:



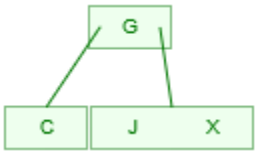
c. C G J X N S U O A E B H I F

I. Inserting C:

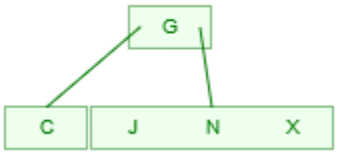
II. Inserting G:

III. Inserting J:

IV. Inserting X:

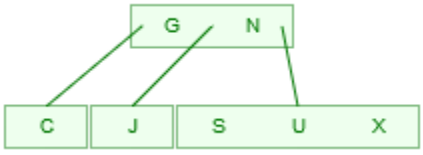


V. Inserting N:

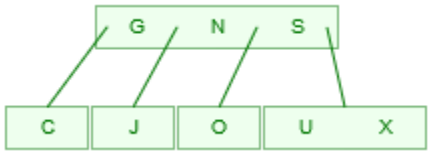


VI. Inserting S:

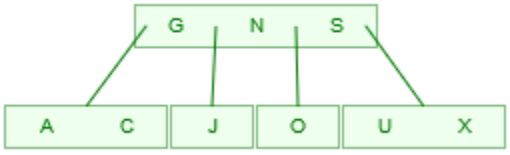
VII. Inserting U:



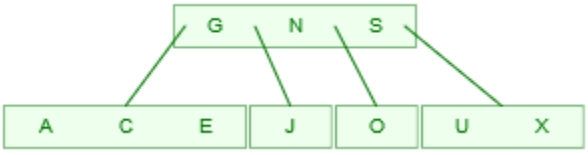
VIII. Inserting O:



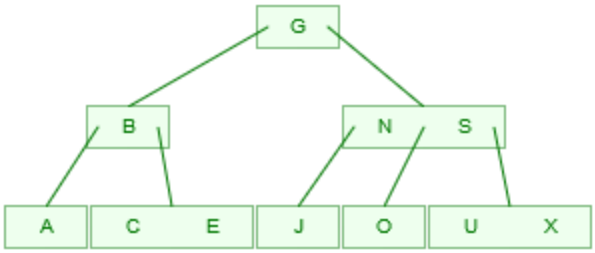
IX. Inserting A:



X. Inserting E:



XI. Inserting B:



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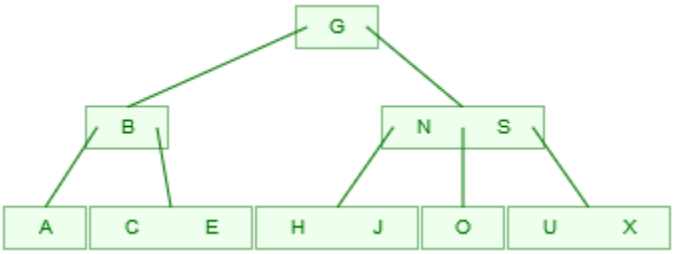

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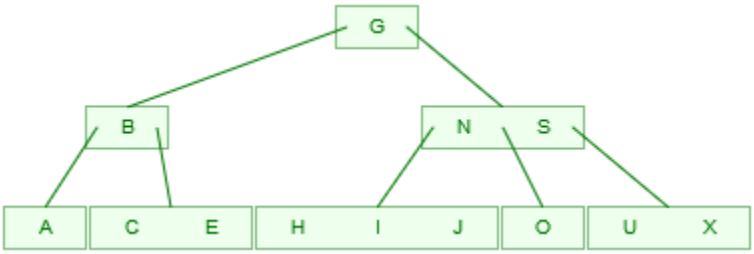
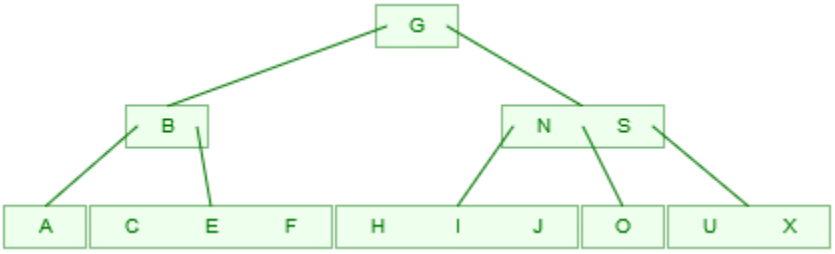


XIV. Inserting F:



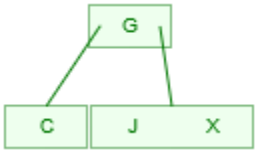
d. C G J X N S U O A E B H I F K L Q R T V U W Z

I. Inserting C:

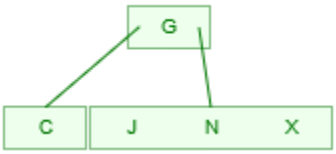
II. Inserting G:

III. Inserting J:

IV. Inserting X:

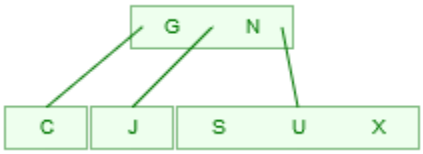


V. Inserting N:

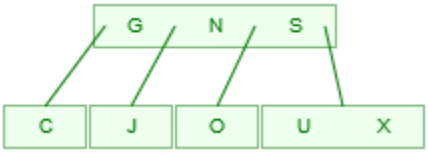


VI. Inserting S:

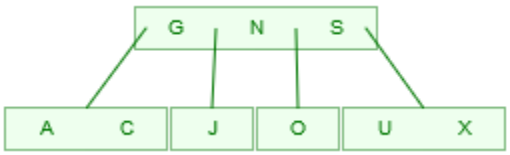
VII. Inserting U:



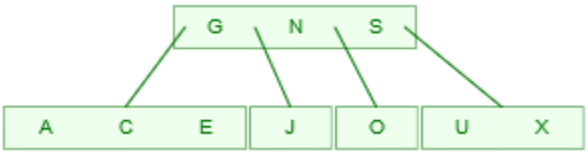
VIII. Inserting O:



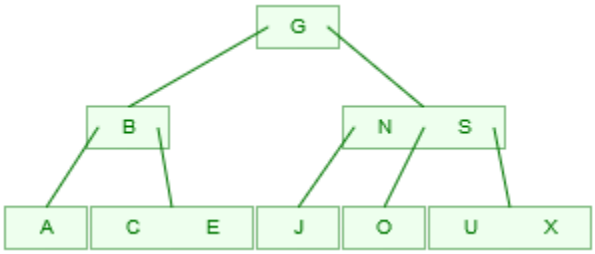
IX. Inserting A:



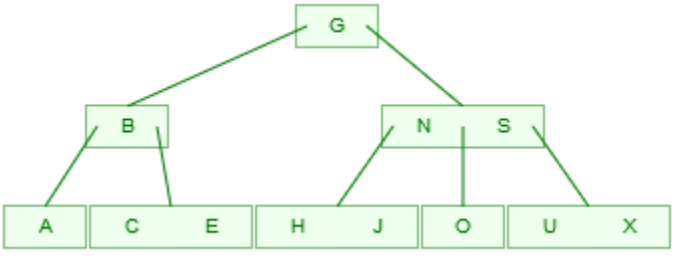
X. Inserting E:



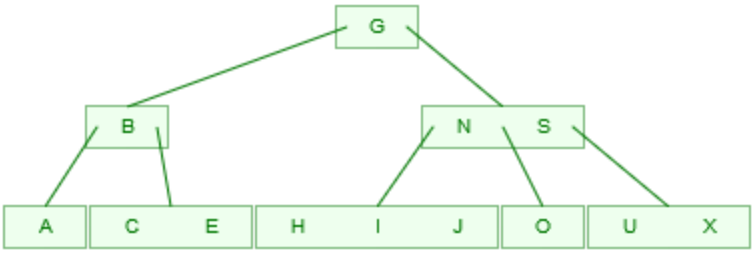
XI. Inserting B:



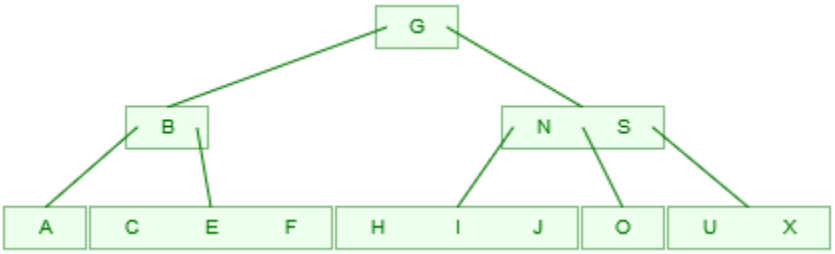
XII. Inserting H:



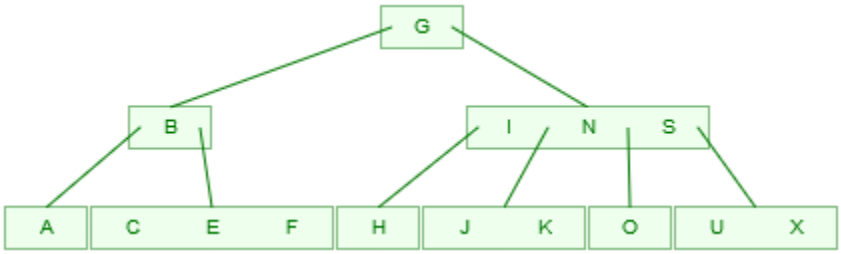
XIII. Inserting I:



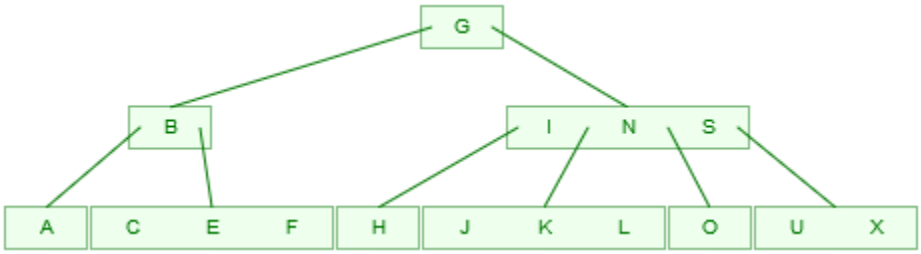
XIV. Inserting F:



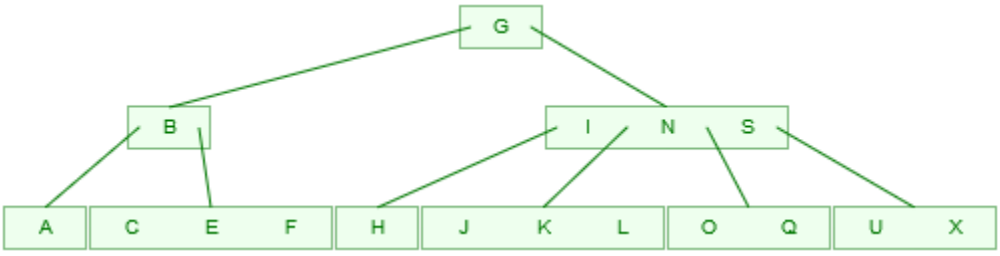
XV. Inserting K:



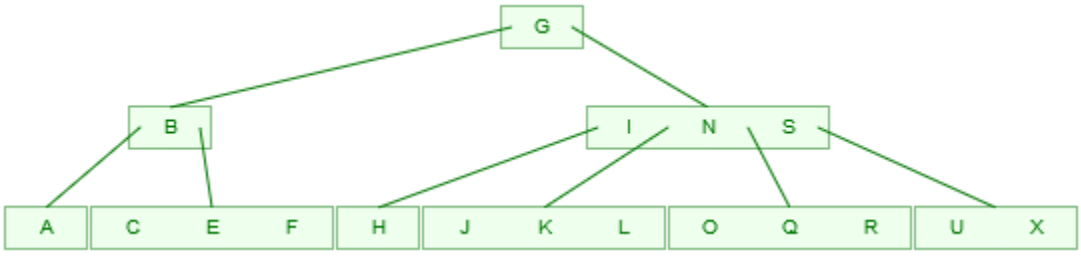
XVI. Inserting L:



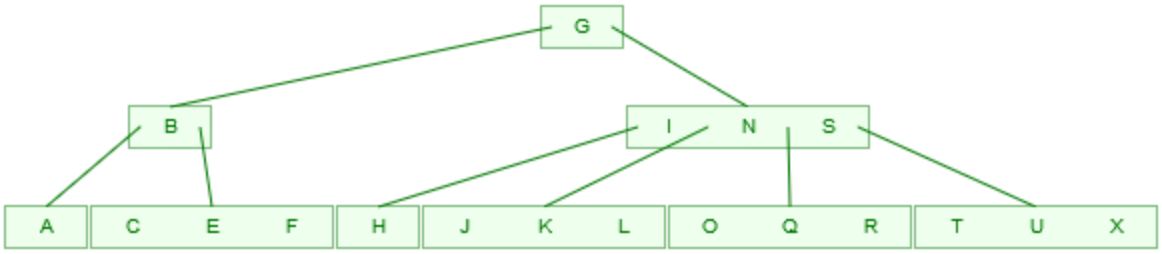
XVII. Inserting Q:



XVIII. Inserting R:



XIX. Inserting T:



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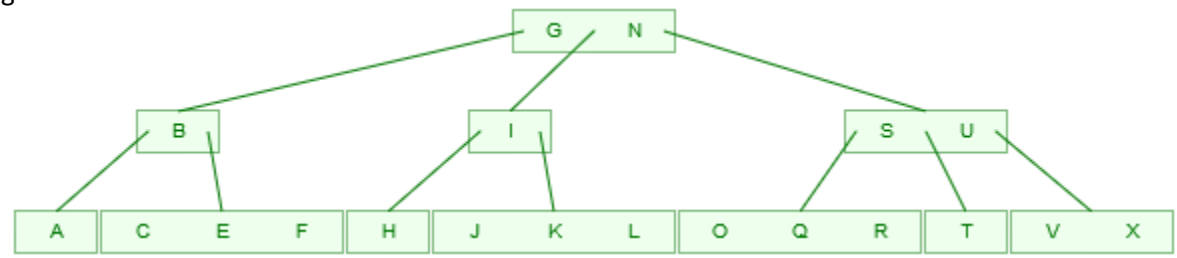
XX. Inserting V:



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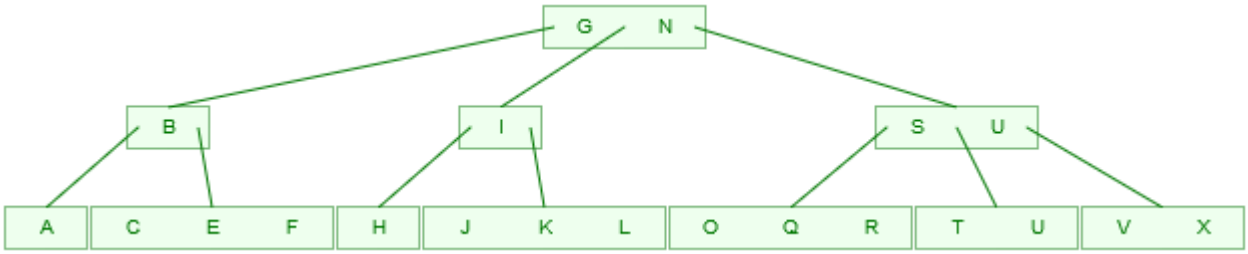
XXI. Inserting U:



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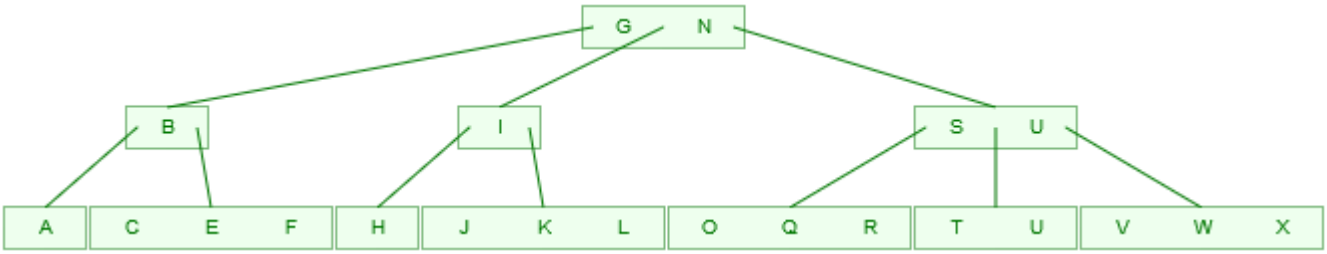
XXII. Inserting W:



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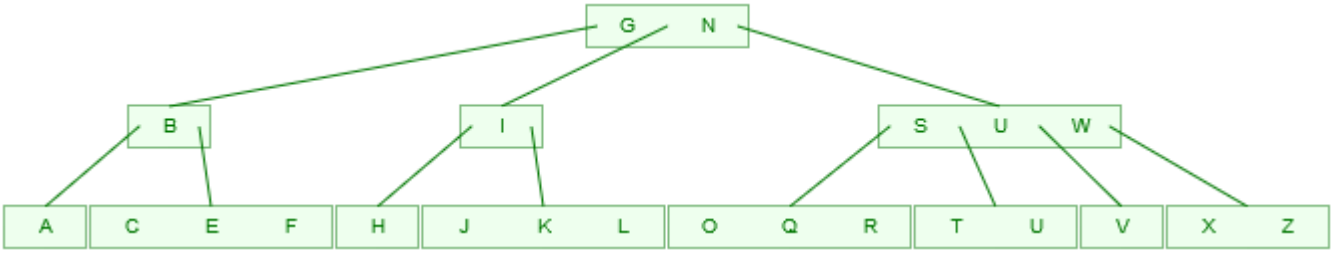
XXIII. Inserting Z:



5. Given a B Tree of order 256,

a. What is the maximum number of children from a node?
   - The maximum number of children will be 256.
b. Excluding the root and the leaves, what is the minimum number of children from a node?
   - Minimum number of children from a node is x/2 which is 128.
c. What is the minimum number of children from the root?
   - Root has 2 children other than if it is a leaf.
d. What is the maximum depth of the tree if it contains 100 000 keys?
   - To find the maximum depth we can use the formula: H_Depth = $\log_d((n+1)/2)$
     a. d = minimum number of children: 128
     b. n = number of keys
   - H_Depth = $\log_{128}((100000+1)/2)$
   - Maximum depth is: 2.2299487 but really is 2 because it cannot be in a fraction.

6. Construct a general resource graph for the following scenario and determine if the graph is completely reducible: R1, R2, and R3 are reusable resources with a total of two, two, and three units. Process P1 is allocated one unit each of R2 and R3 and is requesting one unit of R1. Process P2 is allocated one unit of R1 and is requesting two units of R3. Process P3 is allocated one unit each of R1 and R2 and is requesting one unit of R3.

Answer: