# Problem Set 3 - Networked Producer and Consumer

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# Key Implementation Steps

- Validate user inputs such as consumer IP, port number, thread count, and directory paths using loops and conditional checks before launching the application
- Initialize the main form, load existing videos, and set up the UI components, **ListView and Windows Media Player**, for video preview and playback
- Start a **TCP listener on the specified port** to accept incoming uploads and spawn separate worker threads for processing files from different directories
- Launch dedicated threads per directory to read and send video files from the file system, ensuring concurrent file transmission from multiple sources

```csharp
public MainForm(int consumerThreadsCount, int queueCapacity, int listeningPort)
{
    this.consumerThreadsCount = consumerThreadsCount;
    this.listeningPort = listeningPort;
    videoQueue = new BoundedQueue<VideoUpload>(queueCapacity);

    InitializeComponent();
    BuildUI();

    // Ensure the folder for uploaded videos exists.
    if (!Directory.Exists("UploadedVideos"))
    {
        Directory.CreateDirectory("UploadedVideos");
    }

    // Ensure the UploadedVideos folder exists and load any existing files.
    LoadExistingVideos();
```

```csharp
    // Start the worker threads to process the upload queue.
    for (int i = 0; i < consumerThreadsCount; i++)
    {
        Thread worker = new Thread(new ThreadStart(ProcessQueue));
        worker.IsBackground = true;
        worker.Start();
    }
}
```

# Queueing Details

- Implement a custom **bounded queue**, leaky bucket, that controls video upload buffering and has a fixed capacity set via configuration
- In the queue, the **TryEnqueue** method uses a lock to guarantee thread safety and immediately returns false when the maximum capacity is reached, resulting in file drops
- The **Dequeue** method employs an **AutoResetEvent** to wait until an item becomes available, ensuring that consumer processing occurs only when items are present
- **Duplicate detection** is incorporated in the consumer before file processing, where a check against the "UploadedVideos" folder triggers unique filename generation if a duplicate is found

```csharp
// Bounded queue that drops items if full (leaky bucket)
3 references
public class BoundedQueue<T>
{
    private Queue<T> queue = new Queue<T>();
    private int capacity;
    internal object lockObj = new object();
    private AutoResetEvent itemEnqueued = new AutoResetEvent(false);
```

```csharp
// Try to enqueue an item; return false if the queue is full.
1 reference
public bool TryEnqueue(T item)
{
    lock (lockObj)
    {
        if (queue.Count >= capacity)
        {
            return false; // Drop the item
        }
        queue.Enqueue(item);
        itemEnqueued.Set();
        return true;
    }
}
```

```csharp
// Blocking dequeue (waits until an item is available)
1 reference
public T Dequeue()
{
    while (true)
    {
        lock (lockObj)
        {
            if (queue.Count > 0)
            {
                return queue.Dequeue();
            }
        }
        itemEnqueued.WaitOne(100);
    }
}
```

```csharp
// Duplicate detection: Check if a file with the same name already exists in "UploadedVideos"
string finalFileName = originalFileName;
string filePath = Path.Combine("UploadedVideos", finalFileName);
string duplicateMsg = "";
if (File.Exists(filePath))
{
    // Duplicate found; generate a unique name.
    string newFileName = GetUniqueFileName(originalFileName);
    duplicateMsg = $" Duplicate detected, renamed: {newFileName}";
    finalFileName = newFileName;
}
```

# Breakdown of Producer and Consumer Concepts Applied

- The **Producer** reads video files from user-specified directories and, if a file exceeds 20 MB, optionally compresses it using **FFmpeg** via a separate function that reduces quality for a smaller size without changing the file name.

- After reading the file and header information, the Producer sends the header (filename length, filename, file size) and the file data sequentially over a TCP client and waits for a final response message from the Consumer.

```
if (fileSize > threshold)
{
    // Call the separate video compression function
    if (CompressVideo(filePath, out byte[] newFileData, out long newSize))
    {
        fileData = newFileData;
        fileSize = newSize;
        compressed = true;
        Console.WriteLine($"\nVideo above 20MB, file {originalFileName} was compressed.
    }
    else
    {
        Console.WriteLine($"\nCompression failed for file {originalFileName}. Proceedin
    }
}
```

```
using (TcpClient client = new TcpClient())
{
    client.Connect(consumerIP, consumerPort);
    using (NetworkStream ns = client.GetStream())
    {
        // Send header
        ns.Write(fileNameLengthBytes, 0, fileNameLengthBytes.Length);
        ns.Write(fileNameBytes, 0, fileNameBytes.Length);
        ns.Write(fileSizeBytes, 0, fileSizeBytes.Length);

        // Send file data immediately
        ns.Write(fileData, 0, fileData.Length);
        ns.Flush();

        // Then wait for a response (e.g., OK or QUEUE_FULL)
        byte[] responseBuffer = new byte[100];
        int bytesRead = ns.Read(responseBuffer, 0, responseBuffer.Length);
        string response = Encoding.UTF8.GetString(responseBuffer, 0, bytesRead);
        Console.WriteLine($"\nReceived response from consumer: {response}\n");
    }
}
```

# Breakdown of Producer and Consumer Concepts Applied

- The **Consumer**, on the receiving end, uses a TcpListener to handle each incoming connection, reads the file header, file name, and file data, and then checks for duplicates, renaming files as necessary to preserve unique storage.

- Based on the state of the bounded queue and duplicate detection, the Consumer sends back a final response (O**K, QUEUE_FULL, or DUPLICATE**) to inform the Producer whether the file was accepted, dropped, or renamed.

```
private void HandleClient(TcpClient client)
{
    try
    {
        using (var ns = client.GetStream())
        {
            // Read file name length (4 bytes)
            byte[] intBuffer = ReadExact(ns, 4);
            if (intBuffer == null) return;
            int fileNameLength = IPAddress.NetworkToHostOrder(BitConverter.ToInt32(intBuffer, 0));

            // Read the file name
            byte[] nameBuffer = ReadExact(ns, fileNameLength);
            if (nameBuffer == null) return;
            string originalFileName = Encoding.UTF8.GetString(nameBuffer);

            // Read file size (8 bytes)
            byte[] longBuffer = ReadExact(ns, 8);
            if (longBuffer == null) return;
            long fileSize = IPAddress.NetworkToHostOrder(BitConverter.ToInt64(longBuffer, 0));

            // Now, read the file data.
            byte[] fileData = ReadExact(ns, (int)fileSize);
            if (fileData == null) return;
```

```
bool enqueued = videoQueue.TryEnqueue(vu);
string responseMsg;
if (!enqueued)
{
    // File dropped because the queue is full.
    responseMsg = $"QUEUE_FULL: Dropping file: {originalFileName}";
}
else
{
    // File accepted (or duplicate detected and renamed)
    if (!string.IsNullOrEmpty(duplicateMsg))
    {
        responseMsg = $"DUPLICATE: {originalFileName}{duplicateMsg}";
    }
    else
    {
        responseMsg = $"OK: File accepted: {originalFileName}";
    }
}
```

# Synchronization Mechanisms Used to Solve the Problem

- Use of the lock statement in both the **TryEnqueue** and **Dequeue** methods to protect access to the shared queue, ensuring that concurrent threads do not modify the queue simultaneously.

- Implementation of **AutoResetEvent** to signal waiting threads immediately when new items are enqueued, allowing the consumer worker threads to wake up and process files.

- Multithreading is applied throughout the system: separate **Producer** threads handle file reading and sending, while **Consumer** threads handle network connections and queue processing concurrently.

- An artificial delay using **Thread.Sleep**, is introduced in the queue processing method to simulate slow processing and test the queue's full behavior, ensuring that the drop logic and response messages are triggered as expected.

```
/*
 * Processes the video queue by saving videos to disk and updating the UI
 * Continuously dequeues video data from the shared queue,
 * writes it to the "UploadedVideos" directory, and updates the ListView
 * on the UI thread to display newly saved videos.
 */
1 reference
private void ProcessQueue()
{
    while (true)
    {
        VideoUpload vu = videoQueue.Dequeue();
        // Save the file to disk
        string filePath = Path.Combine("UploadedVideos", vu.FileName);
        File.WriteAllBytes(filePath, vu.Data);
        Console.WriteLine("Saved file: " + vu.FileName);

        // Introduce an artificial delay because otherwise it would process too fast
        Thread.Sleep(1000);

        // Update the ListView on the UI thread.
        this.Invoke((MethodInvoker)delegate {
            if (!listViewVideos.Items.ContainsKey(vu.FileName))
            {
                ListViewItem item = new ListViewItem(vu.FileName);
                item.Name = vu.FileName;
                listViewVideos.Items.Add(item);
            }
        });
    }
}
```

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