# SMART TRAFFIC SIGNAL OPTIMIZATION

SRIRAM VENKATESAN

192372116

CSA0959

PROGRAMMING IN JAVA FOR SCIENTIFIC APPLICATIONS

Question:

You are part of a team working on an initiative to optimize traffic signal management in a busy city to reduce congestion and improve traffic flow efficiency using smart technologies.

**1.Data Collection and Modeling:**

To collect and manage real-time traffic data from sensors, we'll define data structures that can store this information efficiently. We'll have two main entities: Traffic Sensor Data and Intersection.

**Traffic Sensor Data:**

This class will represent the data collected from traffic sensors at various intersections.

**Attributes:**

- **Sensor ID:** Unique identifier for the sensor**.**
- **Intersection ID**: Foreign key linking to the intersection where the sensor is located.
- **Timestamp:** The time at which the data is collected.
- **Vehicle Count:** Number of vehicles detected by the sensor.
- **Average Speed:** Average speed of the vehicles detected.
- **Traffic Density**: Calculated density of the traffic (vehicles per unit area).
- **Queue Length**: Length of the vehicle queue at the intersection.
- **Pedestrian Crossing Count:** Number of pedestrians waiting to cross.

```
public class TrafficSensorData
{
private String sensorID;
private String intersectionID;
private long timestamp;
private int vehicleCount;
private double averageSpeed;
private double trafficDensity;
```

```
private int queueLength;
private int pedestrianCrossingCount;
}
```

**2. Algorithm Design:**

Optimization Algorithm:

The core of the system is the algorithm that analyzes the collected data and adjusts the signal timings to optimize traffic flow. The algorithm considers various factors such as:

Traffic Density: High traffic density might indicate the need for longer green lights.

Queue Length: Long vehicle queues might require an extension of green lights to clear the congestion.

Pedestrian Crossings: If there are many pedestrians waiting, the system should prioritize pedestrian signals to ensure safety.

**3. Implementation:**

Real-time Integration:

The implementation involves integrating with traffic sensors to collect data and adjusting traffic signal timings in real-time. This requires:

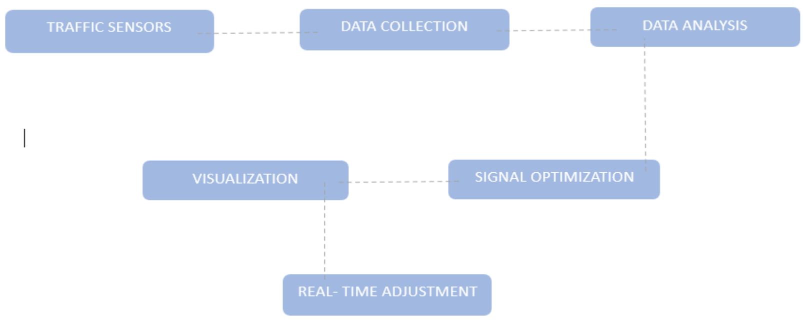
TrafficSensorData and Intersection classes to model the data.

TrafficSignalOptimizer class to implement the optimization algorithm.

TrafficSignalController manages the intersections and periodically updates the signal timings based on the collected data.

**4. Visualization and Reporting:**

Data Flow Diagram: A diagram illustrating how data flows from sensors to the optimization algorithm and then to the traffic signal controllers helps in understanding the overall system architecture.



**5. User Interaction:**

**User Interface:**

A user-friendly interface is crucial for traffic managers to monitor real-time traffic conditions and manually adjust signal timings if needed. The interface should include:

**Dashboards:** Visualize traffic data, signal timings, and historical data.

**Control Panels:** Allow manual adjustments to signal timings.

**Documentation**

**Design Decisions:**

**Data Structures**: Chosen to effectively represent traffic sensor data and intersections.

**Algorithms:** Designed to dynamically optimize traffic signals based on real-time data.

**Assumptions:** Assumed high reliability of traffic sensors and accurate data.

Potential Improvements:

Incorporate machine learning for predictive traffic flow optimization.

Improve sensor reliability and data accuracy.

Integrate with other smart city infrastructure (e.g., public transport schedules).

Testing

**Test Cases:**

Normal Traffic Conditions: Ensure the system optimizes signal timings correctly.

High Traffic Density: Verify the system extends green light duration for high-density directions.

Long Vehicle Queues: Confirm the system handles long queues by adjusting signal timings.

Pedestrian Crossings: Check the system activates pedestrian signals when needed.

**java final codes:**

```
import java.util.HashMap;

import java.util.Map;

import java.util.Scanner;
```

**// Step 1: Define the IntersectionData class to hold sensor data**

```
class IntersectionData
{
   private String intersectionID;
   private String signalID;
   private int queueLength;
   private int averageSpeed;

   public IntersectionData(String intersectionID, String signalID, int queueLength, int
averageSpeed)
 {
      this.intersectionID = intersectionID;
      this.signalID = signalID;
      this.queueLength = queueLength;
      this.averageSpeed = averageSpeed;
   }

   public String getIntersectionID()
{
      return intersectionID;
   }

   public String getSignalID()
{
      return signalID;
   }

   public int getQueueLength()
{
      return queueLength;
   }
```

```
    public int getAverageSpeed()
{
        return averageSpeed;
    }
    public String toString()
{
        return "Intersection " + intersectionID + " - Signal " + signalID + " | Queue Length: " +
queueLength + ", Average Speed: " + averageSpeed + " km/h";
    }
}
```

**// Step 2: Create a service to fetch real-time sensor data**

```
class SensorDataService
{
    private Map<String, IntersectionData> dataMap;

    public SensorDataService()
{
        this.dataMap = new HashMap<>();
    }

    public void addData(String intersectionID, IntersectionData data)
{
        dataMap.put(intersectionID, data);
    }

    public Map<String, IntersectionData> getRealTimeData()
 {
        return dataMap;
    }
```

```java
}

// Step 3: Create a service to control signal timings
class SignalControlService
{
    public void updateSignalTiming(String signalID, int phaseDuration) {
        System.out.println("Updating signal " + signalID + " with duration: " + phaseDuration + " seconds.");
    }
}

// Step 4: Define the main TrafficSignalController class to optimize signals
class TrafficSignalController
{
    private SensorDataService sensorDataService;
    private SignalControlService signalControlService;

    public TrafficSignalController(SensorDataService sensorService, SignalControlService controlService) {
        this.sensorDataService = sensorService;
        this.signalControlService = controlService;
    }

    public void optimizeTrafficSignals()
{
        Map<String, IntersectionData> intersections = sensorDataService.getRealTimeData();

        for (IntersectionData data : intersections.values())
{
            int phaseDuration = calculateOptimalPhaseDuration(data);
            signalControlService.updateSignalTiming(data.getSignalID(), phaseDuration);
```

```
    }
  }

  private int calculateOptimalPhaseDuration(IntersectionData data)
{
    int queueLength = data.getQueueLength();
    // Simple formula: phase duration is queue length divided by 2, within a range
    return Math.max(30, Math.min(120, queueLength * 2));
  }

  public void displayTrafficConditions()
{
    for (IntersectionData data : sensorDataService.getRealTimeData().values()) {
      System.out.println(data.toString());
    }
  }

  public String generateReport()
{
    int totalQueueLength = 0;
    int totalAverageSpeed = 0;
    int count = 0;

    for (IntersectionData data : sensorDataService.getRealTimeData().values())
{
      totalQueueLength += data.getQueueLength();
      totalAverageSpeed += data.getAverageSpeed();
      count++;
    }
```

```
        double avgQueueLength = (double) totalQueueLength / count;
        double avgSpeed = (double) totalAverageSpeed / count;

        StringBuilder report = new StringBuilder();
        report.append("Traffic Flow Report\n");
        report.append("===================\n");
        report.append("Average Queue Length: ").append(avgQueueLength).append("\n");
        report.append("Average Speed: ").append(avgSpeed).append(" km/h\n");
        return report.toString();
    }
}

// Main class to run the program
public class TrafficManagementSystem
{
    public static void main(String[] args)
{
        // Instantiate services
        SensorDataService sensorService = new SensorDataService();
        SignalControlService controlService = new SignalControlService();
        TrafficSignalController controller = new TrafficSignalController(sensorService,
controlService);

        // Get user input
        Scanner scanner = new Scanner(System.in);
        System.out.println("Enter the number of intersections:");
        int numberOfIntersections = scanner.nextInt();
        scanner.nextLine();  // Consume newline

        for (int i = 0; i < numberOfIntersections; i++) {
            System.out.println("Enter details for intersection " + (i + 1) + ":");
```

```java
            System.out.print("Intersection ID: ");
            String intersectionID = scanner.nextLine();
            System.out.print("Signal ID: ");
            String signalID = scanner.nextLine();
            System.out.print("Queue Length: ");
            int queueLength = scanner.nextInt();
            System.out.print("Average Speed: ");
            int averageSpeed = scanner.nextInt();
            scanner.nextLine();  // Consume newline

            IntersectionData data = new IntersectionData(intersectionID, signalID, queueLength,
averageSpeed);
            sensorService.addData(intersectionID, data);
        }

        // Optimize traffic signals and display conditions
        controller.optimizeTrafficSignals();
        controller.displayTrafficConditions();

        // Generate and display report
        String report = controller.generateReport();
        System.out.println(report);
    }
}
```

```java
class IntersectionData
{
    private String intersectionID;
    private String signalID;
    private int queueLength;
    private int averageSpeed;

    public IntersectionData(String intersectionID, String signalID, int queueLength, int averageSpeed)
  {
        this.intersectionID = intersectionID;
        this.signalID = signalID;
        this.queueLength = queueLength;
        this.averageSpeed = averageSpeed;
    }

    public String getIntersectionID()
    {
        return intersectionID;
    }

    public String getSignalID()
    {
        return signalID;
    }

    public int getQueueLength()
    {
        return queueLength;
    }

    public int getAverageSpeed()
    {
        return averageSpeed;
    }
```

```java
    public String toString()
    {
        return "Intersection " + intersectionID + " - Signal " + signalID + " | Queue Length: " + queueLength + ", Average Speed:
    }
}

// Step 2: Create a service to fetch real-time sensor data
class SensorDataService
{
    private Map<String, IntersectionData> dataMap;

    public SensorDataService()
    {
        this.dataMap = new HashMap<>();
    }

    public void addData(String intersectionID, IntersectionData data)
    {
        dataMap.put(intersectionID, data);
    }

    public Map<String, IntersectionData> getRealTimeData()
    {
        return dataMap;
    }
}

// Step 3: Create a service to control signal timings
class SignalControlService
{
    public void updateSignalTiming(String signalID, int phaseDuration) {
        System.out.println("Updating signal " + signalID + " with duration: " + phaseDuration + " seconds.");
    }
}
```

```java

// Step 4: Define the main TrafficSignalController class to optimize signals
class TrafficSignalController
{
    private SensorDataService sensorDataService;
    private SignalControlService signalControlService;

    public TrafficSignalController(SensorDataService sensorService, SignalControlService controlService) {
        this.sensorDataService = sensorService;
        this.signalControlService = controlService;
    }

    public void optimizeTrafficSignals()
    {
        Map<String, IntersectionData> intersections = sensorDataService.getRealTimeData();

        for (IntersectionData data : intersections.values())
        {...}
    }

    private int calculateOptimalPhaseDuration(IntersectionData data)
  {
        int queueLength = data.getQueueLength();
        // Simple formula: phase duration is queue length divided by 2, within a range
        return Math.max(30, Math.min(120, queueLength * 2));
    }

    public void displayTrafficConditions()
  {
        for (IntersectionData data : sensorDataService.getRealTimeData().values()) {
            System.out.println(data.toString());
        }
    }

```

```java
    public String generateReport()
{
        int totalQueueLength = 0;
        int totalAverageSpeed = 0;
        int count = 0;

        for (IntersectionData data : sensorDataService.getRealTimeData().values())
{
            totalQueueLength += data.getQueueLength();
            totalAverageSpeed += data.getAverageSpeed();
            count++;
        }

        double avgQueueLength = (double) totalQueueLength / count;
        double avgSpeed = (double) totalAverageSpeed / count;

        StringBuilder report = new StringBuilder();
        report.append("Traffic Flow Report\n");
        report.append("===================\n");
        report.append("Average Queue Length: ").append(avgQueueLength).append("\n");
        report.append("Average Speed: ").append(avgSpeed).append(" km/h\n");
        return report.toString();
    }
}

// Main class to run the program
public class TrafficManagementSystem
{
    public static void main(String[] args)
{
        // Instantiate services
        SensorDataService sensorService = new SensorDataService();
        SignalControlService controlService = new SignalControlService();
```

```java
        TrafficSignalController controller = new TrafficSignalController(sensorService, controlService);

        // Get user input
        Scanner scanner = new Scanner(System.in);
        System.out.println("Enter the number of intersections:");
        int numberOfIntersections = scanner.nextInt();
        scanner.nextLine();  // Consume newline

        for (int i = 0; i < numberOfIntersections; i++) {
            System.out.println("Enter details for intersection " + (i + 1) + ":");
            System.out.print("Intersection ID: ");
            String intersectionID = scanner.nextLine();
            System.out.print("Signal ID: ");
            String signalID = scanner.nextLine();
            System.out.print("Queue Length: ");
            int queueLength = scanner.nextInt();
            System.out.print("Average Speed: ");
            int averageSpeed = scanner.nextInt();
            scanner.nextLine();  // Consume newline

            IntersectionData data = new IntersectionData(intersectionID, signalID, queueLength, averageSpeed);
            sensorService.addData(intersectionID, data);
        }

        // Optimize traffic signals and display conditions
        controller.optimizeTrafficSignals();
        controller.displayTrafficConditions();

        // Generate and display report
        String report = controller.generateReport();
        System.out.println(report);
    }
}
```