EFFECTIVE CONGESTION CONTROL IN TRAFFIC MANAGEMENT USING WIRELESS SENSOR NETWORK

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ABSTRACT
The continuous increase in vehicular traffic has become an immense matter of concern, as the road network remains limited. In this situation especially, congestion control in wide network of intersections becomes necessary. Existing studies on traffic control algorithm mainly focused on determining the green light length in a fixed sequence of traffic. Therefore, an effective traffic management algorithm would help in resolving this issue. We have developed STSC: Sensor-based Traffic Signal Control, an improved version of adaptive Traffic Control Algorithm, which uses a decentralized system for its operation. In this algorithm we have considered four traffic phases at an intersection, which considers all the possible routes. For this we have used DSRC: Dedicated Short-Range Communications between the vehicles and traffic controller to adjust the phases. An additional feature of this algorithm is to give free pathway to emergency vehicles. We have also developed an algorithm for navigation purpose CTBR: Current Traffic-Based Route telling algorithm, for demand-driven route telling based on current traffic situation. It works by taking input from decentralized traffic controller at a centralized server. The performance evaluation shows that our work can improve in current situation and effectively manage traffic in a wide range of traffic intersection. This report concludes with some future work and useful remarks.

KEYWORDS
1. CTBR: Current Traffic Based Routing.
2. DSRC: Digital Short Range Communication
3. GPS: Global Positioning System.
4. ITS: Intelligent Transportation System.
5. STSC: Sensor-based Traffic signal Control.
1. INTRODUCTION
The advancements of technology have led to the fourfold increase in the power of gasoline engines[5]. Vehicle has become a basic necessity these days. The number of vehicles is increasing at a tremendous extent in the recent times especially in urban areas. So an effective traffic management becomes very necessary. In today's scenario, an Indian driver has to spend approximately 60 hours per month on average in traffic congestion[20]. Greatest reasons for this are poorly timed traffic signals and their inability to adapt to real time traffic, which leads to congestion and jams. Due to this there is loss of time, increasing frustration level of drivers, insufficient consumption of fuel, which is a non-renewable source of energy[5]. It also results decreased effectiveness of emergency vehicles like Ambulance, Fire brigade, VIP Vehicles etc. Therefore an effective, unmanned and cost effective solution becomes very necessary. This project helps to adapt to real time traffic and accordingly give green pathways while keeping in mind that maximum priority is given to the emergency vehicles.

1.1 Intelligent Vehicle wireless detection system:
All the Vehicles in the intersection are connected to a decentralized system. We are using DSRC[1] for this purpose.

1.1.1 Features
- Improving traffic safety.
- Speed detection (Challan System)
- Detect type and length of vehicle.
- Optimizing traffic flow.
- Minimizing traffic delay.
- Minimizing vehicular emissions.
- Providing maximum priority to emergency vehicles.
- Providing demand-driven routes as per real time traffic

1.2 Wireless sensor networks[16] (WSN)
To monitor real time traffic, an intelligent WSN[16] is used. WSN consist of a lot of Traffic Sensor Node (TSN) detectors, which is designed to fetch the number of vehicles on each lane, their type, their waiting time and their speed.

1.3 GPS[15] used in our project
Global positioning System[15] is a radio based navigation system by which vehicles of each category can get the route from source to destination. GPS uses triangular technique to position vehicles.

1.3.1 Capabilities
- Human readable maps in textual form.
- Gives various possible routes with real time number of vehicles on them.

1.3.2 GPS[15] features
- Gives source to destination routes as per demand.
- Also gives alternative routes.
- Source destination route.
- Displacement or shortest route between the two locations.

1.4 Need of dynamic signal traffic control:
The current situation uses fixed and pre-defined system for green traffic signal which is ineffective as it can work well in less busy intersection. This fails when the in-
intersection is more crowded. So to eradicate this dynamic signal control method is used which adapts and works in real time.

2. SURTRAC: Scalable Urban Traffic Control
This research paper shows the advancement in the field of real time, adaptive traffic signal control. It shows research work in the area of multi-agent planning system. Its main characteristics are

- Each intersection of a road network operates in a fully decentralized manner (independently) to promote scalability and reliability.
- Computes green time with the help of data received from the road sensors and its independent of road sensor's type.
- Its a truly a real time system each intersection sends its data to its neighboring intersections at every ounce of a second asynchronously to ensure good operation in busy roads.

- The **Detector** interacts with different road sensors placed on the road side.
- The **Scheduler** is used to schedule the green time based on the data received by the detectors.
- The **Executor** interacts with the Controller to execute the scheduling done by the scheduler.
- The **Communicator** is used to send the intersection data to its neighbouring intersections.
- **Sensors**: Various sensors could be used (which ever is viable).

3. PROBLEM DESCRIPTION

3.1 Features Not Yet Recognized:
- No priority for emergency vehicles[1].
- Automatic challan generation system not present.

3.2 Proposed Technique:
**Assumption:**
1. Each vehicle is equipped to transmit to its detectors.
2. Right turn is free at all intersections for all vehicles.
3. U-turn is treated as left turn.

- Prioritization of emergency vehicles such as Ambulance, Fire Brigade by Emergency Vehicle Recognition through vehicle ID.
- Automatic machine generation of challan of signal violators.
- Effective routing technique using decentralized system working locally (on intersections).
- Limiting waiting time for each vehicle to the minimum possible time unit.
4. METHODOLOGY USED IN PROPOSED WORK

We have proposed two algorithms to control the traffic using Wireless Sensor Networks.

4.1 Problem Notations

There will be four phases to select from:

**Figure 5.1:** The four phases of Traffic Light

- Green line indicates that movement is allowed in the phase that is green light and red line indicates that movement is not allowed in the phase that is red light.
- The right turn for any vehicle coming from any direction will remain green throughout the algorithm.
- Wireless sensors will detect the vehicle related attributes such as: number of vehicles on each lane, waiting time of vehicles, vehicle ID (detection for emergency vehicles) and their speed.

4.2 Proposed Sensor-based Traffic Signal Control Algorithm:

**Variables used:**

- Vehicles can originate from the following directions:
  - Direction = {East, West, North, South}
  - Movement = {Straight, Left}
  - Phase = {a, b, c, d}

1. **Number of vehicles waiting in a lane**:
   - Given by vehicles detected by the sensor present on each lane
   - \( nvl \{ \text{direction, movement} \} \)

2. **Total number of vehicles in a phase**:
   - Calculated from \( nvl \) for each lane
   - \( n\text{vphase}_x = \text{Sum of } nvl \text{ that belong to phase } x \)

3. **Queue empty time for a lane**:
   - Time to empty the queue after giving green light in a lane:
     - \( q\text{etl} = t\text{ci} + t\text{lv} \)
     - where \( t\text{ci} \) - time taken for vehicle to cross the intersection
     - \( t\text{lv} \) – time taken for last vehicle in queue to reach the front of that queue

4. **Queue empty time for phase**:
   - Time to empty the queue for each phase:
     - \( q\text{etp} = \text{MAX}(q\text{etl}) \text{ for each qetl in that phase} \)

5. **Detection of special vehicle (emergency vehicle) in a lane**
   - If there is an special or priority vehicle in a given lane
     - \( SV \{ \text{movement, direction} \} \)

6. **Waiting time for front vehicle in each lane**:
   - This is used to avoid infinite wait condition that occurs when there are few vehicles in a lane
   - \( wt \{ \text{movement, direction} \} \)

7. **Maximum waiting time**:
   - This denotes the maximum time above which a vehicle does not have to wait in a lane to get the green light
   - \( wt\text{max} \)

8. **Maximum phase time**:
   - The maximum time a phase is allowed to get green light:
   - \( pt\text{max} \)

9. **Phase time**:
   - Gives the phase time(ie green light time set for that phase) for a given phase
   - \( pt = \text{MIN}(q\text{etp}, pt\text{max}) \)
ALGORITHM:
1. Initialization:
   ptmax = 90  //Maximum phase time
   wtmax = 120  //Maximum waiting time
   nvl{movement, direction} for all lanes // Detected from the detector

2. Calculation of maximum number of vehicles in a phase:
   nvphase_a = nvl{North, Straight} + nvl{South, Straight}
   nvphase_b = nvl{North, Left} + nvl{South, Left}
   nvphase_c = nvl{West, Straight} + nvl{East, Straight}
   nvphase_d = nvl{West, Left} + nvl{East, Left}

3. Selection of phase:
   a. Check for special vehicle case in each lane
      SV {movement, direction}
   b. If a special vehicle is detected then:
      Assign green light to that phase immediately in which the vehicle is detected if there in case of only one special vehicle
      If special vehicle are present on more than one phase then Assign green light to that phase immediately which has move number of special vehicles
      Else assign green light to that phase immediately which have maximum nv phase
   c. Else If
      i. Compute waiting time for each lane
         wt {movement, direction}
ii. If there exists a path whose waiting time is greater than the maximum waiting time then
Assign green light to that phase in which the maximum waiting time has occurred
d. Else Assign green light to that phase having maximum number of vehicles as computed in step (2)

4. Determination of green light duration for the selected phase
i. qetp = MAX(qetl) //queue empty time for selected phase
ii. pt = MIN(qetp, ptmax) //phase time for selected phase
iii. Set green light time for that phase equal to pt.

CHALLAN GENERATION
The above algorithm takes input from the wireless sensors installed in the vehicles. We can collect the much needed information such as vehicle’s current speed, current phase, vehicle ID, presence of vehicle on detector and penalize the defaulters. The following points are proposed for this purpose:
• With the help of vehicle’s speed and vehicle’s ID, we can check whether any vehicle is crossing the speed limit of that particular lane.
• By having the phase information and vehicle’s ID, we can check whether any vehicle has jumped the red light or not.

4.3 Proposed Current Traffic Based Algorithm:
This algorithm uses with Floyd-Warshall Algorithm[18] for finding shortest path between source and destination in a graph, which is as follows:
1 let dist be a |V| × |V| array of minimum distances initialized to ∞ (infinity)
2 for each vertex v
3 dist[v][v] ← 0
4 for each edge (u,v)
5 dist[u][v] ← w(u,v) //the weight of the edge (u,v)
6 for k from 1 to |V|
7 for i from 1 to |V|
8 for j from 1 to |V|
9 if dist[i][j] > dist[i][k] + dist[k][j]
10 dist[i][j] ← dist[i][k] + dist[k][j]
11 end if

Although this algorithm gave the length of actual path, as summed weights, but it does not return the actual path itself. So to remove that problem, we have introduced a 2-D array variable 'path' to it, which stores the path in it alongside the working of Floyd-Warshall algorithm. Also we have developed and used a function called 'calcpath()', which calculates the path using the 'path' variable from the source to destination. For details on the coding of this algorithm, refer Appendix......

Input:
• simuz.txt, stores the dynamic simulation data(vehicle count or traffic between source and destination), where ‘z’ refers to the current simulation step.
• def.txt, stores all the static multi-intersection connection data(distance between all the immediate neighbor intersections).

Output:
• multiple paths with vehicle count and distance (in kms ).
• first path has the least vehicle count(distance may be larger than shortest possible one).
• second path has the least distance (vehicle count may be more than first path).

5. IMPLEMENTATION USING SUMO SIMULATOR
We have used SUMO Simulator[9][10][11][14] to simulate our proposed algorithms. This simulator is open source, portable, microscopic and continuous road traffic simulation[19][21] package designed to handle large road networks.

5.1 SNAPSHOTS OF ALGORITHM STSC
For the implementation of this algorithm, we have considered a single intersection in which traffic phases are selected according to STSC.

Figure 5.1: The interaction developed in SUMO simulator along with detectors.

Figure 5.2: The multi entry/exit detectors present on the intersection represented in SUMO simulator.

Figure 5.3: The flow of vehicles across the intersection as represented in SUMO simulator.
5.2 SNAPSHOTS OF ALGORITHM CTBR

For the implementation of this algorithm, we have considered 9 intersections in which Traffic Phases at each intersection are controlled using STSC algorithm.

Figure 5.4: Detection of emergency vehicle as represented in SUMO simulator.

Figure 5.5: Nine intersections developed in SUMO Simulator with each intersection having detector.

Figure 5.6: Vehicles flowing through the intersections as represented in SUMO Simulator.

Figure 5.7: Path for vehicle between source and destination as generated by CTBR algorithm.

6. PERFORMANCE EVALUATION AND RESULTS

The main objective of our proposed algorithms is to minimize the overall waiting time of vehicles. In this section, we evaluate our algorithm’s performance using some traffic factors such as waiting time, fuel consumption, carbon monoxide and carbon dioxide emissions.
The conditions of a real intersection considered for the evaluations are listed below. In our evaluations, it is assumed that sigma factor for each vehicle is 1.0.

- Vehicles enter randomly into the network
- The algorithm CTBR starts working after 300 simulation steps and until then each phase is simulated for 45 simulation steps.
- In total 1760 vehicles enter and exit the simulation with the rate of 2 vehicles per second.
- In case of Traditional System or Static Traffic Control, each phase is simulated for 45 seconds each one after the other.

6.1 Waiting Time Static VS Dynamic
We have considered four cases to compare the waiting time between Static or Dynamic Traffic Control. The following graphs are the result of using the STSC algorithm:

Graph 6.1: Comparison of waiting time between Traditional System and STSC when vehicles present on all phases.

Graph 6.2: Comparison of waiting time between Traditional System and STSC when vehicles present on three of four phases.

Graph 6.3: Comparison of waiting time between Traditional System and STSC when vehicles present on two of four phases.
From the above graphs, we can see that there is a significant improvement in the waiting time of vehicles.

6.2 Emission of Gases Static VS Dynamic
The two main harmful gases that a vehicle emits are Carbon Monoxide and Carbon Dioxide. The following graphs show the comparisons:

Graph 6.4: Comparison of waiting time between Traditional System and STSC when vehicles present on one of four phases.

Graph 6.5: Comparison of emission of Carbon Monoxide between Traditional System and STSC.

The above graphs and table shows that there is a reduction in the emission of gases when using STSC.

6.3 Fuel Consumption Static VS Dynamic
The last evaluation is based on consumption of fuel by vehicles in Traditional System and Dynamic System implemented using STSC.

Table 6.1: Total emission of Carbon Monoxide and Carbon Dioxide in Traditional System and STSC

<table>
<thead>
<tr>
<th>Total emission of gases in mg</th>
<th>Traditional System</th>
<th>STSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>1134466.04</td>
<td>943493.23</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>325054244.81</td>
<td>306231410.62</td>
</tr>
</tbody>
</table>
Graph 6.7: Comparison of consumption of fuel by vehicles in Traditional System and STSC.

Table 6.2 Total fuel consumption by vehicles in Traditional System and STSC.

<table>
<thead>
<tr>
<th>Fuel Consumption (in ml)</th>
<th>Traditional System</th>
<th>STSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fuel Consumption</td>
<td>95712929.97</td>
<td>85876466.45</td>
</tr>
</tbody>
</table>

The above graph and table shows that there is a reduction in consumption of fuel when using STSC.

7. CONCLUSION
In this paper, we have proposed two algorithms
- Sensor-based Traffic Signal Control Algorithm
- Current Traffic Based Routing Algorithm

This system offers higher rates of scalability and optimization. According to our evaluation, the average waiting time has been reduced to minimum possible time units, the maximum being 120 seconds for any vehicle. Our proposed algorithm also has maximum priority for emergency vehicles and automatic challan generation system to traffic violators. Moreover, using the second algorithm, the user has the choice to take the shortest route or the route where traffic is minimum. All this is calculated based on the current traffic situation.

7.2 FUTURE WORK
The following points can be considered for further optimizations to our algorithm:
- Prediction of vehicles that are not equipped with sensors.

8. APPENDIX

8.1 GPS: Global Positioning System[15]:
The emergency vehicles always need higher priority for quick movement on roads. So a congestion free solution is very important. Global positioning System is a radio based navigation system by which vehicles of every category can get the route from source to destination. GPS uses triangular technique to position vehicles.

8.1.1 Capabilities:
1. Human readable maps in graphical or textual form.
2. Turn by turn navigation vehicles in textual and speech form.

8.1.2 GPS may be able to answer:
1. Available path for vehicle
2. Alternative routes,
8.2 Wireless Sensors:
There can be a variety of sensors, that can be used in SURTRAC system. We are using one of those sensors that will be cost effective at the same time. As we are using the SUMO Simulator there are different type of detectors available in this simulator. Some of these are:

- **E1 Detectors: INDUCTION LOOP DETECTORS**[14][17]
  These detectors are used separately on a single lane and these only give information about the vehicles passing through them.

- **E2 Detectors: AREA AND LANE BASED DETECTORS**[14]
  These detectors can be used on a single lane or on a group of lanes and gives us the information about the vehicles passing through the area covered by the detectors.

- **E3 Detectors : MULTI ORIGIN OR ENTRY EXIT DETECTORS**[14]
  In our research project we have used these type of detectors in simulation. In this two detectors are placed one at the entry point and one at exit point, both points are specified by us and these detectors give us the data about vehicles that are currently between the area between these detectors or passing through these detectors. These detectors can also be applied on a single lane or a group of lanes

**REFERENCES**


