Using Today's Information Technology to Reduce Traffic Jam in a Traffic Congested City

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Abstract

Traffic jams in many traffic congested cities are an annoying and harmful problem to the residents and travellers of the cities. Traffic jams have many diversified harmful effects on the social, cultural, political and even on the economical and financial stability and prosperity of the cities. Hence, traffic jams need to be removed from these cities at any cost. This paper has addressed a convenient, cost-effective solution to the traffic problems in a traffic congested city using today's computing power and Information Technology. We propose four principal motives: a simulation, a sensor network, a real-time web site and a data mining approach. First, the simulation will consider all the vehicles, public roads, peoples, offices, and educational institutes. The simulation will study the nature, cause, and time of people's movement and will find an appropriate schedule for the vehicles and routes; it will also suggest new working hours for different institutions to reduce congestion. Second, an internet-connected sensor network will continuously monitor traffic density and congestion in different routes. Vehicle drivers will use this system to know the current traffic status of different routes and select the best route. Third, a real-time web site integrated with the sensor network will show the users current traffic and congestion status to plan their trips. The web system would provide a jam-less and efficient route from the source to the destination. Fourth, a data mining approach will use statistical data on congestion and traffic status provided by the sensor network so that historical trends about the traffic and congestion status of different routes can be used to reschedule vehicle routes. We hope a proper design and implementation will lessen the traffic problems in a flexible and cost-effective way.

1. INTRODUCTION

Traffic congestion is one of many serious global problems for both developed and undeveloped countries. In this paper, we addressed the issues of reducing traffic jams in a congested city, an area experiencing rapid population expansion and traffic congestion. The causes behind the traffic problems are mainly significant increase in population and vehicle number, simultaneous presence of motorized and non-motorized vehicles on the same street, traffic mismanagement: violation of traffic rules and regulations, and poor transportation and infrastructure planning. As traffic problems have a diversified bad effect on social, economical, financial, and political stability, preventing traffic problems is now in utmost importance. we propose four principal motives to build an effective traffic system that would lessen traffic jams to a great extent. An effective traffic system and traffic control can also increase the total traffic capability with the existing vehicles. Effective traffic controls are greatly depended on traffic surveillance systems that usually use loop detectors (in many developed countries), which have a high installation and maintenance costs. In view of this, we would propose a relatively low cost solution, which will apply simulations, wireless sensor networks, a real-time web site, and data mining approaches for traffic controls.

We propose a computer simulation to find a proper schedule for the vehicles that will effectively reduce traffic jams. Besides, the simulation will provide some important design requirements for traffic control systems: the number of vehicles needed per route, the scheduling of traffic signals. Sensor networks will provide real time data about the current traffic status over the whole city. Proper utilization of the sensor data about current traffic status can effectively reduce traffic jams on the fly in near future.

We recommend for Berkeley Mica2 motes sensors in TinyOS platform to detect vehicles and traffic jams. The Mica2 mote has a 7.37 MHz processor, 4 KB of RAM, 128 KB of flash memory, 933 MHz wireless radio transceiver (38.4 Kbps transfer rate, 500 feet range), and is powered by two AA batteries. Pluggable sensor boards with temperature, light, magnetic and other sensors are available. The magnetic sensors will be utilized to detect vehicles. The Berkeley motes run the TinyOS operating system, an open source, event driven and modular OS designed to be used with networked sensors. TinyOS handles task scheduling, radio communications, clocks and timers, ADC, I/O and EEPROM abstractions, and power management. Application developers can select a subset of the modules, extend or override them, and statically compile them into the final executable.

A real-time web site integrated with the sensor network will provide sufficient realtime information to the driver's of the vehicles to avoid traffic jams in near future. The day to day data collected through real-time sensor networks will be consulted using a data mining approach to study the causes of traffic jams. The study will result in a new schedule for the vehicles in order to reduce traffic jams.

2. APPLYING COMPUTER SIMULATIONS

To reduce traffic jams firstly, we propose a simulation. The purpose of the simulation is mainly to schedule the public vehicles. Statistical data on the movement of private vehicles will be collected and the data will be used to schedule the public vehicles. The timetable and the specific routes of different public transport will be determined. Besides, new schedule for the opening time and ending time of different institutes: academic institutes, offices, and shopping malls will be fixed to distribute the movement of people evenly and this new schedule will indirectly help in reducing traffic jams.

In the real world, the vehicles and the passengers are continuously moving with time, an event based continuous simulation model is appropriate in our case. The vehicle movement will be simulated in time and the congestion condition will be detected on the fly. The possible events in the simulation are start of a vehicle from a bus stop, stop at the intermediate bus stops, overtake other vehicles, reach very close to a vehicle, change lanes, take a turn in the intersections, traffic signals, a congestion, an accident. The simulation will run over a long period of time and congestion conditions and causes will be studied. The components of the simulation model are

- **Passengers:** All passengers inside, to and from the city.
- **Routes:** The routes over the city, the in and exit routes to and from the city, lanes in a route, and maximum and minimum speed in a route.
- **Bus Stops:** The bus stops inside the city, the bus stops from where buses travel to, and from the city, the capacity of the bus stops, the intersections inside and surrounding the city, and vehicles leaving rate from the bus stops.
- **Vehicles:** The vehicles that run over, to, and from the city, velocities of the vehicles, classifications of the vehicles, vehicle type, and passenger carrying capability of the vehicles.
- **Institutes:** The institutes inside the city and their employee count along with the residential area statistics of the employees, all offices and their starting and ending time, and density and nature of public movement.
- **Traffic Signals:** The traffic signals and their timing.

A simulation model will be defined where the distribution functions of all its input parameters are defined using mathematical or logical expressions. Vehicle leaving rate and passenger arrival rate at different bus stops, the vehicle speed on a road will be expressed using a distribution function. The passenger arrival rate will vary depending on the institute's schedule on the road and on the day of the week. Distribution function of the traffic signals will be defined. Different turning points can be mapped as queueing systems: m/m/1 and m/m/m. The rules for the distributions are defined in [1]. Before the simulation, all the feasible routes of each source and destination of the public vehicles should be known in advance. However, in the simulation we would give preferences to the shortest or near shortest routes in terms of distance and time for a particular source and destination. Using an efficient shortest path finding algorithm (Floyd's all pair shortest path algorithm) all the shortest routes can be determined. At the start of the simulation, the vehicles will be placed randomly in different bus stops and the timer would be initialized to the morning of a day. The vehicles would leave stops using a distribution function. The vehicles will use the information about the positions, speeds, accelerations of other surrounding vehicles along with width of the road to decide it's own speed. At turning points the traffic lights will be turned on and off using some schedule and variable time interval. The vehicles need to know the traffic signal status also to decide their speed, waiting time, and turning. Within the simulation runtime, we have to measure the density of the vehicles at different places, waiting time of the vehicles at different places. The density and the waiting time will indicate the traffic jam condition. Also tracking information regarding unusual events such as accidents can help. As the system is a huge system we can simulate route by route initially.

To determine the proper schedule for the vehicles we have to test different schedule. We have to vary different input parameters to see the effect on the jam status and to determine the proper value of the input parameters. The analysis of the simulation data will provide the value of different output parameters: total number of public vehicles needed for a jam-less city, vehicles needed per route in different time of the day or in different day of the month, schedule and specific routes for public vehicles, guide lines for the private vehicles to avoid jams, schedule for different organizations and shopping malls, schedule and orientations and timings of traffic signals, vehicles service time at different bus stops depending on the passenger density/arrival rate and current congestion statistics. Using advanced methods for simulation: Fractional Factorial, IFFD, Latin Hypercube can minimize the number of simulation runs. Besides, regression analysis, Fourier Amplitude Sensitivity Test can help in fast detecting of most sensitive input parameters [2].

A. A Simple Mathematical Model for Traffic Movement

In this section, we define a probable simple model to simulate cars and to collect the needed parameter value. we work on some assumptions firstly, as long as there's no obstruction (another car or a red light) in front of a car, it will travel at the speed limit of c (light speed) kilometers per hour. Second, If a car gets within a distance of L meters from an obstruction, it will reduce its speed proportionally to that distance. Third, If a car gets within a distance of l meters from an obstruction, it will stop altogether. Fourth, in a region of length d if

$$vehicle\ waiting\ time > 10\ minutes \text{ and}$$
$$vehicle\ count = d/(average\ vehicle\ length) >= 5 \tag{1}$$

we declare a jam condition. Let x denote the distance in meters between two cars (measured from the back of one to the back of another). The speed v of the car is

$$\begin{gathered} c,\ if\ x >= L \\ between\ 0\ and\ c,\ if\ l < x < L \\ 0\ if\ x <= l) \end{gathered} \tag{2}$$

In the second case, $l < x < L$, we assume the car changes speed proportionally to changes in distance, so that v is given by a linear function of x. This means that $v = mx + b$ for two constants m and b. These constants can be determined from the two conditions $v = 0$ when $x = l$, $v = c$ when $x = L$; from these, we can solve for m and b in terms of the three fundamental numbers c, l, and L. In summary, then, we assume that the speed of a car is given by the following function of the distance x to the closest obstacle in front of it

$$\begin{gathered} v = c,\, if\ x >= L \\ v = mx + b,\, if\ l < x < L \\ v = 0,\, if\, x <= l \end{gathered} \tag{3}$$

where m and b can be expressed in terms of c, l, and L. These three numbers, therefore, completely determine the traffic behavior.

In the simulation model, the traffic state at a given time is characterized by the positions, velocities, and the lane index of all vehicles. The decision of any driver to accelerate or to brake depends only on his own velocity, and on the front vehicle immediately ahead of him. Lane-changing decisions, however, depend on all neighboring vehicles. We can simulate accelerations and decelerations using the Intelligent-Driver Model (IDM). In this model, the acceleration dv/dt of a given driver depends on his velocity v, on the distance s to the front vehicle, and on the velocity difference Δv (positive when approaching). Here,

$$\begin{gathered} acceleration = \frac{dv}{dt} = a[1 - (\frac{v}{v_0})^{\delta} - (\frac{s^*}{s})^2] \\ where\ s^* = s_0 + (vT + \frac{v\Delta v}{2\sqrt{ab}}) \end{gathered} \tag{4}$$

The acceleration is divided into a desired acceleration $a * (1 - (v/v_0)^{\delta})$ on a free road, and braking decelerations induced by the front vehicle. The acceleration on a free road decreases from the initial acceleration to zero when approaching the desired velocity v_0. The imposed deceleration increases with decreasing distance to the front vehicle (one wants to maintain a certain safety distance) increasing own velocity (the safety distance increases) increasing velocity difference to the front vehicle (when approaching the front vehicle at a too high rate, a dangerous situation may occur). Model Parameters the IDM has intuitive parameters: desired velocity when driving on a free road, v_0 desired safety time headway when following other vehicles, T acceleration in everyday traffic, a comfortable braking deceleration in everyday traffic, b minimum bumper-to-bumper distance to the front vehicle, s_0 acceleration exponent, delta. Typical values that we can use in the simulation are v_0 = 120 km/h (e.g., 50 km/h for city traffic), $T = 1.8s$, $a = 1\ m/s^2$, $b = 3\ m/s^2$, $s_0 = 2m$, and $delta = 4$. In general, every driver-vehicle unit can have its individual parameter set, e.g., trucks are characterized by low values of v_0, a, and b, careful drivers drive at a high safety time headway T, aggressive drivers are characterized by a low T in connection with high values of v_0, a,and b.

To simulate Lane changing, we can consider symmetric traffic rules where all types of vehicles are allowed to drive and overtake on either lane. Lane changing is governed by two criteria that have to be fulfilled simultaneously. First, the incentive criterion is fulfilled, if the driver anticipates that he could drive more freely on the new lane (own advantage), and he does not force other drivers to brake too hard (disadvantage of others). Second, the “safety criterion” i.e. Lane changes leading to accidents or forcing other drivers to make emergency braking manoeuvres are forbidden.

3. APPLYING SENSOR NETWORKS

Simulation will provide a schedule for the vehicles and routes so that traffic jams are reduced to some extent. However, all the real time situations can hardly be introduced in simulations. Therefore, we argue for sensor networks along with computer simulations that will provide data to reduce or avoid traffic jams on the fly.

A. Hardware and Software Requirements

Usually inductive loop detectors are used in many automated traffic surveillance systems to detect vehicles. However, these detectors are not suitable for large scale deployment as they are destructive, disruptive, and having a high cost of installation and maintenance. Other systems [3] have either high equipment cost, or accuracy greatly dependent on environment conditions. The purposed sensor networks have the potential to revolutionize traffic surveillance technology because of its low cost and ease of deployment. We recommend Berkeley mica2 sensor motes in TinyOS platform for detecting vehicles that use some magnetic technology to detect vehicles. The motes are relatively cheap, easy to use and reliable. The programming of the motes needs nesC and Java.

B. Vehicle Detection Issues

Using the Doppler-shift principle, microwave technology senses moving objects by first sending a signal toward the roadway. When a vehicle passes through this pattern, some of the energy is reflected back to the unit at a different frequency [4]. This application of sensor networks can be used to detect moving targets such as vehicles and travellers, especially approach-only and depart-only objects. The TinyOS sensor motes are based on a similar technology. With the mote’s RF wireless transceiver, the analog-data interface and magneto-meter located on the mica sensor board can be used to detect magnetic materials, such as cars. Besides detecting vehicles, mica2 sensors also have the potential to do vehicle classification and road conditions monitoring. According to [5], we can only detect car’s magnetic material with speeds in a specific interval; thus, the sampling rate needs to be adjusted to be high enough to detect the highest speed cars, and use the absolute magnetic field to detect lower speed cars. Theories utilizing tree construction, node graphs and traversal algorithms optimize situations involving the mica board mote Base Station in trying to detect cars in parking lots [6].

The primary goal of utilizing TinyOS sensor networks is to use signal strength readings to infer the distance between the motes. According to [7],

$$signal\ strength = y = (Clog(x) + v) \tag{5}$$

where x, a distance vector, and v, some minor Gaussian noise, and, C a mathematical parameter that can be optimized depending on a variety of constraints. In addition, a radio antenna can be attached to the mica board mote so as to improve ranging and Radio Frequency (RF) communication. The attachment of this radio helps greatly in calculating the signal strength. The utilization of this signal strength/distancing data has a two-fold benefit in highway applications and analysis [6].

- **Surveillance metrics:** Utilizing sensor detection in surveillance metrics. in [8] Varaiya et al. using video traffic detectors demonstrated its usefulness. The crux of the research essentially involves forming a vehicle re-identification algorithm for consecutive detector stations on a freeway, where downstream and upstream detector measurements were matched with a reproducible vehicle measurement, or vehicle signature[2].
- **Data for PeMS:** Monitoring traffic with sensors serving as information/data in the front-end processors (FEP) of sensors. These processors retrieve data from freeway loops very frequently and the data can be used every 30 seconds to form important operational decisions as in PeMS [8].

C. Sensor Placement/Deployment Theory

The optimal placement of sensors for getting the best possible and most accurate measurements is critically important to data transmission. Firstly, the work done should be the minimum. To minimize the work/power, the amount of data transferred needs to be a minimum. Sensors at different regions send data to the base station and the base station generates output when a vehicle is detected. So our target is essentially finding an optimal mapping of sensor nodes that minimizes the amount of data transferred among the regions to the base station. The standard sensor placement problem is a NP-complete task assignment problem that is centralized and depends on information from global nodes. However, Bonfils and Bonnet [9] propose a decentralized (each node should only maintain information about close-by or local nodes) and adaptive(operators and detections between nodes can be altered at any time, in an ad-hoc fashion) and local solution to the sensor-placement problem. The theory is based on cost, a function of the amount of data received and produced by a node. The cost is estimated from a set of nodes that receive data from an active node that transmits data. Of course, minimization of cost is the goal. Their algorithm progressively refines the placement of operators (nodes) towards an optimal placement. Therefore, we should be able to rig up a sensor network configuration on highways using TinyOS sensors that minimize the amount of data being transmitted. We, thus, minimize the power consumed. However, sensor network topology is one of the main limitations to this algorithm. In the specific case of highways and traffic, if sensors were placed at different geographical heights, i.e. some on a mountain/building, while on the roadway level, data transfer would exhibit non-linear behavior. The ideal, and not very-realistic, case is to have data transferred along straight lines, all on the same topographical surface. Cost would then be simplified to a linear and directly proportional function of distance between nodes. Therefore, we desire the flattest sensor network topology available to simplify and optimize data transmission as much as possible. They also define an oriented sensor network graph (SNG) for the purpose [9].

D. Energy Saving in Placement of Sensors

For energy-efficient localization and tracking of mobile targets, gains in energy-savings come at the expense of increased accuracy in tracking [10]. Therefore, a direct tradeoff exists between energy/power consumption and the accuracy in which we can track objects or measure data. An intuitive way to save energy is to only turn on a subset of sensor nodes in a network, essentially, only the required ones leading to an increased uncertainty in the sensed regions though. Pattem et al. in [10] analyze these energy-quality tradeoffs by first proposing a quality metric and an energy metric, and then using those to develop four main tracking strategies. They recommend selective activation to be the optimal for highway and traffic applications [10]. It would be best if all the TinyOS micaboard sensors could be equipped with intelligent packet-routing capabilities that would allow them to communicate the next area/location of where a car is headed. Once the car heads to that next location, the micaboard motes in the area left by the car would have a mechanism to turn themselves off, while the motes in the next area would be able to turn themselves on. This would propagate successively as a sequence of circles with radius S_p to achieve optimal measurement accuracy and minimal tracking error. Also, power and energy consumption would be in turn minimized. For this setup, it is best perhaps to utilize an omnidirectional ultrasound micaboard, in order to sense the mobile target in all directions. If we use this along with a duty cycled activation [10], and adjust the tuning knobs of t_{ON} or T_D accordingly, then we can be sure we are obtaining the best possible tradeoff between tracking error and energy/power expenditure.

E. The Sensor Network Model or Structure over the City

The bus stops where buses start from needs to be sensor equipped that can be tiny (Mica2/Mic2Dot) or large sensors such as webcams. The total bus stop will be covered with sensors specially at the exit and ingress points. The sensors will detect the exit and in of the buses. The buses can be tagged with it's identification and destination. The sensors will be centrally connected to a base station (PC) through a gateway (sensor). The base will be connected to the Internet. From all the bus stops, the data of how many buses are now on road can be found. The database, our suggestion is to be distributed. we suggest the database should be distributed per group of interconnected routes as the query response time should be a minimum. Besides, all the intermediate bus stops should be sensor equipped to know the exact movement of the buses. Also the well known congestion places should be sensor equipped over a large surrounding region to detect jams also the length and timing of the jams. Moreover, the major turning points/traffic signal area can be sensor equipped. The sensor nodes would also be installed in the middle of each lane of traffic at periodic locations along the roadway and would have 1-hop connectivity with all other nodes at its mile marker, as well as the nodes at the mile markers directly preceding and following its location. For some nodes there will be a gateway. The gateways would provide a wide-area network connection from the sensor network to the data center.

F. How to Detect Congestion Area and Congestion Free Area

By aggregating traffic flow in a fine-grained and highly-distributed manner across all lanes, including any egress or ingress lanes, we will be able to accurately identify traffic state changes in near real-time. In our model vehicle trajectory data are processed locally in a dense network of sensors and shared with neighboring sensors that are upstream, downstream, and in adjacent lanes, facilitating the detection.

G. How Sensor Networks Will Help

At any moment, all the jam status, vehicle distribution and movement status can easily be found. Current jam area and the probable jam area in next few minutes/hours will be determined. Hence, car drivers can take alternate routes. The data will be centrally analyzed by the traffic department using some software (using AI approach) and using some forecasting about the near traffic jam area or suggestion to the car drivers how to take the proper route.

H. How to Draw Driver's Attention of the Congestion and Free Area

Using some display boards at major crossings we can draw driver's attention of the congestion and free area. Displaying traffic jam status and vehicle density status until the next 5/6 bus stops or only the jam area over the whole city can be shown. Some symbolic guidelines for the drivers whether to take the route or not can be provided in the display boards. Besides, some decisions can be taken centrally by the traffic department analyzing current data. The decision can be propagated to the traffic police on roads to guide the vehicles. The traffic polices can use the display board information to guide the vehicles. At the university of Berkeley a way is developed to get updates on traffic hotspots, alternative routes and travel times up to an hour in advance via the Internet or cellular phone.

4. WEB ENABLED SERVICES

We propose a real-time web site that provides the schedule for different vehicles and routes depending on the computer simulation. The web site will be integrated with the sensor networks. This integration facilitates using the sensor data to know the current status of the traffic in the city. The web site will show current congestion areas, how many vehicles are there, how much time will be needed to recover the jam. Also probable alternate routes of the congestion area with some statistics of the congested route.

The web site will be utilized in many different ways such as driver's will consult web site to plan the route from source to destination using a congestion free area. Driver's while on the road will use the display boards to decide about their routes. An easy and quick understandable representation of the traffic information for the display boards will be discovered. Vehicles can be internet enabled using some wireless technology to use the web site. Cars will connect to the Internet instantly and consult web site and close connection. The web site will provide current traffic status data of different routes. The data include number of vehicles in a region, vehicles density, congested and free area, statistics about vehicle velocities in the route, is there any jam on the road, the congestion statistics, how many cars in a jam, the length of the jam, duration of the jam. warning to the cars in jam, warning to the cars who are going to that jam area. The warning will be shown with the display boards. The warnings will also be passed to the traffic police so that they can guide vehicles accordingly. A background process in the web site can analyze the traffic data using some AI techniques to decide to terminate or shorten the traffic jam. Central offices of traffic can utilize this information to the traffic police to guide them to guide vehicles.

5. DATA MINING APPROACHES

Initial schedule for the public vehicles will be determined using computer simulations. While the schedule is in action sensor networks along with guiding the vehicles, will collect day to day traffic information. This volume of data will be analyzed using data mining approaches to study the traffic jam characteristics. The parameters to be understood are locations where jams occur frequently, frequency of jams in different locations, time and density of Jams, causes for traffic jams, and length of a jam. Based on the analysis, new schedule might be needed for many vehicles along with minor schedule modifications to some vehicles in order to reduce future traffic jams.

Data mining analysis adopt one or more approaches: genetic algorithms, neural networks, decision trees, clustering, classification and others while we recommend clustering and classification data mining for traffic data analysis. Initially, clustering data mining will be applied where based upon the supplied metrics/parameters (mentioned above), relationships among the data, input parameters and target parameters(traffic jam/incident) will be discovered. In classification data mining, several traffic classes: severe jam, lengthy Jam, jams at office opening times, jams at office ending times and so on will be defined based on our purpose. Each class will have some predefined values of the parameters. Hence, different types of traffic jams, and their causes, locations, time, density, frequency would be identified easily. This would help us to make decisions where and how to change the schedule for the vehicles.

Different incidents in urban areas contribute around 50 to 60% of the total congestion delay [11]. Managing an incident effectively is one of the key challenges in traffic management. However, we hope an effective use of our approach (simulation, sensor network, real-time web site, data mining) can result in managing incidents successfully with lesser impacts. Data mining can reveal many hidden treasure and understandings in the data to better manage incidents that otherwise can not be found. There is little research on applying data mining techniques in traffic and transport related research. However, some related important researches are dealing with a mass of transportation data, and the advantages of applying data mining to retrieve or analyze the useful data [12], [13], transportation oriented simulation system [14], travel time estimation [15], and logistics [16]. Applying data mining in incident management is forming a new conception [17], [18], [19].

A convenient way to adopt data mining analysis is to use a software that facilitates to mine the data in various ways such as DataScope. DataScope provides a convenient visualization of data in up to six dimensions simultaneously so that data is analyzed visually. DataScope offers a variety of data mining techniques: decision trees, cluster analysis, relation finder, spectrograms and others. Users can use different methods and compare the result to get better insight of the analysis. In DataScope first, all strong relationships in the database will be discovered with the help of relation finder algorithm. The algorithm provides a list of pairs and triples ranked based on the strength of relationship. Then, those output would be visually analyzed for any interesting or new patterns. Second, we will use decision support to arrange the data in the form of clusters based on the comparability of data. After that Fuzzy C-Means (FCM), which is a widely applied clustering method [20] will be used to cluster the data. Again, the clusters will be viewed graphically for further understanding of the data. Incident data are divided into clusters according to flow, density and time relationships. This also helps to visualize the distribution of data under a specific cluster or category. The information represented via visualization aid WILL assist Traffic Management Center (TMC)/traffic engineers to take necessary actions at the occurrence of an incident [21].

We also propose research to investigate the applicability of data mining tools along with statistical clustering techniques to develop a superior traffic signal timing plans for the city under consideration. The use of hierarchical cluster analysis will be used to automatically identify temporal interval break points using time-of-day (TOD) signal control system. The cluster analysis approach is able to utilize a high-resolution system state definition that takes full advantage of the extensive set of sensors deployed in a traffic signal system. Timing plans can be developed based on the clustering results [22].

6. CONCLUSIONS AND FUTURE WORK

In the paper, we propose a cost effective and convenient method to reduce traffic jams in a traffic congested city. Our proposal includes a simulation, a wide area distributed sensor network, a real-time web site, and a data mining approach. Future works may focus on the development of the simulation software, a prototype sensor network and a prototype realtime web site. The data mining approach will analyze the data from the prototype system. An extensive analysis and modification of the simulation model might help to improve simulation output. An in depth analysis of socio-economic factors and the influence of the system to the people will be done. Moreover, a technical and financial feasibility study will be performed to make the plan really fruitful. However, we hope our approach will provide a convenient, cost effective, and practical system to reduce traffic jams in a traffic congested city.

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