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Smart Traffic Management System for Traffic Control using Automated Mechanical and Electronic Devices

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Smart Traffic Management System for Traffic Control using Automated Mechanical and Electronic Devices

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Abstract- In the current context of smart city, specifically in the industrial and market zones, the traffic scenario is very congested most of the time particularly at the peak time of business hours. Due to increasing growth of population and vehicles in smart and metropolitan cities people face lot of problem at the major traffic points of the business towns. Not only it causes travelling delays, it also contributes to environmental pollution as well as health hazards due to pollution caused by vehicle fuels.To keep away from such severe issues many radiant urban communities are right now implementing smart traffic control frameworks that work on the standards of traffic automation with prevention of the previously mentioned issues. The fundamental concept lies in collection of traffic congestion information quickly and passing the alternate strategy to vehicles as well as passengers with on-line traffic information system and effectively applying it to specific traffic stream. In this context, an enhanced traffic control and monitoring framework has been proposed in the present article that performs quick information transmission and their corresponding action. In the projected approach, under a Vehicular Ad-hoc Network (VANET) scenario, the mobile agent based controller executes a congestion control algorithm to uniformly organize the traffic flow by avoiding the congestion at the smart traffic zone. It exhibits other unique features such as prevention of accidents, crime, driver flexibility and security of the passengers. Simulation carried out using Ns2 simulator shows encouraging results in terms of better performance to control the delay and prevent any accident due to profound congestion up to a greater extent.

Keywords: VANET, Smart City, Traffic Management, Video Monitoring, Signal System,

1.Introduction

Fundamental features of designing an enhanced traffic control system consist of linking traffic signals and traffic control centres with GIS enabled digital road map of the town using intelligent computational power of data analytics [9] as a key module. In this context, the basic challenge lies in usage of real time analytics on on-line traffic information and correctly applying it to some basic traffic flow [13] & [14]. Data analytics tools [18] & [19] takes data from the Traffic Management System [9] and using GIS mapping under real time support they provide useful information to the drivers in the vehicles and help reducing the traffic congestion. Additionally, basic tourist information such as visiting places, parking area and distance are also projected in real time basis on large digital screens installed at city centres [20] entrance points to guide the drivers towards their destination. This helps to save fuel and finally to save a lot of time spent in searching various visiting places[11]. The smart living style in metro cities [20] is also fulfilled as the environment becomes pollution free and more hygienic[10].

The projected transport system has been planned in a Vehicular Ad-hoc Networks (VANETs) scenario as these networks are becoming more trendy technology in smart road traffic management and control systems. The problem faced by smart cities in terms of traffic congestion issues can be solved better by the use of VANETs as there is a network connectivity between the vehicle and the network infrastructure. Therefore, predictable information regarding road condition ahead and route information can be directed to the smart vehicles in transit and intelligent decisions can be taken sufficient time before any problem occurs. In other ways VANET in smart cities helps to reduce the problems of congestion, accidents, crime, parking problems and population overhead. Due to the overall development of the wireless technology, their applications are immense on vehicles and vehicles have been converted to smart vehicles to be accessed under smart traffic applications. The traditional driving systems and drivers have also converted to smart drivers with more technical knowledge of receiving smart signals from traffic controllers, understanding them and act accordingly. VANETs support flexible communication between vehicles and traffic controlling systems in both infrastructure based and in wireless medium without fixed infrastructure. The proposed traffic congestion solution in smart city uses an improved technical explanation to the problem with powerful data analytics made by mobile agent dynamically under VANET scenario in a smart city.

Mobile agents are flexible software programs supporting platform independence and good compatibility among computer workstations, client and servers and between controllers and peripheral devices. They are autonomous and re-configurable during run time so that they have the ease of being used as a support with any application program. Mobile agents are greatly used in database applications, digital signatures and on-demand network applications. Throughput of the mobile agent based applications are greatly affected as per the level of complex task handled by the agent. The challenge lies in carefully selecting the scripting language which can be smoothly implemented to communicate between platforms. In the proposed application, mobile agent has been used to implement the congestion control algorithm in an automated traffic control system in smart city context. The article has been organized in the following manner. Section 1 focuses on the introduction part, section 2 describes an extended literature survey on the related area and similar application details. Section 3 illustrates a detailed demonstration of the proposed model under VANET and detail technical functionality are explained in terms of various modules used in the system. Similarly the safety and security aspect of the system is also highlighted here. Next, section 4 demonstrates the simulation carried out using Ns2 simulator with technical configuration and results. At last section 5 concludes the paper with scope for further improvements to the model.

2. Related Work

This section presents a complete literature survey on similar subject with relevance to the proposed approach.In [23] a real time distributed framework has been proposed to classify the urban road network congestion level using VANET. The article proposes models based on concept of spatial and temporal measures on synthetic data extracted from a specific case study. A low cost real time smart traffic management system has been presented in [8] using Internet of Things (IoT) and Big Data [25] .It provides improved service by implementing traffic indicators to update the traffic related information at every instance of events taking place in the network. In this approach low cost sensors with capacity of vehicle detecting system applications are embedded in the middle of the road at an interval of every 500 meters and 1000 meters. IoT devices [12] are used to acquire the traffic related on-line information quickly and further sent for processing at the Big data analytics [25] centers. Intelligence based analytical tools are used to scrutinize the traffic density and solution strategies are modeled. Congested traffic is managed by a mobile application based on the explored traffic density and alternate solution of this. An on-road air quality monitoring and controlling method has been proposed [24] with development of agent-based model that includes urban road network infrastructure and assesses real time and approximate air pollution index in different segments of the road and produces recommended strategies for road users. Such strategies include reducing number of vehicles usage in most polluted road segments, reducing the pollution levels with increasing vehicle flow on the roads. Data sets used for this purpose are collected from a location of quality monitoring system, road network information available and embedded low-cost e-participatory pollution sensors.Mobile Cloud Computing supports technical development in smart cities. An Improving Healthcare application using mobile cloud computing and big data analytics [25] has been proposed in [1] where a cloudlet-based mobile cloud-computing infrastructure has been developed. Comparative study and analysis has been done with a benchmark evaluation of Hama's graph package and Apache Giraph using PageRank algorithm[2].

Comparative studies and empirical evaluations have been performed in big data applications [10] in this article. For dynamic usage of electricity in smart city , a novel approach for clustering of electricity consumption behavior has been applied [3] and Markov model is applied to model the dynamic electricity consumption and a clustering technique has been developed by fast search and find of density peaks (CFSFDP) which is primarily carried out to obtain the typical dynamics of consumption behavior. A scheduling algorithm, which is called multi clouds partial critical paths with pretreatment (MCPCPP), for big data workflows in multi clouds is presented [4]. This algorithm incorporates the concept of partial critical paths, and aims to minimize the execution cost of workflow while satisfying the defined deadline constraint. A hierarchical distributed Fog Computing architecture to support the integration of massive number of infrastructure components and services in future smart cities has been carried out [5] and a smart pipeline monitoring system based on fibre optic sensors and sequential learning algorithms to detect events threatening pipeline safety has been developed. An Ant Colony Optimization (ACO) based joint VM migration model for a heterogeneous, MCC based Smart Healthcare system in Smart City environment [6] has been proposed where the user's mobility and provisioned

VM resources in the cloud address solves the VM migration problem.Smart transportation system is very much in smart city context. Therefore, to analyze how analytics [25] can be used to build a smart transportation system has been proposed in [7] and it imposes that Smart phones should be linked to smart traffic signals [10] & [11] to achieve the objective of smart transportation system. Performance of the communication protocol specifically traffic control systems in vehicular ad-hoc networks (VANET) is primarily influenced by the density of the traffic in terms of number of vehicles. In this direction the broadcasting performance of 802.11p for VANETs has been studied and analysed [22] and results focuses on accuracy of the improved mathematical models with features of inter-vehicular communication. Basically the analysis highlights correct applicability of the contributed methodology on proposed models and the performance of the VANET protocols on practical configured road networks.

3. Our Projected System

An Intelligent Traffic Management Framework has been proposed in this section as depicted in fig.3. The planned framework deals with traffic control system STMS as the core module and it has the sub-modules such as video control system, Traffic Control System,, Supervisory computer control system and peripheral devices.The Traffic Control System manages and controls the heavy traffic during pre-defined rush period on the road. It uses the video monitoring system to identify excess traffic through video camera and when the amount of vehicles in particular path increases a pre-calculated threshold value, it informs the traffic control in-charge of STMS with an alarm indicating “traffic limit reached” and prevents any further vehicle to enter in that path.

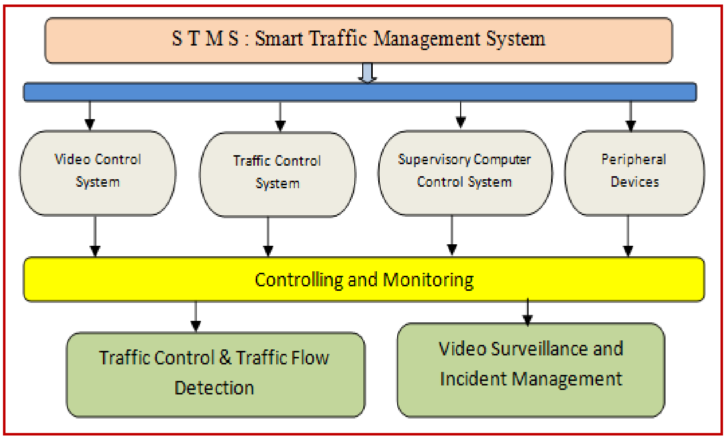

Fig.1.Block diagram of the proposed system

Fig.1 shows the basic block diagram of the proposed system with all the functional components and controlling system. So the next vehicles would be diverted towards another selected path, hence controlling the traffic. This traffic control system incorporates efficient transmission and uninterrupted communication by sending and receiving correct signal in proper time events. The smart peripheral devices handle the correct configuration of input sensors and output actuators to capture and detect the events and send the response and required information to control points. Similarly deployment of CCTV Camera at noticeable traffic points which covers maximum range of scenario is also important activity of this module.

3.1 Intelligence Computation and Data Analytics

In the proposed system, smart data analytics has been used to tactfully handle the congestion scenario and control the congestion with the implementation of dynamic mobile agent. The designed procedure used for preventing traffic congestion is as follows.

- Step 1- Total number of vehicle information transiting, crossing and waiting for a specific traffic at a particular time range is sent by the traffic signal sensor device to the central server.
- Step 2- The above real time data from sensors serves as input to the data analytic engine and used by the mobile agent at the STMS supervisory computer control system which is connected to the GIS mapping of the roads.
- Step 3 – When the congestion level crosses a particular threshold value, the data analytic engine sends a broadcast message to all the agent computers through mobile agent service situated at traffic controllers to divert the next two and four wheeler passengers to an alternate route.

- Step 4 – When the congestion level decreases the threshold value, again another broadcast message goes to the traffic computer controllers to manage the vehicle system properly.

3.2 Characteristics and attributes

i. Fair load balancing - It performs fair load – balancing among all the available traffic points by re-routing vehicles from overloaded traffic centres.
ii. Flexibility of Priority - It checks the priority of the vehicle in case of emergency and allows to pass such vehicles with higher priority.
iii. Prevention from accidents - In case of any symptom of accident ahead, it alarms the vehicles in queue and re-directs their route and necessary action are taken by human operators.
iv. Security Enabled features during Emergency – Due to any physical climatic problem, hardware failure or any network issue, if the STMS controlling system predicts chance of any link failure, then it broadcasts alert messages to all the sensor points sufficient time before so that preventive measures can be taken to restore all the on-going activities as well as precautions can be taken.
v. Use of Dynamic Mobile Agent for flexibility of communication
vi. Help on Parking Places & correct route information -
vii. When the system detects a vehicle from other states, or outstation, it guides the drivers regarding nearby places, route information, tourist places and parking places with digital guidance system.
viii. Two versions of the proposed system has been developed here,i.e STMS with Route Divert and STMS with STOP and WAIT. The STMS with Route Divert protocol runs at the signal point SP1.1 (fig.3) after entering a range of one kilometre of the proposed VANET model's traffic range where the driver chooses to divert his route in other direction in case of excess congestion at the traffic. STMS with STOP and WAIT version is used at the second signal point within half kilometre range of the proposed model (fig. 3) where the driver of the smart vehicle chooses to wait for some time (to go in the same traffic flow) till the congestion is released.

3.3 Design of Smart Vehicles

This section provides an average assessment of basic pre requisites before implementing the proposed model in a metropolitan city. Generally, the fundamental requirement for the proposed traffic control framework includes one urban traffic control centre, centralization of around 200 intersection points in the city, approximately 4,700 vehicle loop detectors, 60 video detection cameras, fifty signalisation devices for blind persons , replacement of approx. 1,400 signal points, Continuous service maintenance applications .Co-ordination among all the major systems in a smart city [16] such as all critical city systems like transportation, energy, public services, public safety, health care, telecommunications are capable of communicating with each other to allow coordination and improve efficiency [17]. They are capable of generating, transmitting and processing data about a wide variety of related activities within the city. The proposed applications focus on how emerging transportation data, technologies, and applications can be integrated with existing systems across a city, helping both cities, citizens, and businesses achieve goals for safety, mobility, sustainability, and economic vitality in an increasingly complex, interdependent and multimodal world.

As the proposed smart application in this article is meant for traffic control in a smart city context, a particular traffic scenario has been considered for simulation purpose and it is assumed that a smart e-board has been embedded to every registered vehicle of the system. Ultimately every vehicle of the city has to be automatically registered through Govt. RTO Office to be used in the proposed system. All the vehicles of the city are included in the smart application registration process and they have a microcontroller chip connected to the PCB(Printed Circuit Board) of every vehicle which contains the information such as type of vehicle, weight, priority level, manufacture, driver name, driver adhaar card no., no. of passenger, capacity, crime_signal, help_signal, danger_signal, emergency_note, fuel level(in litre) and speed.

VEHICLE_TYPE specifies the type of vehicle if two wheeler, four wheeler , three wheeler or any other type with code ,WEIGHT refers to the weight of the vehicle (kilogram) , PRIORITY refers to the priority of the vehicle to pass on the current traffic point MANUFACTURER specifies the manufacturer's code and details, DRIVER field holds the name of the driver, ADHAR NO refers the ADHHAR card no of the driver, NO_PASS refers to currently how many passengers are loaded to the vehicle CAPACITY refers to the maximum capacity of the vehicle, CRIME_SIG, HELP, and DANGER signal filed are there to be used by the passenger/driver in transit. They can switch these buttons on in case they encounter some indication of crime or danger signal or if they need external help.

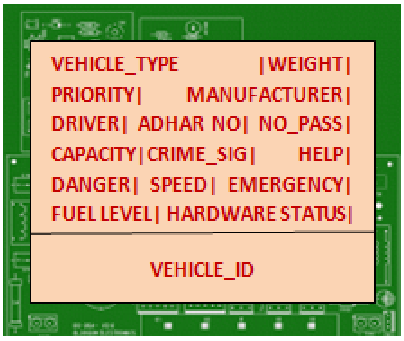

Fig.2. Fig.1 micro_controller chip used in STMS

These signals will be read by the intelligent micro sensor engine while the vehicle passes through the smart traffic control system and necessary action will be taken by the traffic authority in order to rescue the passengers in the vehicle. SPEED refers to the current speed of the vehicle. It is important to reduce the speed of the vehicle to a minimum level as specified in the STMS. EMERGENCY switch will be on when the vehicle carries out some emergency activity such as taking serious patients to hospital, engaged in military activity or any VIP person visited etc. FUEL LEVEL indicates the level of fuel in the vehicle. HARDWARE STATUS indicates that the engine, brake and other important mechanical parts of the vehicle are in good working condition or not. If any problem is found, then automatically a beep signal will be generated while the vehicke passes through the range of the network in the STMS. Then necessary action will be taken by the traffic authority for maintenance. VEHICLE_ID refers to the registered vehicle identification no. provided by the RTO (Regional Transport Office, Govt. Of India).

3.4 Practical Mechanism

Functional mechanism of the proposed model has been explained in this section. As shown in fig.3 there is a heavy congestion scenario in traffic. The main traffic controller device is placed at the central point of the traffic. This is a single scenario of one traffic point of the city. Similar STMS controller devices are deployed at every traffic point. Two signal point nodes called SP1.3 and SP 1.4 are placed at 0.5 k.m. distance from the centre of traffic post because maximum congestion takes place at this range. Next to this, another two signal point nodes called SP 1.1 and SP 1.2 are placed at 1 k.m distance from the centre of traffic post to start controlling the vehicles from a longer distance.

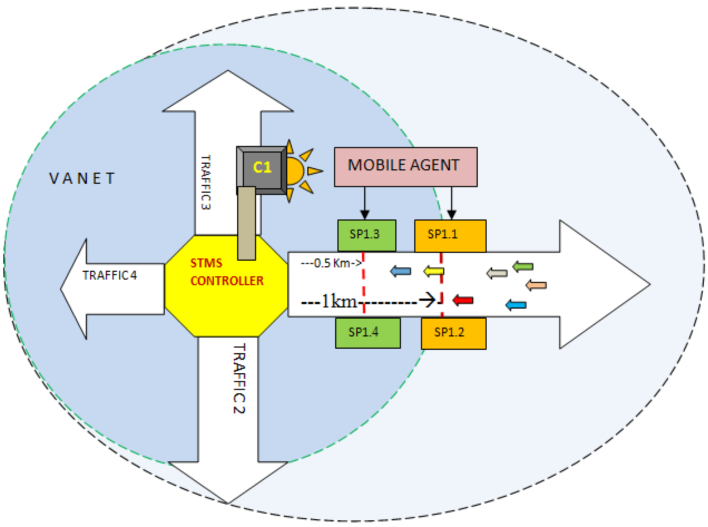

Fig.3. Basic functional diagram of the proposed STMS approach

Every smart vehicle considered in this model carries self identifiable information in its micro controller chip embedded in the vehicle PCB, so after entering the VANET zone of STMS, the vehicles are controlled and monitored by Mobile Agent. In the proposed scenario, C1 video camera which provides input to the video control system, periodically sends traffic status information to the STMS controller. As this traffic model has been designed for the city of Bhubaneswar,INDIA, so during simulation, we have taken a traffic capacity of 1000 to 2000 vehicles by considering a specific traffic area called Khandagiri square at Bhubaneswar city. During peak period of the day such as the office time which is between 9.am to 10 a.m , the traffic is maximally congested. Flow chart of the proposed system for estimation of congestion and its prevention by mobile agent has been depicted in fig.4.According to the flowchart, when a smart vehicle enters to the VANET configured zone, first its weight is checked by the sensor devices to calculate the congestion density that may be caused due to the vehicle. In this way, the total vehicle count is estimated periodically for every vehicle, when the traffic congestion threshold value for number of vehicles reaches its maximum capacity, then the proposed algorithm is executed by the proposed system.

3.5 Projected STMS for Path Alteration

The mobile agent offers two types of control during congestion. STMS with Route Divert and STMS with STOP and WAIT. The STMS with Route Divert protocol runs at the signal point SP1.1 (fig.3) after the vehicle enters a range of one kilometre of the proposed VANET model where the driver chooses to divert his route in other direction in case of excess congestion at the traffic. STMS with STOP and WAIT version is used at the second signal point (SP 1.3) within half kilometre range of the proposed model (fig. 3) in case the driver of the smart vehicle has chosen to wait for some time till the congestion is released. The stop positions and waiting time are recorded by VANET network configuration.

The mobile agent is connected with two sensor points SP1.1 and SP 1.3 from a distance of 1 k.m and 0.5 kilometer respectively from the central traffic post. If there is a congestion of vehicles sensed within the area of one kilometer of the traffic post by the mobile agent, then it triggers SP1.1 sensor to choose an option from the vehicle driver either divert the route or stop and wait. Depending on the response, if divert is selected, then the route of the incoming vehicle is diverted by sending divert signal with the proper alternate route no.

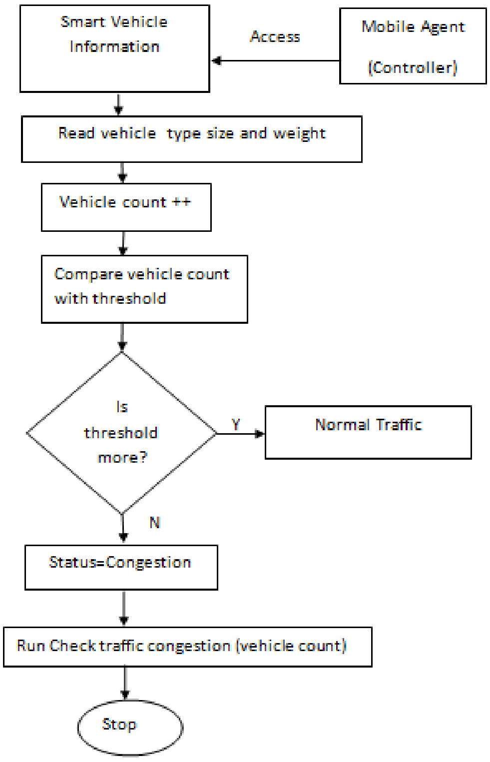

Fig.4. Flowchart of traffic congestion and prevention method

Otherwise SP1.1 validates the correct configuration of the vehicle's microcontroller and takes necessary action if required. This involves calling appropriate mechanism for emergency, priority checking human operators take precautions to provide necessary help on crime or any other symptom of criminal attacks are controlled. Then it forwards the vehicle towards the direction of SP1.3. As this is a one-way traffic system, the similar functions are carried out by SP 1.2 and SP 1.4 in the other side of the road respectively.
Here, the congestion level is estimated by the dynamic Mobile Agent [24] following the algorithm given in fig.5. A dynamic Mobile Agent is used here due to flexibility of its platform independence and good compatibility during communication between one system to other and it can be dynamically re-configured during run time as per requirement.

```
Check traffic_congestion (vehicle_count)

{

Let N be the traffic capacity

If vehicle_count exceeds N

then {alert vehicle ; input response}

{if response=='w' then wait}

Else{if response=='o' then re-route vehicle}

Check traffic_congestion(vehicle_count)

}
```

Fig.5. Algorithm used by Mobile Agent at congested traffic flow

The algorithm used by Mobile Agent is unique in this approach as it calculates the two wheelers, three and four wheelers with different values for congestion level. The Mobile Agent executes this script continuously with arrival of the vehicles to the boundary of the proposed VANET network range and sends the congestion level to the STMS controller. Therefore, at any given period of time the traffic details and congestion status of the road is available in the real time database maintained by STMS controller.

3.6 Safe Travel and Safety Support

The anticipated system conserve safety of the vehicles as well as the lives of the passengers as the vehicles are connected under a VANET scene and other connected vehicles always remain in contact with each other. Therefore, the vehicle can run safely with higher mobility with road congestion related up-to-date information. Data from connected vehicles makes travel easier and also help to handle the bus and other vehicles less polluting and makes it easier for drivers to foresee hazardous weather environment . The sensors fixed at the smart boards of the vehicles have multiple features such as generating warning alarm at any dangerous events. Sensors also keep track of each and every moment of the drive specifically it is important when any single traveler or aged traveler travels . The sensor stores the body postures of the human body in its memory and can detect any abnormal event such as accident, heart-attack, any external attack or even can sense any unusual activity in the vehicle and can alert other connected vehicles during accident for help. The traffic control and traffic flow detection system also includes traffic rule violation detection, e-challan generation, traffic analytics and simulation modeling on unforeseen situations. Any exceptional incidence taking place on the road such as theft, robbery, murder can be easily detected by the video surveillance and incident management module resulting prevention of such activities.

4. Test Analysis and simulation

The planned traffic representation has been simulated using ns2 [15] simulation tool. The nodes in a VANET can sense moving information around them which helps in monitoring the traffic, controlling the speed of the vehicles and many other traffic congestion parameters. In a VANET, the vehicles which act as mobile stations move within the VANET network range. Mobile stations are configured with various communication parameters. Two types of communication are possible using the VANET nodes, vehicle to vehicle communication and vehicle to infrastructure(V2I). In this simulation work, we have used the V2I approach in which vehicles interact and response with the road side sensor units through network routing devices at the road side. To simulate a realistic VANET scenario, ns2 has been integrated with SUMO and MOVE tool [15].

Table 1. Network parameters used in Simulation

Parameter	Value
Channel Type	Wireless Channel
Propagation	Radio-propagation model
Network Interface	Wireless Phy
MAC Type	MAC/802_11
Interface Queue Type	Drop Tail
Antenna Model	Antenna/OmniAntenna
Max Packet Size in ifq	100
X Dimension	1000
Y Dimension	1000
Simulation Tool	Ns2

Table 1. describes the network parameters used during simulation in Ns2 [15]. There are two basic elements in MOVE such as the map editor and the vehicle movement screen. To crate the road topology, the map editor is used and to create the vehicle movements, the vehicle movement editor is used. This editor also helps the users to specify vehicle route information such as total number of vehicles to be included in the simulation scenario in a particular route, the vehicle departure time, origin and destination of vehicle, transit period of the vehicle, speed etc which are configured during simulation. We have specified the vehicle configuration here as explained in section 3.3.The RSU (Road Side Unit) nodes and general vehicle nodes are configured with various network parameters. IEEE 802.11p protocol designed for VANET [20],[21] & [22] is also in-built in ns2 [15]. The output of the MOVE goes to a trace file containing simulation results which can be visualized in NAM and further be analysed using awk, tcl or any other scripting language in order to get various analytical output. This section shows the comparative analysis of the proposed model with traditional traffic system.

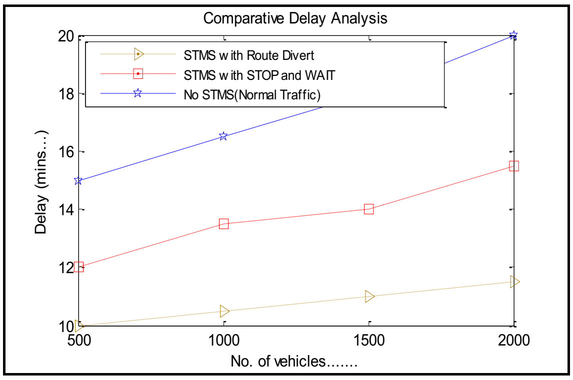

Fig. 6 Comparative delay analysis

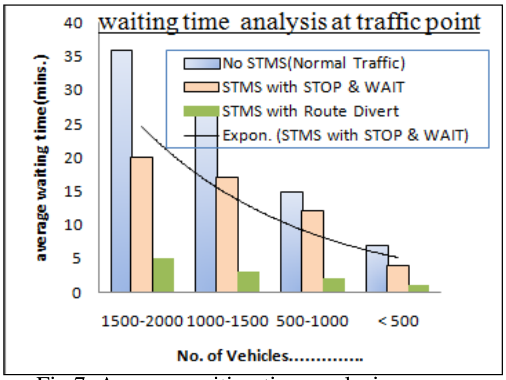

Fig.7 Average waiting time analysis

The simulation has been carried out under three traffic scenario with variable number of vehicles and the results are obtained by extracting output values from trace file created after simulation. The data has been cultutured as required using the awk scripts. Traffic Scenario 1 is No STMS which refers to the normal traffic position with no automated software used. Scenario 2 refers to STMS with Route Divert. As depicted in section 3.5 this scenario includes the result when the vehicle driver has selected to divert to alternate route at signal point SP1.1. Scenario 3 refers to STMS with STOP and WAIT which shows the result of simulation when the vehicle driver selected to stop for some time and wait till the congestion is released. Fig. 6 shows the comparative delay analysis of our proposed traffic model with three scenario. In STMS with route divert option the delay is minimum as there is no time spent for wait and the minor delay occurred is due to the time for deciding the option to be selected at signal point SP1.1 and re-route the vehicle direction in alternate way.Fig.7 shows the analysis of waiting time in the said three scenario. The x-axis indicates the range of vehicles and y-axis indicates the average waiting time by vehicles. It can be seen that as the traffic congestion increases, the average waiting time also increases.

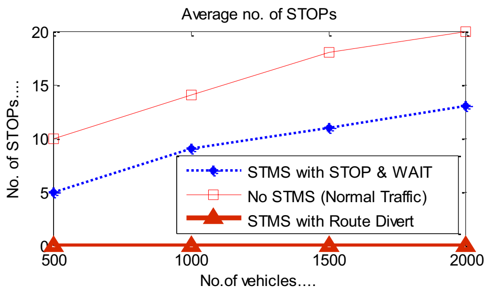

Fig.8 Comparison of no. of STOP points

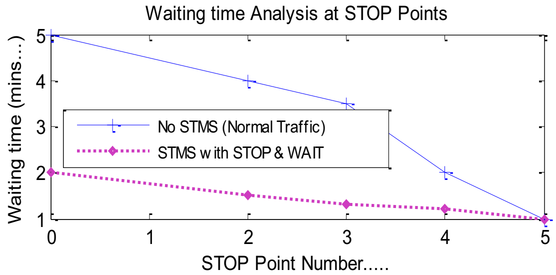

Fig.9 Analysis of waiting time at STOP points

Similarly, fig.8 depicts the average number of stop positions by the vehicles with varying condition of traffic. This depends on the waiting points controlled by the SP1.3 signal point as shown in fig.3. Fig.9 indicates the average waiting time found during simulation by the proposed system STMS under a particular vehicle range between 1500 to 2000. It can be noted here that the stop points are controlled by the automated signals from SP 1.3 to the corresponding vehicles. As the no. of stop point increases, the congestion gradually gets reduced and the waiting time at stop points gradually decreases. But the waiting time in normal traffic (No STMS) is too high at the stop points.

5.Conclusion

With the advancement of emerging technology, industrial and educational development there are more opportunity of employment and better scope of education as well as research in developing cities. The life style of people in metro cities with large volume of population is equally affected by various application and service systems. Therefore currently most of the cities are in the process of transforming into smart cities by adopting automated systems in all possible sectors. With an objective of developing a new transport system for vehicles in a smart city, this article proposed a modern traffic control system using connected vehicle technology under VANET configuration with an integrated approach of solving general traffic related issues in a high volume traffic gateway. For the overall benefit of the traffic system, various modules like video monitoring, smart traffic control system, signal system and smart devices are included in the presented approach with detailed structure of their smart functionality. Simulation results show that it has an improved rate of congestion control in traffic points as it uses advanced technology of automating vehicles, mobile agent and big data analytic tools.

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