Improvement of Conventional Traffic Signaling Device - Self Routing Traffic Light System

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Abstract: - Traffic congestion becomes a serious issue nowadays especially at urban cities area. When road users come at the intersection point, there is always a conflict “who can go first” on their mind. Due to the high volume of vehicles on the road, intersection points need a traffic signaling device to control the traffic flow. That is the reason traffic signalling device is installed at most of the intersection point especially in urban cities. Traffic signaling device is used to ensure the smoothness of traffic flow and provide time system and direction to road users. Therefore, road users are clear to cross over the intersection point. However, road users still need to spend a lot of time for waiting their turn at the intersection point. This is because the conventional traffic signaling device not intelligent enough to control a high volume of vehicles. The objective of this paper is to propose a new programming method for traffic signaling device which is called “Self Routing Traffic Light” as it is to reduce road user’s waiting time at the intersection point. One of the simulations called “Simulation of Urban Mobility (SUMO)” is used to create simulation and collecting data. According to the simulation, several methods is used to control the traffic signaling device such as sequencing method and sensor demand method for conventional traffic light system and proposed method. From the data analysis, the waiting time and travel time of road users spent at the intersection point between conventional methods and proposed method is decreased. As a conclusion, the proposed method will be a practical solution for those traffic signaling device which will be installed at intersection point to ensure the efficiency of traffic flow.

Key-Words: - Traffic Signaling Device; Simulation; Vehicles; Traffic Flow; Intersection Point; Traffic Congestion

1 Conventional Traffic Signaling Device

Generally, traffic signaling device is an infrastructure asset which used to control the vehicle and pedestrian traffic. Traffic signals control the right direction at signalized intersections to reduce the conflict of road users [1, 2, 3]. Next, it can improve the safety and efficiency movement of vehicles and pedestrians. Basically, traffic signaling device used to provide timing at each intersection to distribute the green wave for road users to across an intersection [4].

Apart from that, National Transportation Operations Coalition (NTOC), an informal group in advancing the transportation system management and operations leading the transportation professionals to recognize the traffic signal device around the worlds. In NTOC’s technical report state that, any changing in a traffic signaling device must achieve changing travel demands that can affect efficiency of traffic flow. First, the traffic signaling device able to made the traffic flow smoothly at intersection point to reduce traffic congestion and improve the mobility along the street. Next, the traffic signaling device able to reduce the waiting time and travelling time of road users when at the intersection point. Thereby, it will reduce the negative impact to the air quality and reduce the fuel consumption [1].

1.1 Types of Traffic Junction

Basically, traffic junction is made up by two or more segment at the intersection point and a traffic signaling device need to be installed at that traffic junction. When road users enter a junction, timely system and direction is provided by the traffic signaling device for road users to get the clear direction to across the junction and avoid the conflict occur with other road users at other lane. Without installation of traffic signaling device, road users will get confuse with the priority across the junction. In worst case, accident may happen if some road users having bad attitude in driving and rushing to cross the junction [5].

Basically, there are two types of traffic junction which is "Three way junction" and "Cross junction". Three way junction is built by three segments of road connected to a junction in "T" shape which one segment is often minor road and another segment is often major road [6,7]. The angle between the two segments of road is 90 degree straight as shown in Fig. 1(a). Next is cross junction where four segments of road connected together to form a junction. The angle between the four segments is based on the structure of road, but mostly is close to 90 degree as shown in Fig. 1(b).


Fig. 1(a): Three way junction


Fig. 1(b): Cross junction

Based on our research, the conventional traffic light systems are not intelligent enough to manage a high volume of vehicles and inefficient in controlling the traffic flow. In this paper, the proposed method able to improve the inefficient of the conventional traffic light system. A smart traffic signaling device able to give a clear instruction to road users, so that they won't get confuse in crossing the intersection point.

1.2 Component of Traffic Signaling Device

There are three components of traffic signaling device such as display unit, controller unit and sensor unit as show in Fig. 2 [9].

Fig. 2: Block diagram of component traffic signaling device

Display unit used to visualize stop and go signal for road users to cross the intersection point [10]. Basically, the display unit is an output of the traffic signal while the sensor unit is used as the input of the traffic signal system. The sensor unit is a device that used to sense the present of vehicle before the traffic junction. A signal will be sent from sensor unit to controller unit for triggering the traffic indicator [11]. Thus, controller unit is the most important device to process the signal from sensor unit and give response to display unit [12]. An efficiency of traffic signaling device is depend on the performance of controller unit, the decision is make by controller unit either provide longer green period or short for certain lane. Most of the controller unit perform on same rules but different region or countries will use different standards, but the general idea still the same which is by using logics to control the direction and timing.

1.3 Conventional Traffic Signaling Device Programming Method

Generally there are two common methods used in programming traffic light controllers which is sequencing method and sensor based method. The sequencing method works in a fixed timing pre-programmed without considering the real time changes at the intersection point. While, the sensor demand method is improved version compared to the sequencing method which is capable to detect real time changing [13].

The sequencing method are no detections for any approaching vehicles and the signal continuously cycles regardless of actual traffic demand or real time changes in a certain traffic light intersection. The controller triggers the traffic lights based on a fixed sequence which is from Lane 1 to Lane 2 to Lane 3 to Lane 4 and cycle back to Lane 1 to continue with the same sequence as shown in the Fig. 3 below [2, 8, 14, 15].

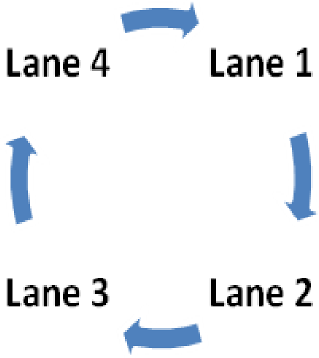

Fig. 3: Sequencing method motion diagram

The sensor demand method is embedded with detection sensor which is usually placed at the end of each lane towards the traffic light junction. The traffic light controller is capable to decide the sequence and the timing of a lane based on the priority method (first in first out method with fixed timing). There are detections for all approaches and the traffic signal is set to provide the green light on-demand or only with the presence of vehicles [2, 8]. The sensor based method can be best described as in the motion diagram shown in Fig. 4.

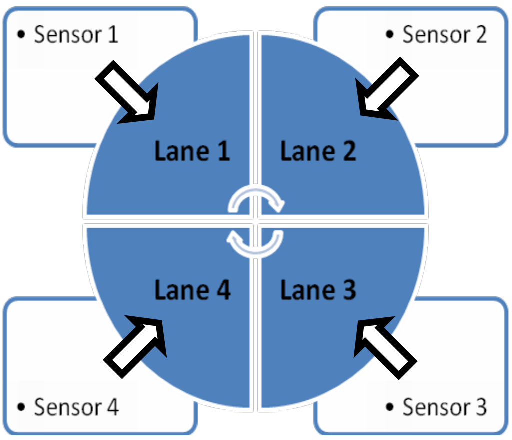

Fig. 4: Priority sensing motion diagram with all possible inputs

2 Limitation of Conventional System

Traffic congestion or normally called 'traffic jams' is an unsolved issue in many urban cities around the world. Some of the root causes of traffic congestion are increased rapidly in number of vehicles, insufficient public transport, bad weather, and also due to stationary and moving bottlenecks on road [16]. During peak hours, traffic routing will fail due to the high volume of vehicle and conventional traffic signaling device unable to control such high volume on vehicles.

Traffic routing problem is dealing with a vehicle travelling on a road. Each driver also needs to make a decision to move their vehicle from starting point to destination and the time taken along the journey. The time taken by the vehicle to reach the destination is depending on the speed of the vehicle. The speed can be affected by some event such as a road accident, road construction, number of vehicles, number of roan lanes and etc. This will cause the shorter distance in the road not to be used and the drivers or users tend to use another road which could be longer distance. Based on the problem, it will increase the travelling time or the environment pollution which will result in wasting of fuel and money. The main reason for such a scenario is because of the traffic routing involves large number of agents and uncertainty as shown in Fig. 5 [17] which is subjected to many factors.

Fig. 5: Traffic congestion due to high volume of vehicles

The vehicles travelling on a map and each vehicle has their own starting point and ending location which will fall to a certain travel time. Due to some event such as traffic congested, traffic accident, road closures and etc., it may decrease the allowed speed on street and increase the travelling time. The allowed speed is depends on the type of street, different street got different limit of speed.

Once traffic is congested, the waiting time of road users will increase and it will also affect the car user's fuel usage and cause the environment pollution [18]. Fig. 6 had shown the effect of environment pollution. For example, the conventional solution which is the traffic light system is monitored by the local authority but unfortunately not solving the traffic congestion problem. The authority may develop new roads in the middle of the city but it is costly and tale longer time to complete it [19]. Apart from that, some authority will introduce intercity train such as the light rapid transit (LRT) in Kuala Lumpur, Malaysia and many more in other parts of the world.

Fig. 6: Environment pollution due to traffic congestion

In major cities, with increasing number of vehicles on street road will cause heavy traffic congested especially at the main junction during peak hours. The peak hours fall in the morning period which is before office hours and in the evening when everyone is heading back after office hours. In this matter, the time wasting for the road users will be increased. Therefore, one of the traffic modes called Normal Mode [20] had been invent to solve the problem which is the longest delay for that road which has a high volume of vehicles. But, it is only works on before and after office hours. Other than that, it is no practical solution yet.

Some of the traffic light junction, even the lane is empty but road users on the other lane still need to wait for their green wave. Such a practice is quite common in many traffic light junctions because the traffic light remains red for the preset time period. The road users will remain waiting until the light turn to green. If the road users try to jump the red light, they have to face the consequences in paying a fine or in the worse case end up with road accidents [19]. Some researchers try to solve this problem by creating a system to detect the traffic flow on each lane and set the timing according to the condition of each lane which could be a reasonable time of waiting and travelling [21]. In some cases like emergency situation which involve vehicles like ambulance, fire brigade and police car will remain stuck on the road especially during heavy crawl as shown in Fig. 7 below. This is because the other road users are waiting the traffic light to turn to green and this is a critical problem for those who are in emergency situations.

Fig. 7: Ambulance stuck at traffic junction when traffic congestion

The next situation involves the system which is unable to provide information of certain traffic light junction to the road users. Traffic information such as congested road and alternate routes available in case of congested should be relayed to the road users in real time basis. It is better to inform the road users about the traffic situation ahead them. By relaying such information, the road users can choose the alternative route to their desire destination by themselves [19].

Fig. 8 illustrates the problem which is very common and currently happening nowadays around the world.

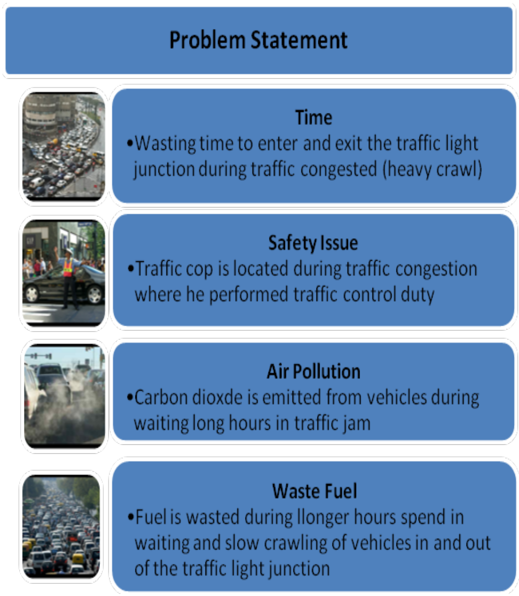

Fig. 8: Problem incorporated with the traffic routing

3 Self Routing Traffic Light

In effort to provide a solution for such miseries, a novel implementation of Self Routing Traffic Light which can incorporate with self-algorithm program will be a practical solution. The new sensor placement method as shown in Fig. 9 capable in counting the total number of vehicles entering a certain junction and exiting from a certain junction on real time basis. Based on the sensor detection, the programmable logic controller will trigger the traffic light indicators according to the real demand [7]. In this case, the use of a mathematical approach such as self-algorithm may be one of the solutions which could help in alleviating the traffic congestion problem. The new sensors placement will increase and improve the smoothness of traffic flow within the available resources by creating intelligent features to the conventional controllers.

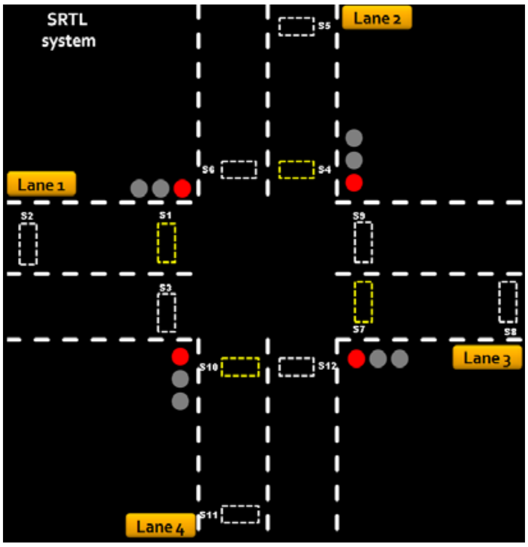

Fig. 9: Self routing traffic light – New sensor placement

The new traffic controller model would create intelligent within the controller and react to every change on sensor detection in ensuring better traffic control without human interventions at all time. Such intelligent system would result in less waiting time and travel time with improved safety features for vehicles. The basic idea of the self-algorithm traffic light controller system work based on real time changes as it is detected by the sensors placed on strategic location on each lane that connected to a traffic light junction. Based on the changes in the sensor, the traffic light controller able to make decision and give the right priority which sufficient amount of time for better flow of traffic. In this new sensors placement, there are three sensors on each lane, two for measure the entering lane and one for the exiting lane. The block diagram of a self-algorithm traffic light controller system is shown in Fig. 10.

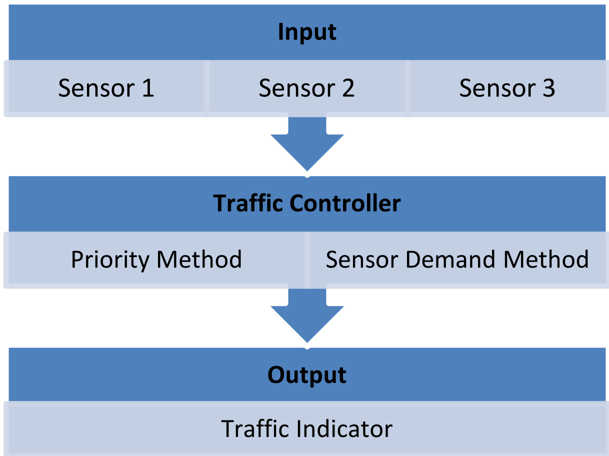

Fig.10: Block diagram of new sensors placement traffic light controller system

4 Simulation of Urban Mobility (SUMO)

"**S**imulation of **U**rban **MO**bility" (SUMO) is an open source traffic simulation. Basically, SUMO is developed by two organizations which are Centre for Applied Informatics (ZAIK) and the Institute of Transport Research at the German Aerospace Centre. In this simulation, it has highly portable and it performs in microscopic road traffic simulation to manage large road networks [24]. In microscopic model, each vehicle has its own model and route, mean that it can moves individually though the network created. SUMO consists a single vehicle moving through a given road network and it allow to manage a large set of traffic management topics. This open source software is free of charge and this feature is very common in commercial software package. Open source software becomes more famous because it gives users the right to use it and modify it [22-26].

4.1 Simulation Setup

The simulation created based on the current scenario on the road which called traffic period. Traffic period can be categorized into three sections which are no-peak hour, off-peak hour and peak hour. A traffic junction at Batu Berendam, Malacca, Malaysia is taken as a reference on the traffic period for one day is show in Fig. 11.

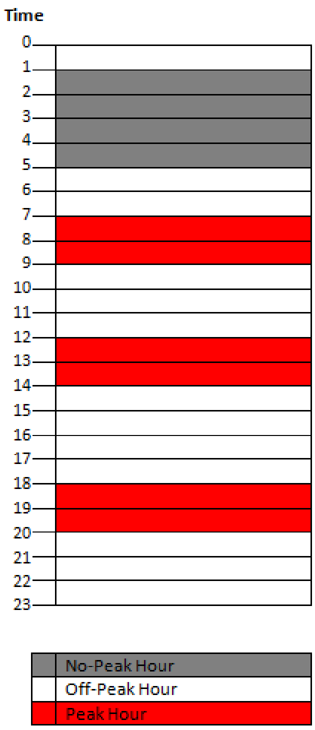

Fig. 11: Traffic period of a traffic junction at Batu Berendam, Malacca, Malaysia.

From Fig. 11, traffic congestion only happened at peak hour which are from 7am to 9am, 12pm to 2pm and 6pm to 8pm. This is due to most of the workers going to work and come back from work and, during school day, that is the period for student going to school and coming back from school. To classify the peak hour, a traffic manual from U.S. Department of Transportation, Federal Highway Administration state that, "in a cross junction, the volume of vehicle exceed 800 in one hour time is consider as peak hour section" [27]. Table 1 below show the data preparation for setup the simulation in one hour time.

Table 1: Data preparation

Traffic Period	**Number of Vehicles**
No-Peak Hour	50
Off-Peak Hour	200
Peak Hour	1250

Based on the data at Table 1, three simulations had been done for three different methods to control the traffic signaling device which are sequencing method, sensor demand method and self routing traffic light as show in Fig. 12a, 12b and 12c.

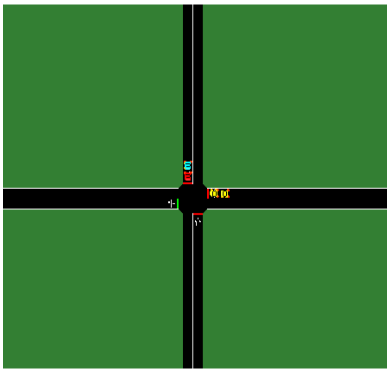

Fig. 12a: Simulation of sequencing method created using SUMO

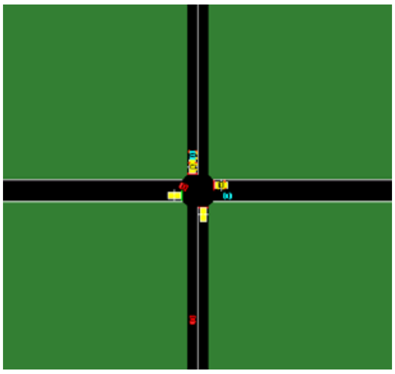

Fig. 12b: Simulation of sensor demand method created using SUMO

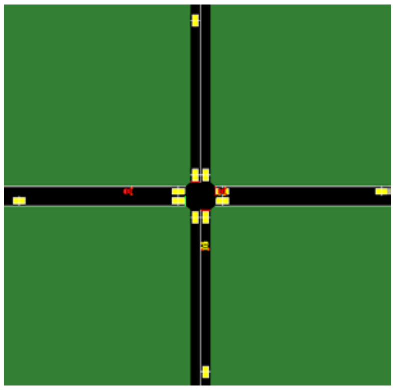

Fig. 12c: Simulation of self routing traffic light created using SUMO

Every simulation have three sections of traffic period, each section is one hour. The different between the three simulations is the sensor placement as mention in previous section. Different sensor placement will use different algorithm to control the traffic controller. In the simulation, we only focus on average waiting time and average travel time used for each vehicle. The average waiting time and average travel time are taken from total 1500 vehicles which are run in three section of traffic period and each section is one hour.

5 Result and Discussion

As the result, average waiting time taken by the sequencing method is 75.16 seconds and average travel time is 106.5 seconds as shown in Fig. 13.

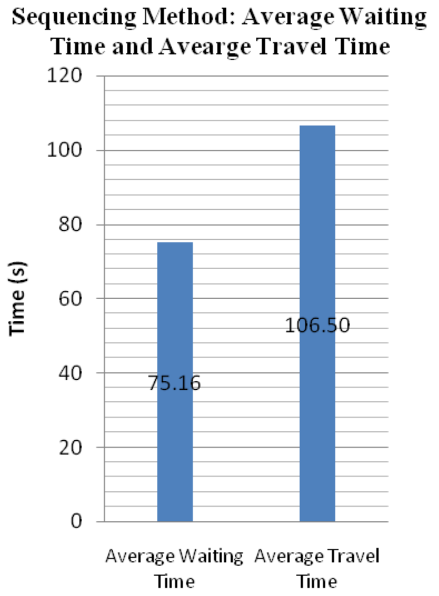

Fig. 13: Average waiting time and average travel time for sequencing method

Next, the average waiting time and average travel time for sensor demand method are reduced. The average waiting time taken by sensor demand method is 69.76 seconds and average travel time is 100.65 seconds as shown in Fig. 14.

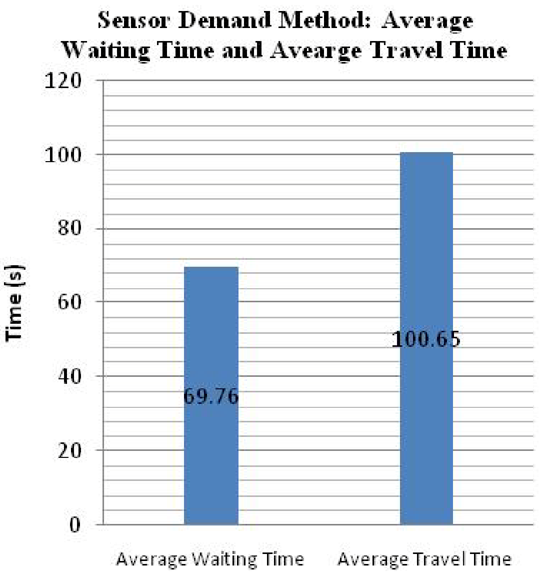

Fig. 14: Average waiting time and average travel time for sensor demand method

Lastly, self routing traffic light show a better result compare to sequencing method and sensor demand method. The average waiting time taken by self routing traffic light is just 27.52 seconds while average travel time is just 56.35 second as shown in Fig. 15.

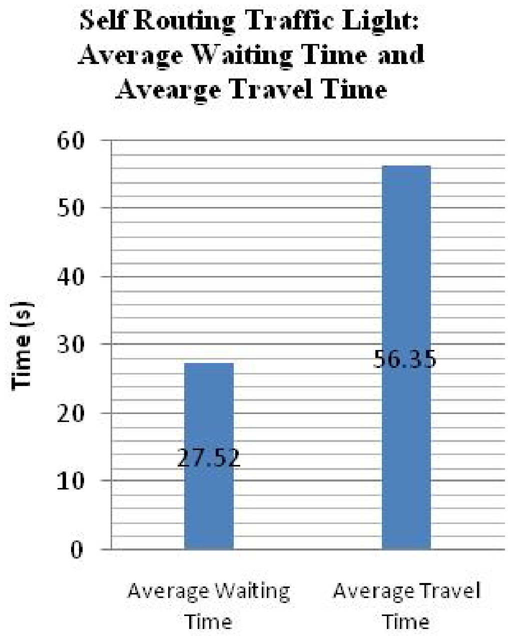

Fig. 15: Average waiting time and average travel time for self routing traffic light

In summary, sensor demand method reduces 7.18% of waiting time and 5.49% of travel time compare to sequencing method. In other hand, self routing traffic light reduces 63.38% of waiting time and 47.09% of travel time compare to sequencing method. It is proven that, self routing traffic light will be the practical solution to solve the traffic congestion issue. With the new sensor placement, the controller programming method able to measure the volume of vehicle enters and exit at the traffic junction.

6 Conclusion

Traffic light is an important device which is used to control the flow of vehicles on certain traffic light junction. The smoothness of a traffic light depends on the traffic routing on street. Once there is problem on traffic routing it will slow down the flow of the whole routing and also the travelling time of road users. Without a traffic light system, the safety on the road is main question among the road users. Based on the proposed system, new sensors placement and the idea of using 3 sensors for each lane on a certain junction is the best solution to overcome the problem of the conventional system. In comparing with the conventional system, it is able to vary the effectiveness of a traffic light system. The effectiveness of a traffic light system depends on the waiting time of a vehicle and many other factors such as reducing the time in and out of a certain traffic light junctions, reduce air pollution and etc. At the same time, it can save the environment around the world. The feedback of the new traffic light system can prevent accidents from happening due to the smoothness of traffic flow.

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