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IoT Based Real Time Traffic Monitoring System Using M/G/1 Queuing Research

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ABSTRACT--- ***Vehicular Traffic crowding is paramount worry in urban cities. The use of technologies like Intelligent Transportation systems and Internet of Things can solve the problem of traffic congestion to some extent. The paper analyses the traffic conditions on a particular urban highway using queuing theory approach. It researches on performance framework such as time for waiting and queue length. The results can provide significant analysis to predict traffic congestion during peak hours. A congestion controlling action can be generated to utilize the road capacity fully during peak hours by using these results.***

Kewords—Vehicular Traffic congestion, queuing theory, traffic congestion order, Intelligent Transportation systems (ITS), traffic density, M/M/1, M/G/1, G/G/1, G/G/k model, traffic flow.

I. INTRODUCTION

In countries like India with high level of population vehicular traffic congestion on roads and its subsequent effects such as drastic increase in harmful gas emissions, increase in fuel consumption, tremendous increase in driver fatigue have become prime concerns for the government and town planners. Though the efforts have been put up to control and avoid congestion, the results are not satisfactory as the number of commutators and vehicles are exceeding road capacity. The use of technologies such as Intelligent Transportation systems (ITS) are in the infantry stage or not matured enough to fulfil the needs. In comparison with the foreign countries like USA the use of information and communication technology has not grown enough to completely solve the traffic congestion problem in all aspects. Government has taken initiative in the development of smart cities with the use of digital world. There is a huge scope for the Internet of things to explore various applications in the context of smart city in India. Internet of Things along with ITS can solve the traffic congestion problem to large extent.

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As per Gartner's hype cycle billions and more than that of world population is living with smart devices. The use of these smart things can definitely help in addressing the traffic congestion problem. IoT can provide a way to smart transportation. It can offer a smart traffic monitoring, Analysis of the traffic data and dynamic congestion control techniques in the traffic management. The traditional remedies to increase the road capacity such as Ramp metering, congestion pricing, VIP lanes are not able to provide satisfactory results due to financial investments required are huge and rise in vehicle number is exponential. Based on the everyday variation in travel needs advanced analysis methods should be used. Advanced traffic modelling tools and network simulators can be used to carry out the research operations.

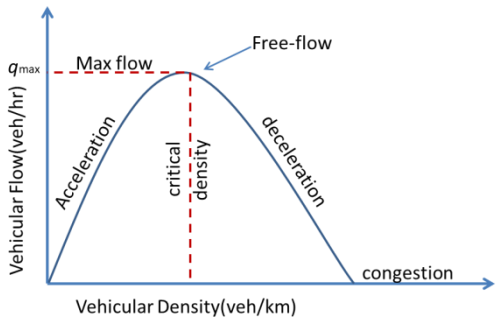


Fig. 1: Traffic flow vs Density relationship.

A. Traffic flow Theory

The traditional traffic flow theory [1] [8] [9] [10] explains the relationship between the traffic flow and density. Initially when the vehicle enters the lane and traffic density is less the vehicle starts accelerating. The vehicle flow increases till the traffic density reaches to a critical value. At this it is a free flow phase. It totally depends on dimensions of the road. After critical density value vehicular speed starts decreasing and it is the start of congestion phase. Here it starts queue formation. This continues to a jam phase where maximum density is reached and vehicles halts on the road, queue length is at max. By observing the figure 1 it can be conclude that there are two different phases of traffic. In first phase, if the density of the vehicles is lesser then the speed of the vehicle is as fast as they can. It is also called as free-flow traffic which is seen by thick line in fig 1.

This type of phase remains in this state till density reaches to its maximum flow; it is also called as critical value. During the first phase some of the vehicle needs to influence their momentum to maintain the distance from the other vehicle on the road. This is also called as forced flow. It is seen by dashed lines. The traffic reaches to its second phase due to some of the reasons like angle of road, slanting of road at upward direction i.e. this happens due to some slower and big transportation vehicles and accident occurrence etc. The traffic reaches its jam phase where vehicle stops or moves slowly.

Paper gives the study of different queuing model for traffic monitoring. One of the models among all from study will be the best suitable to conclude the paper. As the aim of the work is to monitor the traffic and provide some action by using the IoT devices depending on the type of traffic in real time, we use the suitable model for monitoring the traffic on highway. We also observe the traffic flow during the different time slot. In order to see the traffic pattern we have taken one month traffic samples. We also monitor the traffic on real time so that we can have some action to normalize the traffic.

Queuing theory expresses mathematical distribution of probability and expected number of vehicles on the road. It described the effect of different queuing parameters such as number of vehicles of the road and traffic congestion.

II. RELATED WORKS

A traffic monitoring system consists of one or more hardware devices such as Matlab enabled Raspberry pi device, camera to monitor the traffic which provide some traffic data in the form of count vs time to arriving vehicles.

We find various real life examples of queuing systems such as manufacturing system, ATM service and so on. Vehicles arriving on the road find the lanes busy and generally join a waiting line which is a queuing system.

A. Queuing System Elements:

A queuing system is defined with three things. First, Arrival rate second is Departure rate and last is scheduling policies.

1) Arrival Rate:

Arrivals of vehicles may originate from one or multiple rode lanes referred to as the calling population. Rate of arrival of vehicles in the monitoring region is calculated. An example of arrival rate may be of an arrival of vehicles during the specific time in the monitoring region by the total number of vehicle passes from the day starts till that movement of time. If the λ is the arrival rate then it is calculated by number of vehicle detected on that particular frame At time t by the total number of vehicles counted from each frames from starts of the day i.e. addition of vehicle count detected from starting time to the current time of the day.

2) Departure Mechanism:

Departure rate is defines by the number of lanes (R) on the road. If vehicles has T_i as a service time at the ith time instance at the average service rate of a vehicles is $\mu = 1/(T(R))$. The service rate is totally depends on queuing discipline that the server choses to process the vehicles.

3) Scheduling Policy:

Queuing discipline defines the service mechanism of lane or in how much time the vehicle is processed on the road. There are various scheduling policies depending upon applications. The most among used policies are:

LIFO - vehicles are assisting in a last-in first-out manner,

FIFO - vehicles are assisting on a first-in first-out basis.

Priority - vehicles are assisting in order of their importance such as emergency vehicles, ambulance on the basis of their service requirements.

B. Queuing approach

From the flow density diagram it can be seen that queuing theory approach is very much related to traffic management and can become helpful in reducing the congestion. The authors in [2] have provided strong foundation to encourage research in application of queuing theory in traffic management and used basic queueing models to analyze the traffic data. There are various queuing models to analyses the traffic data. It can be found that queuing theory has been exclusively used for traffic analysis at signalized intersections. Using queuing theory approach the various characteristics such as waiting time, queue length can be found to avoid the traffic congestion. . Depending on the nature of vehicle arrival rate and service rate we have M/M/1, M/G/1, G/G/1, G/G/k and few other queuing models. Queuing symbols are used to specify the nature of queuing model.

TABLE I: Queuing Models

Model	Arrival Procedure	Service Procedure
M/M/1	Poisson	Poisson
M/G/1	Poisson	General
G/G/1	General	General
G/G/1 State Dependent	General	General

1) M/M/1 Model:

The M/M/1 forms the basic queue knowledge where both arrival rate and departure rate follow Poisson distribution and it suitable for normal traffic conditions. Authors in [3] optimized service rate by analyzing the traffic flow parameters using M/M/1 model. Using multiple servers that is M/M/n model has been used by authors in [4] to analyses traffic data at the urban intersection.

2) M/G/1 Model:

With M/G/1 queuing model arrival rate follow exponential distribution and service time is generally distributed. During traffic congestion the arrival rate is the exponential but the departure or service rate is not exponential but follows general distribution which results in queue formation. M/G/1 queueing model can be used in analysing the delay in data packets in telecommunication channel [5]. In this paper we consider M/G/1 model to analyse the traffic data as it suits for traffic congestion scenario where vehicles enter exponentially but departure is not exponential and can follow general distribution if remedy is provided for congestion control. Following table gives the list of parameters used and their notations.

TABLE II: M/G/1 model parameters

Parameter	Description
ℵ	Arrival rate
μ	Assistance rate
ρ	Server utilization
a	Maximum service rate
b	Minimum service rate
σ^2_s	Variance in the service time
Lq	Number in the queue
Wq	Waiting time in queue
L	Number in the system
c	Number of servers
W	Waiting time in system

For single channel queuing system if arrival rate is less than the departure rate that is σ < 1 system is stable but if σ > 1 queue formation happens. For an M/G/1 system has following performance parameters:

1. *Traffic Intensity*

The median number of vehicles being processed is the proportion of arrival and service rate

$$\rho = \frac{\lambda}{\mu} \quad .....(1)$$

For a steady type of system the assistance rate always exceed the arrival rate and therefore value should be each time less than 1(one). Because of this, it is popularly known as component factor of the server (in our case it is utilization of road by vehicles).

2. *Variance in the service time*

$$\sigma_s^2 = \frac{(b-a)^2}{12} \quad .....(2)$$

3. *Number of vehicles in the Queue*

$$L_q = \frac{\lambda^2\sigma_s^2+\rho^2}{2(1-\rho)} \quad .....(3)$$

4. *Vehicles waiting time in the Queue*

$$W_q = \frac{L_q}{\lambda} .....(4)$$

5. *Vehicle's overall Waiting time in the system*

$$W = W_q + \frac{1}{\mu} \quad .....(5)$$

6. *Total Number of vehicles in the system*

$$L = W * \lambda \quad .....(6)$$

7. *Proportion of time road is idle*

$$I = 1 - \rho \quad .....(7)$$

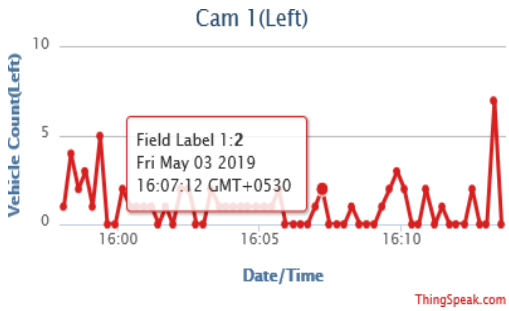
III. RESULTS AND FINDINGS

A. *Traffic data acquisition*

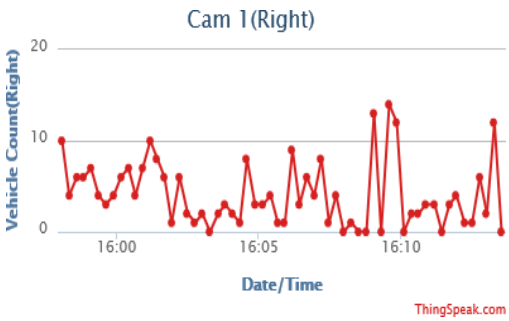
Gathering the traffic management data plays an important role in development of ITS [6].The traffic data can be collected through traffic light camera or vehicular sensing [7].In order to acquire the traffic data a smart traffic monitoring system consisting of CCTV camera and processor was designed. Data gathered on a cloud platform to get the real time acquisition. Figure 2 shows the IoT based camera which uses the Raspberrypi-3 mounted on highway to collect traffic data. Pi-3 collects the real-time data separately from left and right side of the road from the camera which is mounted on it. After collecting the data using camera pi sends this data to the web by using internet connection.

B. *Performance Analysis*

The system monitors the number of vehicles passing on the road section of highway of length 500 meters for a period of 24 hours on both left and right side of the road. The arrival rate λ is the number of vehicles per unit time and depends upon the vehicles passing the road. The system does not classify the vehicles such as car or heavy load vehicles. The average maximum speed that can be achieved by the vehicle 60 km/hr. and the average minimum speed during congestion can be 10 km/hr. Following figure 3 shows the sample data collected on cloud platform which is the vehicle count on left and right side of the road.



(a) Traffic on the road(Left)



(b) Traffic on the road(Right)

Fig. 3: Vehicle count vs Time a) Traffic on the road (Left) b) Traffic on the road (Right).

Figure 3 (a) shows lest side traffic is lesser compared to the right side as shown in figure 3(b)

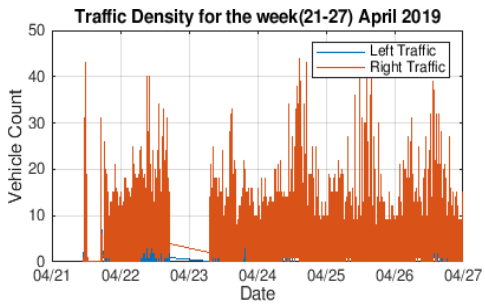
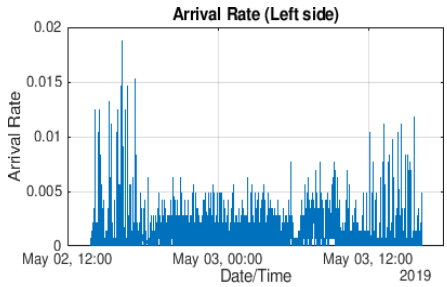


Fig. 4: Traffic Density

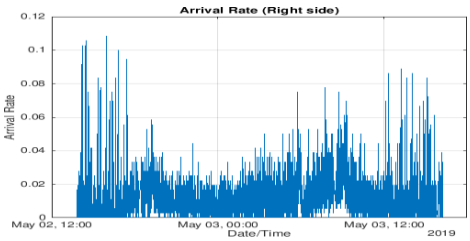
We analyzed the traffic density for week as well. During peak hours when commutators travel for offices high traffic peaks are observed during morning and evening in figure 4.It can be observed that right side of the road is heavily loaded with the vehicles compared to the left side and can lead to a congestion during peak hours. Whereas left side is not utilized fully.

The arrival rate can be found based on vehicle count collected throughout the day which is number of vehicles per minute. Following figures 5 (a) and (b) show rate of arrival for left and right side of the road for 24 hours.

The traffic intensity which is a measure of road utilization is found in figure 6(a) and (b).It is observed that traffic intensity on right side is more compared to the left side of the road.



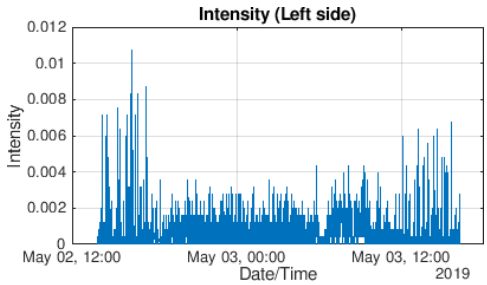
(a) Traffic on the road (Left)



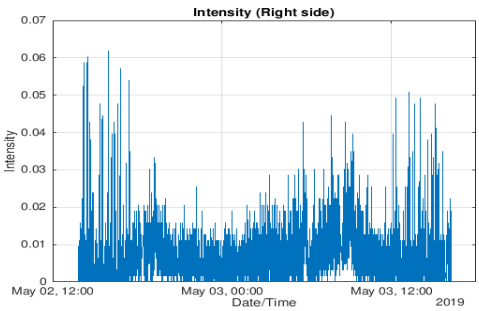
(b) Traffic on the road (Right).

Fig. 5: Date/Time vs Arrival Rate a) Traffic on the road (Left) b) Traffic on the road (Right).

The following figure 6 a and b shows the waiting time versus arrival rate. It is observed that waiting time in queue increases as the arrival rate increases leading to a dead lock condition.

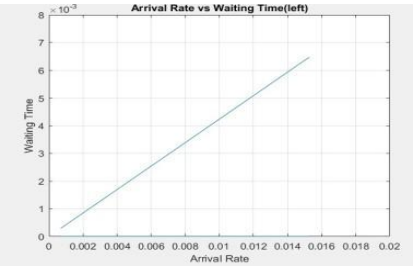


(a) Traffic on the road (Left).

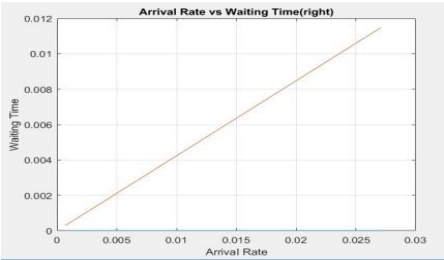


(b) Traffic on the road (Right).

Fig. 6: Traffic Intensity a) Left side of the road b) Right side of the road.



(a) Traffic on the road (Left).



(b)Traffic on the road (Right).

Fig. 7: Arrival Rate vs waiting time a) Traffic on the road (Left) b) Traffic on the road (Right).

Figure 7 (a) and (b) shows the graph, it explains Arrival Rate vs Waiting time of vehicles, as the number of vehicle increases on the road with respect to time, waiting time is increases linearly.

IV. CONCLUSION

In this paper we monitored the real time traffic data using IoT device on highway which is also called as a smart traffic monitoring system by collecting the data on data aggregator. We found the various performance parameters using M/G/1 queuing model which suits to the congestion scenario perfectly. It is clear that during peak hours when traffic flow on one side of the road is higher compared to the other side. One side of the road is congested compared to the other side which leads to more travel time and waiting time.

The results suggest that underutilized side of the road having lesser traffic can be used to divert the traffic flow of the heavily loaded side which can be implemented with lane management technique. The advanced technology such as Internet of Things and Intelligent transportation system (ITS) can definitely provide methods to implement these remedies. This will help in reducing congestion.

V. FUNDING

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