Traffic Congestion Detection and Control using RFID Technology

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Abstract

Road traffic poses a major challenge for most of the urban areas. With the growing number of vehicles each day, resolving this issue is paramount. Though use of existing popular technologies for traffic congestion and detection control have been studied in recent times, none of them provides an automated system that manages traffic based on detected level of congestion. The objective of this paper is to propose an effective scheme for road traffic management which is fully automated and foolproof considering the rate of ever growing traffic in urban areas. In this paper, we discuss the existing and most widely employed technologies for traffic detection and congestion control with their limitations and also propose an alternative model for the same which employs RFID technology. The basic idea used for traffic management here is to detect and control congestion by using a decision making algorithm which determines how the traffic light operates based on the information collected from RFID devices.

Keywords

Traffic congestion, Traffic detection, Congestion management, Active RFID

1. Introduction

Road congestion is an ever growing problem as the number of vehicles is growing exponentially and the road infrastructure cannot be increased proportionally. This leads to increasing traffic congestion. Traffic congestion occurs due to high volume of traffic or high vehicle density within a particular stretch of road. A vehicle may slow down owing to numerous reasons, leading to the subsequent slowing down of the following vehicles and hence causing traffic congestion. These reasons have been studied vastly and different technologies have been explored to detect and control traffic congestion.

Most popular method of controlling traffic is a traffic signal which operates simply on timers. They are programmed to function in a specific manner irrespective of the traffic at a given time of the day. Inevitably, they fail to avoid congestion. However, these days detectors are commonly employed which use the most common technique of inductive loop. Other technologies include GPS devices, Radar technology etc. But these technologies have several drawbacks for example they fail in certain situations, have installation and maintenance problems and cost limitations etc.

In this paper, we propose a smart and fully automatic system that can detect congestion in real time, and subsequently manage it efficiently to ensure smooth traffic flow with the use of RFID devices. Our idea is based on the principle of RFID tracking of vehicles.

An RFID i.e. Radio Frequency Identification system consists of two main components, the small transponder, more commonly known as a tag, which is attached to the item needing identification (here, vehicles) and the interrogator, or reader, which in some cases is used to both power the tag and read its data without contact [2]. The RFID tag consists of all the information regarding the item to which it is attached and this can be wirelessly transmitted to the reader [1].

This paper is organized as follows: Section 2 describes the most common reasons resulting in traffic congestion. Section 3 discusses the existing technologies available for traffic management and also about their limitations. Section 4 gives a detailed description of the scheme proposed through this paper

and Section 5 concludes the paperwork with a highlight on scope of future work in this area.

2. Understanding the Causes of Traffic Congestion on Roads

Let us first start by understanding the factors contributing to traffic congestion. Traffic congestion is a condition on road networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. The following are a few most commonly observed causes of traffic congestion:

2.1. Spontaneous Slowing Down of Vehicles

Real time observations have shown that in heavy but free flowing traffic, jams can arise spontaneously. For example: due to abrupt speeding down of a vehicle. This causes the subsequent vehicles to slow down thus, reducing the capacity of the road at that given time.

Congestion can also be attributed to other incidents like an accident or single car breakdown, poor weather conditions, road work etc. These incidents being very rare may not be considered while designing traffic management schemes. The image below illustrates such an incident.

Figure 1: Illustration of Traffic Congestion due to Breakdown of a Vehicle

2.2. Traffic Congestion at Junctions

Here, let us consider a four-way junction with a simple traffic signal functioning on a timer for traffic management. Let us assume these roads allow bidirectional traffic flow. The mechanism used to operate a traffic signal is programmed and does not vary according to the amount of traffic from a particular direction. Consider the figure below.

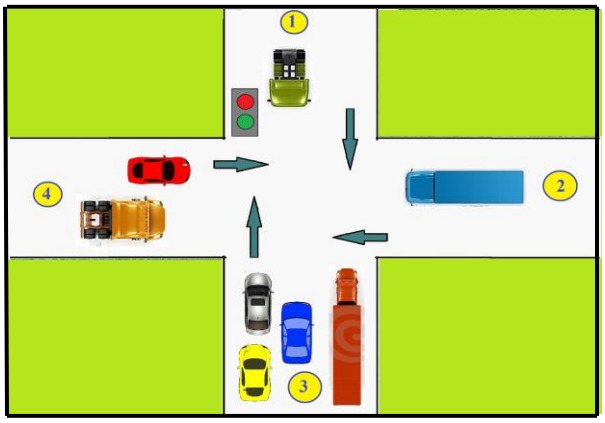

Figure 2: Illustration of Traffic at a Junction

We can see the traffic moving from lane (3) to (1) is quite large compared to the traffic on other lanes.

Assume at time instant t_1, the traffic signal is Red for lane (3). At instant t_2, it turns Green and back to Red at instant t_3. Not all vehicles may be able to pass from lane (3) to (1) within this interval. This leads to further accumulation of vehicles due to incoming traffic at road (3) thus causing congestion. This is one of the disadvantages of fixed timer programmed traffic signals.

3. Earlier Work

Several technologies have been proposed for congestion detection such as inductive loop, magnetometer, visual camera, radar etc [4].

While inductive loops that can be placed on the roadbed work at all traffic speeds and are effective at estimating traffic speeds, they have a few drawbacks like their maintenance and installation is quite difficult. Apart from this, they are susceptible to high error rate in detection and transmission of traffic information.

Conventional traffic signals:-

The traffic signals that have been programmed are programmed with a fixed timer. Hence they do not consider the volume of the traffic on the street before taking a decision of green or red light. Hence if the volume of traffic is large, it may result in accumulation of traffic on the street and the junctions.

Radars have also been widely used for this purpose. Basically radars detect the signals from the moving traffic and estimate the number of cars crossing it.

From this data, approximately the volume of the vehicles on the street can be found out. There is a central processing unit which gives this data to the traffic signal which changes the interval of the red and green light appropriately [5]. However the disadvantages of the radar are that they are very expensive and also there can be a problem of interference with other signals in the atmosphere. Also it becomes difficult for the radar to detect the signals from the cars which overlap (as in, are at the same position in parallel lanes).

Another technology used in this field is a magnetometer. Magnetometer works on the same principle as radar and has almost the same disadvantages and advantages of radar. The detection principle used by a magnetometer is as that it detects the change in the earth's magnetic field when a magnetic object like a car crosses it.

There are many other traffic management systems which exist and have their own advantages and disadvantages. Each system can be very effective in some circumstances and not in others. Hence, even though so may systems exist we propose one more system which is discussed in the paper which has many other advantages apart from just traffic management.

4. Proposed Congestion Detection and Control Scheme

Our scheme ensures the following to control traffic congestion:

i. Smooth traffic flow on road
ii. Congestion detection and control at any road leading to a junction
iii. Priority-based traffic control

Let us consider a stretch of road with readers placed at an interval of every 100 metres (This distance between two readers may be varied according to the information about volume of traffic passing through a particular road from statistics obtained through observations). Refer the following figure.

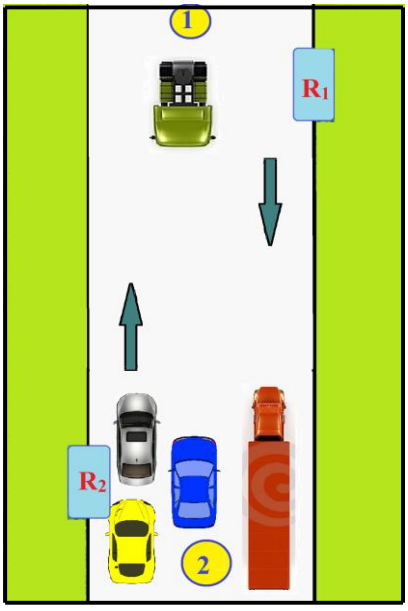

Figure 2: Illustration of Traffic Congestion Detection on a Straight Road

When a vehicle passes reader R_1, the active RFID tag of that vehicle sends a beacon frame to R_1 [3]. This frame consists of all the information regarding the vehicle and also a time stamp of the instant the vehicle passed the reader. When it crosses that stretch of road and passes R_2, its information along with the time stamp is collected by R_2. Reader R_2 sends back this information to the preceding reader i.e. R_1. From the information collected by the two readers, the speed of the vehicle is calculated by a Central Processing system and this information is stored in the database. The Central Processing System can be an 8051 microcontroller or any other higher processor depending on the location of the road and volume of traffic passing through it. We have recommended an 8051 microcontroller since it has its own internal memory, simplicity and is programmable to an extent which is sufficient of carry out necessary activities for traffic management [2].

Now let us consider another situation where four roads meet at a junction. Refer the following figure.

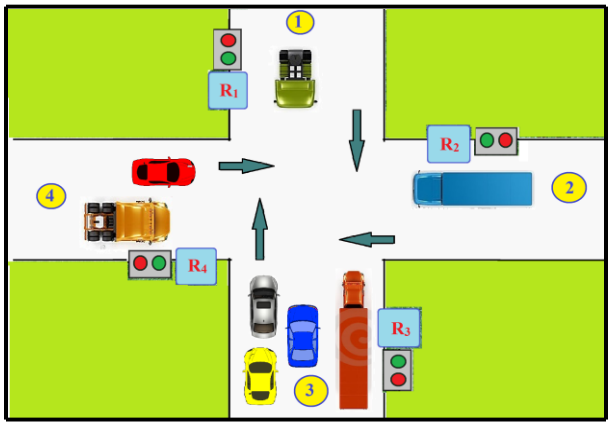

Figure 3: Illustration of Traffic Congestion Detection at a Junction

Information regarding the vehicles approaching towards the junctions is collected in the same way as on a straight road, on a junction. The only difference here is that we place a reader on each of the roads meeting at the junction as shown in the figure. Readers R_1, R_2, R_3, R_4 collect information from the respective roads and transmits this to the Central Processing System.

From the information collected from different readers, the Central processing unit calculates the volume and speed of vehicles on each road. Also, an added advantage of using an automated Active RFID system for traffic congestion control is that we can set priority to different types of vehicles depending on the type of vehicle, for example, an ambulance, fire brigade or police vehicle. By setting such priority, the time these vehicles may have to wait at a signal can be minimised or traffic at other roads meeting at a junction can be halted for a few seconds letting these high priority vehicles pass. Priority can also be assigned according to the time of the day, for example, container vehicles are assigned higher priority after midnight on a highway.

The basic architecture of this system is shown below:

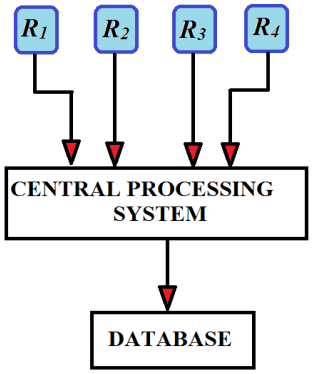

Figure 4: Basic Architecture of Proposed Traffic Management System using Active RFID

For effective and automatic traffic detection and congestion control, the Central Processing System carries out the following steps:

- Since volume of traffic can fluctuate very rapidly, it is not possible to alter traffic signals based only on this factor. So, a minimum time is set for which traffic signal remains constant before checking for the volume of traffic again.
- A maximum time is set after which a constant traffic signal must change irrespective of the volume of traffic. This is done to ensure no vehicle has to wait too long at the crossing.
- Speed of vehicle is determined by the time taken for it to cover the distance between two readers. If speed of a vehicle is below a specified threshold, it is detected as congestion and the Central Processing System notifies the preceding traffic signal about this. On receiving such information, traffic on that corresponding road is halted for certain duration to avoid congestion on the proceeding road. This step avoids accumulation of too many vehicles at any road leading to a junction.
- Vehicles assigned higher priority is let immediately after the duration of Red signal at the corresponding road ends irrespective of the volume at other roads.

This working can be explained by the following flowchart. In figure 3, we see four roads meeting at a junction. Let the volume at roads 1, 2, 3 and 4 be V_1, V_2, V_3 and V_4 respectively.C_N is the count of the number of times Green signal is given to road number

N, where N is the road number from 1 to 4. This count has been assigned in order to ensure that no vehicle has to wait for too long at the traffic. We increment each C_N each time the traffic is allowed to pass through road N to ensure that vehicles on a single road are not allowed to pass consecutively more than a certain number of times. After C_N reaches it maximum value (here, three), the signal at that road turns Red irrespective of the volume of traffic there. T_N is the minimum duration for which a vehicle has to wait at the crossing i.e. the duration for which the traffic signal remains Red.

Let us understand the working of this system using the flowchart shown alongside and Figure 3. As we can see in the figure 3, road no.3 is the road with maximum volume of traffic. Let us say the volume is V_3. We have initial values as C_N=1 and T_N=10 seconds. The Central Processing System first checks if any vehicle on any road has been assigned high priority. Let us assume, here no vehicle has been assigned high priority. Next we check for the road with maximum number of vehicles. Here, it is road 3. Note that, if both the above conditions are not applicable i.e. there is no vehicle assigned high priority and the volumes on all roads meeting at the junction are equal, then by default, traffic at road 1 will be allowed to pass. Since here, road 3 has maximum volume of traffic, we allow vehicles on that road to pass for 10 seconds. The count for that road i.e. C_3 is incremented. Now, this entire cycle repeats. The maximum number of times vehicles on one particular road are consecutively allowed to pass as per our scheme is three. After that, the values are re-initialised.

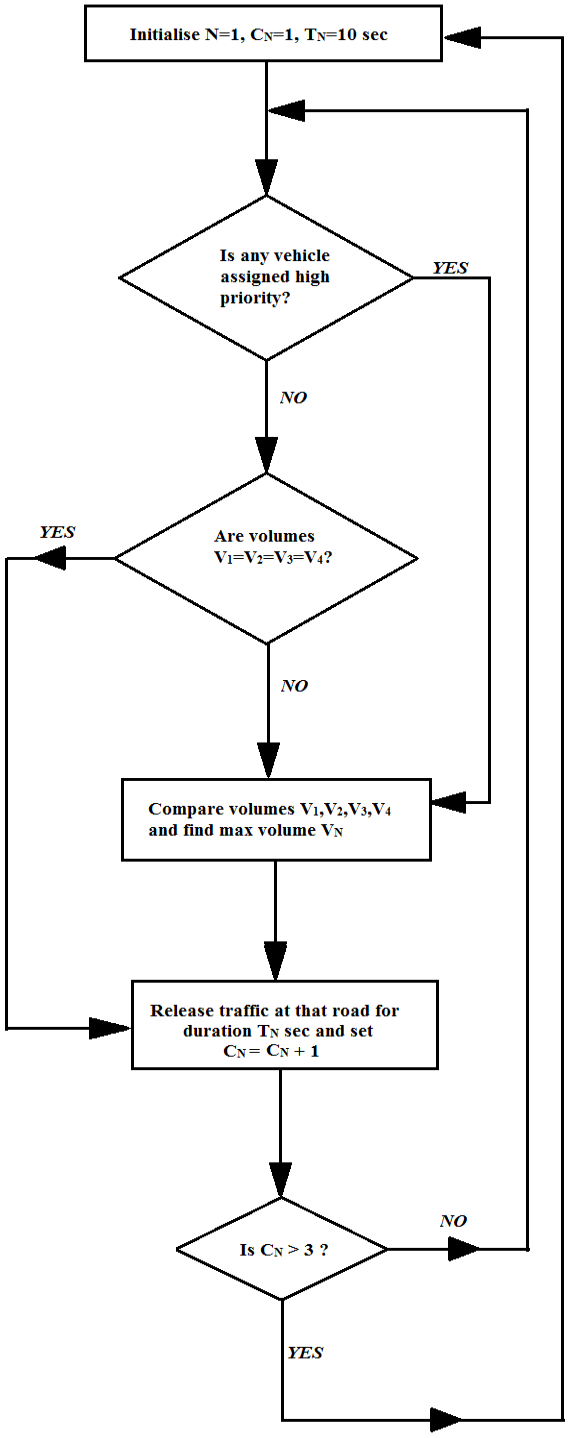

Figure 5: Flowchart explaining the Working of Traffic Congestion Detection and Control using RFID System

Apart from congestion control, this scheme has the following advantages:

- Traffic signals are fully automated and operated according to the current volume of traffic.
- Differential priorities can be assigned to vehicles like ambulances, fire brigade.
- Reportedly stolen vehicles, or vehicles booked for offence can be tracked.
- Reliable traffic data can be generated for statistical purposes [4].
- This technique can be used to avoid accidents that may occur on highways where sirens can be used to indicate an accident ahead.

Another feature of this system is that it can function even in case where a reader in any path fails. In such cases, when the other reader in that path tracks a vehicle, the Central Processing System checks whether it has just crossed the readers in other paths converging at the junction or not. From this, the direction of travel and other information such as speed can be obtained.

5. Conclusion

We have devised a method for creating a system for controlling road traffic. Our system is based on the principle of using the RFID technology to track the vehicles and using the data obtained from that to control and manage the traffic. The advantages of our method have been clearly mentioned in the paper. Though there are many existing methods used to manage the traffic and many more which are currently being devised, this field of study will always have a future scope because of the continuous increase in the number of cars being driven on the street and the uncertainty of events that can cause traffic. Also, this system may be employed in traffic management of other modes of transport like Indian railway system where trains travel at an interval of every 3 minutes to increase the efficiency of the system. The proposed scheme is a very basic system for employing Active RFID devices for traffic congestion detection and control and further enhancements can be made to make it more suitable and viable.

6. References

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