Monitoring Urban Roadspace Usage with Radio Frequency Identification Tags and Internet-of-Things

György Szabó[1], Ervin Wirth[2], Anna Czinkoczky[3]

[1]Budapest University of Technology and Economics/Hungary · szabo.gyorgy@epito.bme.hu
[2]Budapest University of Technology and Economics/Hungary
[3]Szent István University/Hungary

Abstract: With the increasing traffic congestion and hazardous air pollution it is still a key issue to find an objective and dynamic method to control the traffic flow of urban places. The paper proposes a complex system that is based on Radio Frequency Identification (RFID) technology, the 17-digit Vehicular Identification Number (VIN) and a Decision Making System (DMS) augmented with proper traffic regulation algorithms that can modify the traffic flow in real time. In addition to this, it is possible to obtain an approximation of objective air pollution data for each vehicle type by using the complex system which can be used by local authorities to redefine the roadspace allocation in cities.

Keywords: RFID, VIN, real time traffic control

1 Introduction

With the rapid growth of urbanization there is an increasing competition between vehicles (cars, buses, trams, bicycles and motorbikes) for the available road space in cities. Numerous solutions have been introduced (e. g. congestion charges in London, Stockholm, Singapore), but these measures do not optimize the traffic, just merely give the priority of road usage for the rich people. Some other cities are using contraflow lanes systems, where the direction of traffic can be changed to match the peak flow of vehicles (rush hours). These static solutions somewhat ease the congestion and pollution problems of the roads, nevertheless do not adapt to the rapidly changing environmental regulations

Several vehicle owner groups (taxis, bikers, car owners) try to lobby for the priority usage of road space. The aim of this paper is to give an objective criteria of road usage optimization based on real-time traffic flow. We would like to introduce an automated traffic monitoring system using the Internet-of-Things (IoT) and Radio Frequency Identification (RFID) tags.

The traditional automated vehicle detection based on the character recognition of the licence plates of vehicles is not always satisfactory, since some vehicles are not equipped with a licence plate (i. e. bicycles, scooters) or even if they are – the bad weather and climate can interfere with the visibility and recognition of the vehicle.

On the other hand, RFID tags provide a very effective, yet rather cheap technology for identification of any object carrying an active RFID tag.

We argue that the easiest, cheapest and most reliable automatic vehicle detection is achieved using RFID technology, *so the requirement of our proposed system is that every vehicle is equipped with a simple and cheap (less than 1 USD value) passive RFID tag.*

The usage of RFID tags on vehicles is not limited to traffic monitoring only, they can be used efficiently on pay roads for highway toll collection – or similarly to the animal tracking – for finding lost or stolen cars, etc.

Journal of Digital Landscape Architecture, 3-2018, pp. 319-326. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-642-0, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537642034.

Some countries (e. g. India) have already required mandatory RFID chip instalment in passenger cars or trucks, since they allow seamless flow of highway traffic (no need to stop at toll gates) hence, they decrease congestion and air pollution.

When a vehicle with an RFID tag comes by a fixed monitoring station which is positioned at some well-designed intersection points of roads, the RFID reader will read the passive RFID tag of the vehicle. Every vehicle is equipped with a 17-digit VIN code (Vehicle Identification Number) which is an equivalent of EPC code (Electronic Product Code a universal identifier that provides a unique identification for all products anywhere in the world). By transferring VIN code data to an RFID tag, the system can automatically collect information about the vehicle type, lenght, registration, pollution and control status.

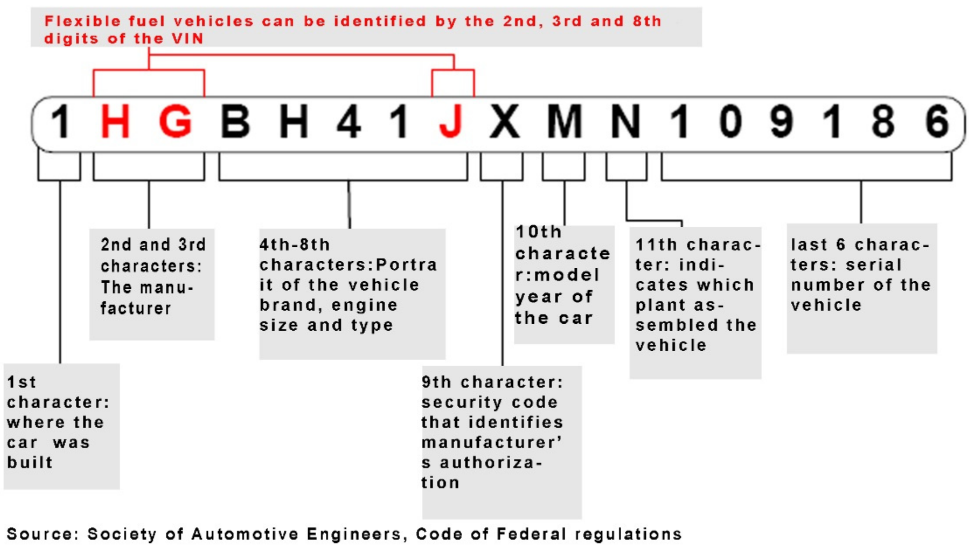

Fig. 1: Vehicle Identification Number (VIN)

2 RFID Technology in Brief

2.1 Components of the RFID System

The system consists of 4 main components:

- Active tags (also called transponders) with internal power supply, which are used to identify goods or to store data and histories.
- Interrogator (I-Card, i-PORT) and handheld devices (mobile), which exchange information with the tags and host computer systems.
- Various antenna types/characteristics for different applications.
- A central computer system as a basis for control and monitoring.

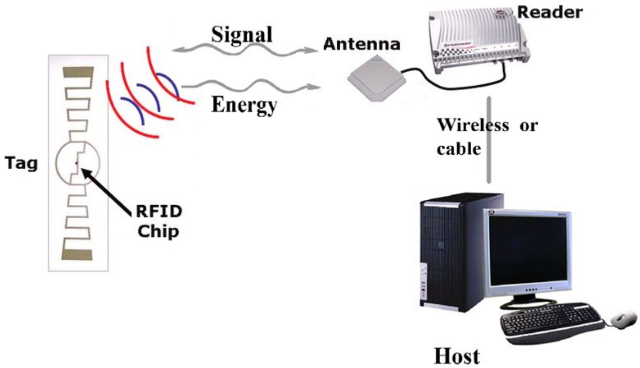

Fig. 2: RFID system

The data (position, vehicle type, ID, timestamp, speed) will be sent to the monitoring centre using GPRS network and IoT.

2.2 Previous Research: Bicycle Road Optimisation with RFID Technology

In 2013 the present authors implemented a similar RFID monitoring system that was developed for bicycle traffic monitoring only. The system was rather cheap (less than 1000 USD) and was successfully used at a test site of the Budapest University of Technology and Economics.

It was a basic monitoring system, without the intelligent data management system that will be introduced later.

The following figure shows an RFID tag initialization in the city bike monitoring experiment. Prior to monitoring, the RFID tags had to be initialized, i. e. equipped with the necessary information. The following figure shows an example of the process:

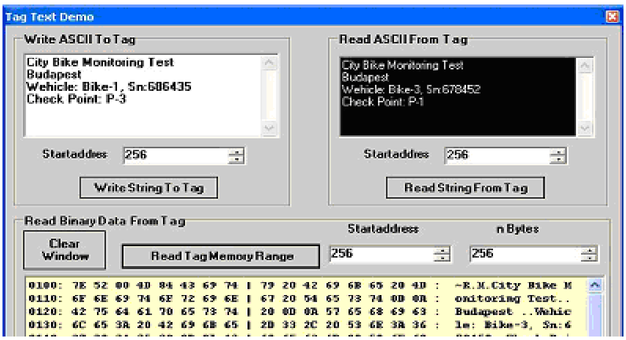

Fig. 3: Initializing an RFID tag

We also had a test road with proper antennae placed at several points. The following figure shows the test site of the bicycle monitoring system developed by the authors (displayed with Google maps).

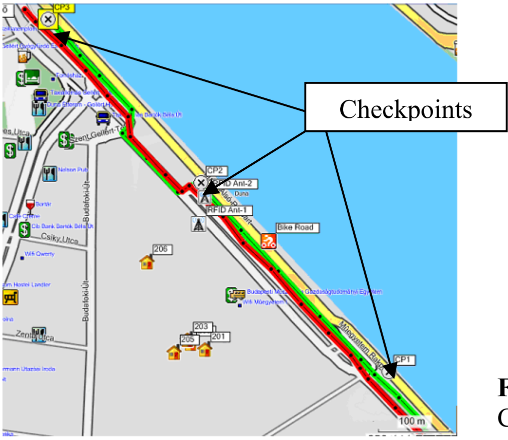

Fig. 4:
Checkpoints on the test road

However, the volume of the bicycle traffic in general does not have such a massive impact on city roads and air pollution than car traffic. Moreover bicycles do not pose environmental threat, so the RFID bike traffic monitoring was not really favoured by city officials. The bicycle road optimization was not a really successful issue, so the test system stayed in incubation. In the past few years, wi-fi connection and mobile technologies (IoT) have become ubiquitous and very reliable, so real time data processing of general traffic data can be achieved. It has made possible to improve traffic optimization by combining real time traffic monitoring with effective traffic regulation algorithms and decision making systems.

2.3 Data Management System of Traffic Data

Figure 5 shows a main city road where RFID interrogators are placed that can obtain all the important information about all vehicles crossing the intersection.

The traffic (vehicle) data obtained from the RFID interrogators (R1, R2, …, R8 on Figure 5) is sent to a Central Database Processing System (CDPS). The CDPS consists of two main parts:

- a dynamic database which contains all the records of the vehicles currently passing at an intersection A;
- a static (permanent) database that contains all the records of the vehicles that have been crossing intersection A.

In order to obtain the direction of the travel for a given vehicle V, we need to install two readers in each lane before and after the intersection on both roads (yielding the total of 8 readers) according to figure 5.

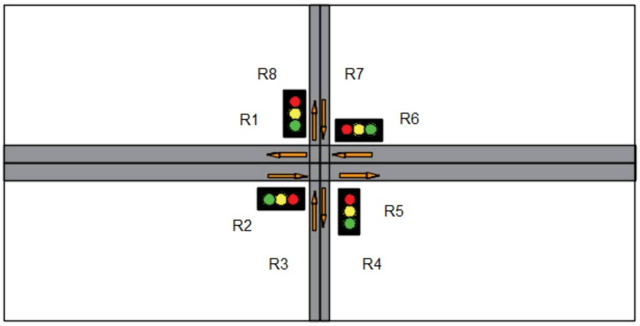

Fig. 5: RFID interrogators located at intersection A

Since R1, … R8 readers record the VIN of the vehicle and as well as its timestamp, it is possible to obtain the direction of the traffic for every vehicle. A given vehicle is read twice at an intersection (before the crossing and after it). And from the position of the readers and the relation between timestamps it is possible to determine the travel direction of every vehicle at a given intersection. Suppose that the vehicle V is read by R2 and R5 readers, and if the appropriate timestamps (t2, t5) are obtained such that t2< t5, then it means that the vehicle heading eastward. (CHATTARAJ et al. 2009)

2.4 Advantages of RFID over Other Existing Technologies for Traffic Monitoring

Besides RFID solution, there are other existing technologies that are capable for real time traffic monitoring. There is an increasing popularity of GPS systems, however the GPS-based technology does not have features that are obtained by RFID system in two respects:

- GPS technology is more expensive than RFID (only trucks are equipped with compulsory GPS which costs approx. 100 USD). The the cost of a simple RFID chip is about 1 USD, which is significantly lower.
- *GPS based systems can provide only positional and velocity data*, but cannot provide emission data of vehicles, so it cannot be used for an optimized traffic regulation due to not providing important emission and environmental data, which is a disadvantage.
- *GPS can be turned on/off*, i. e. it requires voluntary participation in traffic monitoring. Contrary to GPS systems, passive RFID tags will always broadcast the programmed information (VIN) to the readers at the given points of intersection. So if the vehicles are equipped with compulsory RFID tags as it is the case in India, the conditions for automatic traffic monitoring are fulfilled. RFID chips can be used very effectively for automatic fee collection on highways and allow seamless traffic flow on other toll roads as well, which is a clear advantage.
- *Licence plate recognition systems* or optical recognition systems (Automatic Licence Plate Reader or ANPR) are less reliable than GPS because ANPR is badly affected by severe weather conditions, and the licence plate data does not give enough information about fuel type and emission data.

Hence, we can conclude that the other existing monitoring technologies (GPS, ANPR) are less favourable for traffic optimization than the RFID technology, because RFID can obtain the most complex data about the real traffic.

3 Discussion

3.1 Components of the Intelligent Traffic Monitoring System

The urban area must be segmented into zones and at the intersections of roads leading into the most frequented city area. These intersections must be equipped with RFID antennae that collect information about the vehicles entering into the zone. The collected data will be sent to the Central Database Processing System (CPDS) using IoT and wireless communication. The following figure (Figure 6) illustrates the process.

The CDPS then sends this information of the Decision Making System (DMS) which operates the traffic signals which is also shown on the same diagram.

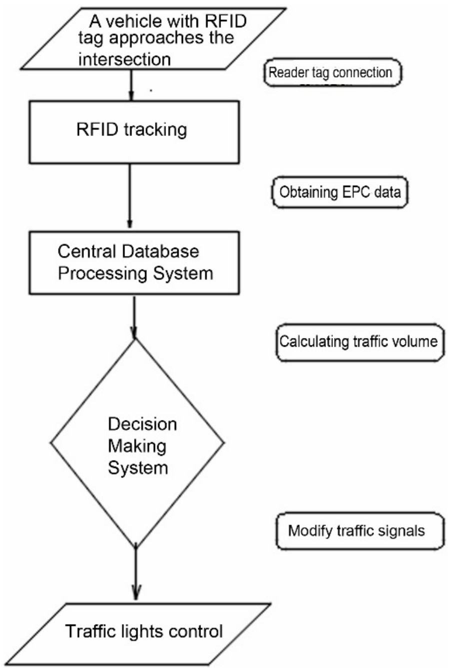

Fig. 6:
Components of the complex traffic monitoring and control system

The DMS can be programmed by various algorithms, the details of the programming is beyond the scope of this paper. We would like to name some key aspects of the dynamic traffic control:

- type of vehicle (buses, trams, etc.) should be taken into account;
- time of the day is relevant;
- pollution factor, etc.

3.2 Aggregating the Expected Traffic that Converges to the Given Intersection

In order to know what the expected traffic will be at intersection A in the next short time period, we need to obtain the total volume of the traffic on each road that converges into the given intersection. It can be done by the central CDPS using Internet-of Things (IoT) and wireless communication.

The traffic data are stored in database records and can be aggregated for arbitrary time periods (e. g. rush hours, weekdays, months, etc.)

The present paper provides only the main technological components of the traffic monitoring, but cannot deal with detailed computing algorithms and DMS solutions which are also essential for the fully developed system.

4 From Traffic Monitoring to Traffic Optimization

Our paper presented a complex traffic monitoring system that is based on RFID technology. By using this system it is possible to obtain real time traffic flow all vehicles passing through an observation point where RFID antennae are placed. Besides the flow rate of the vehicles, it is possible to collect environmental and pollution data from the VIN (Vehicle Identification numbers) (see Figure 1), since the VIN contains the engine type (character 8) and by aggregating the traffic flow, authorities can calculate the total number of environmentally hazardous cars crossing a given intersection daily or in a given time period.

For downtown or urban area we can combine the total vehicle traffic and pollution data, i. e. city officials could have real data to support traffic regulation. Moreover, it is possible to make models to estimate how the total emission of CO_2 or other hazardous substances could be modified if some vehicle categories were excluded from a given traffic zone.

It is possible to aggregate the traffic data and analyse it with appropriate computer algorithms, so a complex decision making system can be built upon the monitoring data.

With the data obtained by this RFID monitoring system local authorities can introduce appropriate measures to cut down or minimize environment pollution.

5 Conclusion, Outlook

The aim of the present paper was to introduce an RFID and IoT based complex traffic monitoring system with two features:

- obtaining real time vehicle distribution (including fuel types);
- real time traffic control (a decision making system of authorities and city planners).

The monitoring system can automatically collect real time data from the vehicles. This data can be aggregated for the given vehicle types to have a real information about the actual use of the urban roadspace in given time intervals.

By analysing the traffic data, the following observations can be made:

- What is the actual lane traffic density? (i. e. How many vehicles pass through the checkpoint in a given time period?).
- What is the aggregated traffic density for a given direction?
- What is the distribution of the vehicle types? (i. e. What is the ratio of cars, motorbikes, bicycles, buses, trams?).
- Aggregated passenger count estimation for each vehicle type (in case of cars it is 1.45 according to latest EU statistics https://www.eea.europa.eu/...passenger-vehicles/occupancy-rates-of-passenger-vehicle).

From the vehicle types and total vehicle number it is possible to estimate the total emitted pollution, noise, space requirements for the vehicles and we can compare this data with the utility of the vehicle.

Local authorities then can analyse the RFID data and make restrictions for less preferred vehicles, to promote favoured travel methods or vehicle-types, based on real and objective traffic data. Hence, traffic planning and roadspace usage can be optimized with the proposed RFID traffic monitoring system combined with proper decision making algorithms and authorities' involvement.

References

AYOUB FIKRI , EL MEHDI ZRIHNI & YASSINE SALIH A. (2015), A smartphone-based system for traffic congestion control using RFID tags (IEEE conference 25-27 March 2015 INSPEC Accession Number: 15308135. DOI:10.1109/EITech.2015.7162983.

ANURAN CHATTARAJ, SAUMYA BANSAL & ANIRUDDHA CHANDRA (2009), An Intelligent Traffic Control System using RFID. IEEE Potentials, 28 (3). http://www.insider-car-buying-tips.com/vin_number_decoder.html.

KATHAWALA Y, A. & TUECK, B. (2008), The use of RFID for traffic. International Journal of Technology, Policy and Management, 8 (2) 111-125.

SZABÓ, G. & CZINKÓCZKY A. (2014), Bicyle Road Optimization using RFID tags. https://www.academia.edu/1175848/Bicycle_Road_Optimization_Using_RFID_Tags.

WEN, W. (2010), An intelligent traffic management expert system with RFID technology. Expert Systems with Applications, 37 (4), 3024-3035.