Advanced Logistic Systems – Theory and Practice, Vol. 17, No. 2 (2023), pp. 46-53.
https://doi.org/10.32971/als.2023.015

INTRODUCTION OF VEHICLE COMMUNICATION AND INTELLIGENT TRAFFIC MANAGEMENT SYSTEMS

DÁVID MAKÓ[1], ÁKOS CSERVENÁK[2]

Abstract: *Nowadays, the vehicle industry is heading for a significant change. There are fundamental debates about what type of drive would be ideal for vehicles in terms of environmental awareness, because environmental protection has become one of the main directions in vehicle production, especially due to the fluctuating raw material sources in today's uncertain situation. Another issue that is at least as important is traffic safety. Almost everyone agrees that the way to safer traffic is mainly through the development of vehicle communication. This is a direction that develops in all vehicles, regardless of drive, construction, or performance. There are several types of vehicle communication systems, but it is not easy to categorize these systems, as it is difficult to clearly separate them, as there are quite large overlaps between them. This article provides an overview of these vehicle communication systems.*

Keywords: *logistics, vehicle communication, intelligent traffic control system*

1. INTRODUCTION

Nowadays, the automotive industry is heading for a significant change. There are fundamental debates about the ideal type of powertrain for vehicles from an environmental point of view, as environmental protection has become a major trend in vehicle production, especially in today's uncertain situation of fluctuating raw material sources. The other equally important issue is road safety. Almost everyone agrees that the road to safer transport lies largely in the development of vehicle communication. This is a direction that is evolving in all vehicles, regardless of their drive, construction or performance. There are different types of vehicle communication systems, but it is not easy to categorise them, as it is difficult to separate them clearly, as there is a lot of overlap between them.

The topic of this paper is related to a topic I have previously developed [1], which describes the difficulties of differentiated vehicle transport and the development of a device-level solution that started in the previous work. The background of the idea related to the present paper is intelligent traffic management systems, within which the aim is now to present the development of a specialised system for emergency vehicles. The basic problem is presented based on the experiment carried out in [2]. In it the high accident rate of discriminated vehicles is clearly mentioned. To support this, a video survey was carried out in collaboration with the German Red Cross emergency response base, during which an ambulance and an emergency medical vehicle were equipped with a video camera and a GPS data recorder. These recorded the behaviour of other road users during real emergency journeys and collected driving data, such as speed and route information, over a 9-day period. During this period, 21 typical emergency trips were recorded. On average, each trip lasted seven minutes and was driven through four red and three green lights. Passing through a number of intersections during the trips, it was observed that each red light caused a delay of 15-30 seconds, and 50% of the trips had at least one red light situation where it took more

[1]BSc, University of Miskolc, Institute of Logistics, Hungary
mako.david2000@gmail.com
[2]PhD., University of Miskolc, Institute of Logistics, Hungary
akos.cservenak@uni-miskolc.hu

than 30 seconds to create a corridor for the emergency vehicle. An average of 2.5 civilian drivers responded inappropriately, causing a total delay of approximately one minute per trip, in addition to two dangerous situations recorded on each trip and one near-crash situation. These clearly show that an intelligent traffic management system could solve a major road safety problem. However, this requires finding the optimal settings for proper operation, including ensuring that no dangerous situations or disruptions occur in the event of an emergency scenario. The challenge is the many possibilities that could arise in such an emergency. A differentiated vehicle can travel on many different routes, at different times, at different speeds. Furthermore, in the event of an emergency (lights and sound signals are activated), specific rules apply in the Highway Code. This means that there are even more exceptional and "special" cases, all of which need to be taken into account in a realistic simulation.

This article gives an overview of these vehicle communication systems. In the second chapter, two of the most relevant vehicle communication technologies for this topic are presented. In addition, existing studies on intelligent traffic light systems are also mentioned in this chapter.

2. VEHICLE COMMUNICATION AND INTELLIGENT TRAFFIC MANAGEMENT SYSTEMS

In this chapter, vehicle communication systems that can be effectively used for intelligent traffic management are presented together with application examples. In addition, several technologies based on intelligent traffic lights are described, based on an article presenting related work. The focus will now be on intelligent traffic light technologies to assist differentiated vehicles.

2.1. Intelligent Rescue System

In addition to its own development, [3] presents four other possible implementations. The first is a so-called Intelligent Rescue System, which is a traffic management system using a RISC microcontroller. This technology allows drivers of differentiated vehicles to control traffic lights. This type of control is carried out by the ambulance driver via an input device, selecting the road he wishes to drive through. As soon as the ambulance driver presses the keypad, the RF (radio frequency) transmitter in the ambulance sends a signal (binary signal) to the RF radio signal receiver in the traffic light controller. This signal contains information about the ambulance's location, route and traffic congestion. When the signal is received by the RF radio signal receiver, it is decoded, after which the traffic light sequence is interrupted and the emergency mode is activated. In the emergency mode, the traffic light gives the ambulance priority to pass by turning green for the ambulance in the emergency lane, and the traffic lights in all other lanes turn red. After the ambulance has passed, traffic and lights will return to the original schedule.

2.2. IoT (Internet of Things)

In Blog [4] they write about an Intelligent Traffic Monitoring and Control system based on a version of IoT that already uses artificial intelligence, called AIoT. The article focuses on the concept of Smart Traffic, which is already based on the aforementioned system and has many advantages. The system optimises traffic and improves safety by dynamically adjusting control mechanisms using sensors, cameras and routers. Such software, if capable of real-time image processing, can react quickly and flexibly to changes in traffic volume, density and capacity. For example, traffic lights can give priority, prioritise free and dedicated public transport, or, based on dynamic lane management, free up bus lanes for motorists when the bus is not using them. A further advantage, closely related to the system to be implemented in this thesis, is the prioritisation of emergency vehicles, made possible by intelligent traffic control. In [5], an article on "smart" traffic lights is described in detail. The cycle settings of these smart traffic lights are grouped into three categories: according to traffic density, according to the expected path of discriminated vehicles, and according to the interests of pedestrians. From the perspective of these three situations, this paper analyses the systems and technologies used in the development of traffic light technology (in which IoT-AIoT technology plays a major role), as well as the development of future intelligent traffic light technology. Also in [5], the importance of smart traffic lights for differentiated vehicles is discussed. The technology consists of each vehicle sending information to each other (about their speed), the duration of the green light is calculated based on the distance of the vehicle from the intersection and the estimated time of arrival. The number of vehicles is counted using cameras and emergency vehicles are distinguished using sensors. Another solution is mentioned, where RFID tags are used to detect emergency vehicles and activate emergency protocols. Under normal operating conditions, the normal signal sequence is maintained, but when the emergency protocol is activated, the state of the device changes and then returns to the default state when the emergency is over. In [4], a control system based on a software defined network (SDN) and IoT is presented. In case of an emergency, it uses traffic cameras to modify the traffic light cycle by having the SDN controller interact with the network to collect traffic data and, based on this data, to order the traffic light cycle. Also in the journal article [7], RFID technology is used to control traffic signals by measuring vehicle density. They propose RFID-based technology that eliminates congestion during busy hours and provides protected lanes for emergency vehicles. The main purpose of this system is to manage traffic efficiently and help emergency vehicles to move properly. Emergency vehicles emit a signal when they detect an RFID signal within a certain distance. When approaching the distinguished vehicle, the traffic server notifies the Arduino at the node, and then this signal, acquired by the Arduino, is matched by the RFID signal received from the RFID reader. This confirms whether the vehicle is in an emergency situation or not. Until the green light is confirmed, the vehicle with the differentiated signal is given a clear path. If the emergency vehicle receives the RFID signal from the Arduino, it will receive a green signal at the traffic lights along its expected route. The traffic information will be sent to the server so that users can use the web pages to determine traffic conditions. Figure 1 shows an example of an IoT system.

2.3. Networked vehicles-V2X communication

There are more possible V2x (Vehicle-to-other) types, which are listed as follows:

a. V2N: Vehicle-To-Network=Vehicle-to-Network communication
b. V2V: Vehicle-To-Vehicle=Vehicle-to-vehicle communication
c. V2P: Vehicle-To-Pedestrian
d. V2I: Vehicle-To-Infrastucture=Vehicle-to-infrastructure communication

The different types can be observed in Fig. 2 [9].

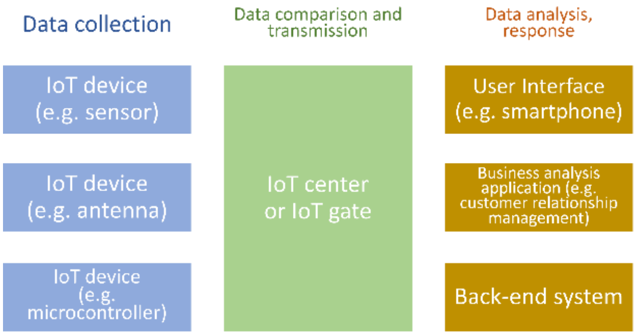

Figure 1. Example of an IoT System [8]

The journal article [6] mentions an application within the V2V network called the Context-Aware Safe Driving Navigator (CASD). It can provide drivers with a safer driving experience by helping them to detect dangerous situations or obstacles.

Also in [8], use cases for V2I networks are mentioned. It mentions a navigation service called Self Adaptive Interactive Navigation Tool (SAINT) that uses V2I networks to optimise road traffic globally. The enhanced version (SAINT+) is able to provide the fastest of different routes to the accident scene for differentiated vehicles, while also providing civilian vehicles with efficient detours.

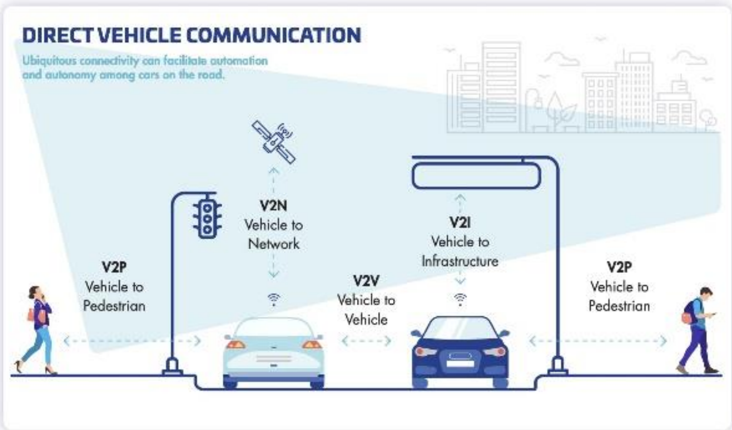

Figure 2. Illustration of the V2X communication [11]

2.4. Smart traffic light system for emergency vehicles

In [12], they describe the implementation of a development using a layered architecture for a smart traffic management system, consisting of a physical layer, an intermediate software layer and an application layer. The middleware consists of an adapter layer and a temporary database that receives data from Google Maps. An Ethernet chip is needed for connectivity, LED lights and Arduino to control the lights. The adapter layer acts as a client wrapper for the various STLS technologies that provide information to the system, such as GPS and WiFi etc. It acts as a device driver that allows the various STLS technologies to work seamlessly with the middleware. The middleware is responsible for several functions, including 1) retrieving and processing raw data from the following sensors available in the system, 2) pre-processing the data and resolving any conflicts, rejecting outliers and drawing conclusions, and 3) storing, sharing, distributing and publishing the data. in the STLS system. The STLS database is a temporary database containing fresh data provided by Google Maps and the MQTT messaging service. Google Maps data is used to find the shortest route and the location of traffic lights on the route. The MQTT protocol is used to publish the time of arrival of each traffic light on the route and to deliver this information to all subscribing traffic lights. The application layer consists of an Android application running on a mobile device. The Android application allows the user to select the starting point and the final destination. Google maps can be used to find the shortest route from the source to the destination, as well as the location of all traffic signs along the route. The Android app then sends the arrival time of each traffic light to the corresponding traffic light controller. Finally, when an emergency vehicle arrives at the traffic lights on the route to its destination, it finds them open without conflicting with other signals at the intersection.

2.5. Smart ambulance system

Also mentioned in article [3] is the use of an intelligent ambulance system to give permission to any emergency ambulance by turning all red lights green on the emergency vehicle route. The system is implemented using GPS, Global System for Mobile Communication (GSM) and ZigBee technology, the system sends the patient's parameters to the hospital every few minutes so that it can monitor the patient's condition. The microcontroller unit is connected to the ambulance control room to send the details to the control centre and traffic signage. The system uses ARM Cortex-M32 as interface with traffic signal and ambulance section, ARM Cortex-M3 system enhancements and higher level of support block integration. This intelligent system is a low-cost system, thanks to ZigBee technology, which is cheaper than other WPAN reason, GPS freely available to all and GSM. The primary purpose is to detect the emergency vehicle and track its position to provide a wireless signal to the emergency vehicle. Conventional technologies use image processing to recognise the emergency vehicle, but this technology is affected by weather conditions, which prevents recognition of the emergency vehicle. So this smart system uses a ZigBee transponder and receiver that works in all weather conditions. On the smart system side, a high frequency reader is required to provide long range. ZigBee transponder must be embedded in the vehicle dashboard. The system consists of three parts: ambulance, control centre and traffic signalling system. The intelligent ambulance sends its position and patient parameters to the control centre. The control centre sends the route to the nearest hospital to the intelligent vehicle, the ambulance selects the route and all traffic signs in that direction turn green.

2.6. Intelligent traffic management system

In [3], you can read about an intelligent traffic management system that provides easy passage for differentiated vehicles. The system consists of three parts, and the technologies used in the system are ZigBee, Radio Frequency Identification (RFID) and Global System for Mobile Communication (GSM). The first part deals with counting the number of vehicles passing along a given route at a given time and timing the green signal on the route. An RFID tag is placed in each vehicle so that when it is passed, the RFID reader counts the number of vehicles passing. The methodology for knowing the green light duration and the number of vehicles is as follows: if the number of vehicles is more than 10, the green light duration is set to 30 seconds. If the number is between 5 and 9, the green light duration is set to 20 seconds, and if the number is less than 5, the green light duration is set to 10 seconds. The second part deals with the evacuation of ambulances, each ambulance has a ZigBee transmitter module and the ZigBee receiver is implemented in each traffic node. The ZigBee receiver waits for a signal from a ZigBee transmitter in each ambulance.When the ZigBee receives this signal, the traffic light turns green. The traffic light turns red again as soon as the ambulance has passed. The third part presents a method to detect the stolen vehicle, the RFID reader detects the stolen vehicle, the module compares the unique RFID tag read by the RFID reader with the stolen RFID tags stored in the RFID reader by the system. If a match is found, the beacon turns red for 30 seconds. It also sends an SMS to the police.

2.7. Systems similar to the system to be implemented

This subsection presents a paper that describes traffic simulation software in general and how it works. It covers the mathematical background behind the simulations. It also mentions an article whose authors use the same software as the one used for the simulation we are going to present.

In [13], software simulations are presented using intelligent traffic control technologies. The article clearly discusses the importance of intelligent traffic management tools for differentiated vehicles and states, "Delays of emergency vehicles such as ambulances and fire trucks are undoubtedly among the most critical consequences of traffic congestion, as they can cause significant losses of property and loss of human lives." This paper presents the detailed operation of an Adaptive Traffic Light Control System (ATLCS) proposed by the authors to reduce urban congestion during the afternoon rush hours. At this time of the day, most people working in the city centre usually leave their workplace and go home. The system gives priority to vehicles leaving the city centre via the main roads by having traffic light controllers synchronise the traffic lights in a given direction so that vehicles travelling in that direction do not have to stop as often. This would reduce stop and go times and as a result more vehicles could leave the city. By giving these vehicles priority, the number of vehicles in the city centre would be reduced, which in turn would ease congestion there. A key requirement for the successful deployment of an effective ATLCS is an accurate estimate of the number of vehicles on the road. This can be achieved in a number of ways, such as inductive loops, magnetic sensors, magnetometers or even cameras. After examining their advantages and disadvantages, the authors chose magnetometer sensors as the main sensing technology to be used in their system. These sensors are able to detect the presence of vehicles passing over them by sensing changes in the Earth's magnetic field. They have a number of outstanding features, such as being easy to operate on battery power and their performance does not deteriorate in bad weather conditions.

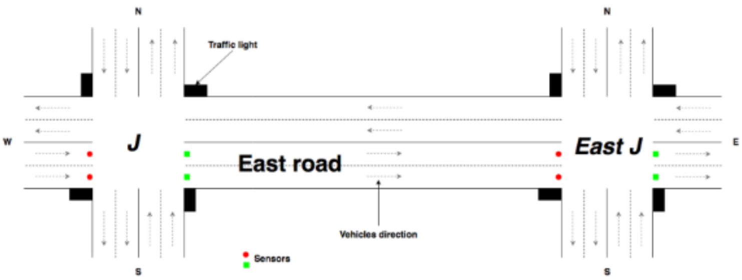

Figure 3. Illustration of sensors placed in nodes [13]

In this study, only two-lane roads are considered, therefore the road network architecture requires four sensors per node, as shown in Figure 3, which depicts the installed sensors.

The article [14] also strongly supports the fact that discriminated vehicles have a very difficult time gaining the right of way in urban environments. While using sirens and lights, they can run through red traffic signals, but this can lead to very dangerous situations, as already shown at the beginning of this paper. The simulation of the project presented in [14] was implemented using PTV Vissim software (the simulation presented in this thesis was also implemented using this software). In the simulation, discriminated vehicles were defined alongside civilian vehicles and provided with a continuous green wave to allow them to pass through an intersection without significant deceleration. "The software prioritises traffic modes to different degrees. If an emergency vehicle signals via V2X communication that it needs a clear passage, the software manages the traffic lights accordingly, allowing the vehicle to pass through the intersection without slowing down - with minimal impact on other road users".

3. Summary

The technology used in the research linked to this article is designed to prevent a common hazard that car drivers often encounter. In the first chapter of the paper, in addition to an introduction, a device developed in previous work is briefly presented, which is a discriminative vehicle approach warning system for civil vehicles. Another potential use of the device is to signal its approach not only to civil vehicles but also to intelligent traffic management systems. The literature background of this thesis includes an experiment presented in chapter two, which clearly showed how much time is lost by an emergency vehicle in a congested urban environment due to inadequate traffic management systems. This was followed by a presentation of vehicle communication systems that effectively support intelligent traffic management systems. In addition, a number of other intelligent traffic management techniques are also described in the second chapter.

References

[1] Makó, D. (2021). *Sürgősségi járművek közeledésének egyéb járművön belüli jelzésére szolgáló rendszer megvalósítása*, Scientific Student Work, TDK Conference, University of Miskolc, 2021 november 15. Miskolc

[2] Bosquez, C.; Lovato, M.; Lucas, L.: Ambulance alert system step in frequency modulated using SDR, in ANDESCON, IEEE, 2014 https://doi.org/10.1109/ANDESCON.2014.7098575

[3] Nono R., Asudais R., Alshmrani R., Alamoudi S. & Aljahdali A. (2020). Intelligent Trafic Light for Emergency Vehicles Clearance, ADCAIJ, **9**(3), 89-104, https://doi.org/10.14201/ADCAIJ20209389104

[4] CallioVision: *Intelligens forgalomfigyelő és -szabályozó rendszerek*, 2020-2021

[5] Yusuf, A. N. A., Arifin, S, A., & Zulkifli, F.Y. (2021). Recent development of smart traffic lights, *IAES International Journal of Artificial Intelligence* (IJ-AI), **10**(1), 224-233, https://doi.org/10.11591/ijai.v10.i1.pp224-233

[6] Rego, A., et al. (2018). Software Defined Network-based Control System for an Efficient Traffic Management for Emergency Situations in Smart Cities, *Futur. Gener. Comput. Syst*, **88**, 243-253, https://doi.org/10.1016/j.future.2018.05.054

[7] Naik, T., Roopalakshmi, R., Jain, D. R. N, P. & Sowmya, B. H. (2018). RFID-Based Smart Traffic Control Framework for Emergency Vehicles, *2018 Second Int. Conf. Inven. Commun. Comput. Technol.*, pp. 398–401, https://doi.org/10.1109/ICICCT.2018.8473001

[8] Gillis, A. S.: *What is internet of things (IoT)?* TechTarget, 2021

[9] Kovács, Sz. (2020). *Járműinformatika, Bevezetés*, Miskolc University Press

[10] Jeong, J., Shen, Y. & Xiang, Z. (2019). *Vehicular Neighbor Discovery for IP-Based Vehicular Networks*, Sungkyunkwan University

[11] V2X: *What is Vehicle to Everything?* Thales, 2021

[12] Almuraykhi, M. K. & Akhlaq, M. (2019). STLS: Smart Traffic Lights System for Emergency Response Vehicles, 2019 International Conference on Computer and Information Sciences (ICCIS), Sakaka, Saudi Arabia, pp. 1-6, https://doi.org/10.1109/ICCISci.2019.8716429

[13] Aleko, R. D. & Djahel, S. (2020). An Efficient Adaptive Traffic Light Control System for Urban Road Traffic Congestion Reduction in Smart Cities, *Information* **11**(2), 119, https://doi.org/10.3390/info11020119

[14] Schmidt, S.: *Smart traffic lights enable emergency vehicle priority*, PTV Group, 2021