*Article citation info:*
Wróbel R, Sroka Z, Sierzputowski G, Dimitrov R, Mihaylov V, Ivanov D. Driving protocols: the possibility of using routing protocols in autonomous transport. Combustion Engines. 2024;196(1):3-9. https://doi.org/10.19206/CE-170418

*Radosław WRÓBEL*
*Zbigniew SROKA*
*Gustaw SIERZPUTOWSKI*
*Radostin DIMITROV*
*Veselin MIHAYLOV*
*Daniel IVANOV*

**Combustion Engines**
**Polish Scientific Society of Combustion Engines**

# Driving protocols: the possibility of using routing protocols in autonomous transport

ARTICLE INFO

Received: 11 May 2023
Revised: 28 July 2023
Accepted: 3 August 2023
Available online: 6 November 2023

*Removing the human factor from transport (in the direct sense) is still a plan, reaching into the future. However, this plan does not require so much imagination – autonomous vehicles can already be found on the roads. Currently, they are not only autonomous but also independent, i.e. decisions about traffic parameters are made in the vehicle. In the future, with more autonomous vehicles, there will be a need to connect them with a communication network, which will eliminate a number of telematic problems. It remains an open question how to make this network? Is it based on the modern Internet network? What and which data will be necessary to achieve the "right relations" between autonomous vehicles (hosts of network)? The article presents one aspect of the mentioned problem; the amount of data generated by an autonomous vehicle is presented in light of the processing capabilities of modern ICT systems.*

Key words: *autonomous vehicle, transport protocols, routing protocols, transport of the future, telematics*



## 1. Introduction

The automobile market is facing (as it typically does) new challenges and its evolution is accelerating. One of the new challenges is the idea of autonomous vehicles. The main aim behind attempts to replace human drivers with machines is to minimize or even eliminate human error (but still meet emission standards [2]). According to WHO, 1.25 million people die annually in road accidents around the world. While full statistics on road accidents are not available in developing countries, data show that over 80% of collisions and accidents in developed countries are caused by humans [2]. A key requirement for a driver is to have high mental ability to accurately evaluate the situation on the road and make responsible decisions. Motor skills are equally important, as they allow the precise execution of the intended maneuvers. Research indicates that road accidents are mainly caused by young drivers (aged below 25) and by people older than 60 years [3]. However, the reasons for the accidents were different for the two groups: the older people have lowered motor skills, while the younger people show impulsive behavior, aggression or even a pathological fear of driving a vehicle. Although the poor condition of roads and vehicles is (often) mentioned as the main cause of accidents and collisions, research shows that such events are most frequently caused by an inappropriate response from the driver. The problem of high car accident rate can be solved by increasing the skills of the driver (requires stricter traffic regulations), improving the condition of the infrastructure, validating vehicles or delegating control over the vehicle to a unit which is capable of minimizing the number of driving errors, i.e. by fully automating the driving process (the driver only defines the destination).

## 2. Last-mile transport in Personal Rapid Transit networks

Over the years, scientists and engineers have been pursuing options to shift the responsibility for driving a car from humans to machines. The idea dates back to the 1920s [2]. The motivation behind the early attempts made in the U.S. has not changed – to improve safety and reduce the number of fatal accidents. Currently, car manufacturers compete in developing self-driving technologies in order to gain prestige which allows them to draw specific clients and offer them services not offered by the competition.

The first automated guided vehicle (AGV) was the Guide-O-Matic, which was able to follow a wire path and which was constructed in the 1950s by Arthur „Mac" Barrett, owner of Barrett Electronics [5]. Another modification is an inertial navigation system (INS) with reference points, coordinates, a gyroscope and sensors for detecting the position – following the idea that a modification of the route consists of the modification of the reference points. Despite making the impression of intelligence, such vehicles still only move along a predefined track and are not able to independently plan actions and make autonomous decisions. They perform carefully planned movements in a limited space, owing their increased popularity largely to high efficiency and precision, as well as to the fact that they can be used in working conditions harmful to humans.

The PRT system is a modern type of urban transportation (typically electric). Its basic elements are small vehicles capable of transporting a limited number of passengers and moving autonomously in a designated aerial space or in a dedicated traffic lane [5, 6].

In its current form, PRT can provide transport in an on-demand mode or supplement local transportation systems in which no intermediate points exist between the starting point and the finish point and in which the infrastructure comprises redundant tracks, allowing an optimal route choice depending on the conditions.

In September 2019, an autonomous bus manufactured by EasyMile transported passengers to the local ZOO in Gdansk, Poland, as part of the Sohjoa Baltic program titled: "Transformation to ecological and autonomous last-mile public transport in the Baltic region" [8]. This experiment may be considered the first widely available public PRT application in Poland. For passenger safety, the operator present in the vehicle was required to react in case of problems, and the bus moved along one, dedicated lane of Karwieńska street – the lane was closed to other vehicles.

Although all vehicle manufacturers agree about the CASE standard (connected, autonomous, safe, and efficient – the last one being frequently understood as electric) they rather disagree on the technical details of this system. The 2019 CASE agreement was signed by Aptiv, Audi, Baidu, BMW, Continental, Daimler, FCA, HERE, Infineon, Intel and VW [16]. The above car manufacturers work independently, focusing on building advantage over their competition and providing their cars with cutting-edge equipment. However, their ultimate goal will be to develop a uniform and complex system that will be implemented by all of the manufacturers and which will serve as a basis for designing equipment used in autonomous vehicles. Failure to adhere to such defined standards will result in a significantly increased road-accident risk.

The Society of Automotive Engineers (SAE) identifies six levels of driving automation, with level 0 representing no driving automation and level 5 – full driving automation [2]. Levels 1–4 are intermediate, with gradually increasing driver support during maneuvers and analysis of the situation on the road and around the vehicle.

Level 3 raises the greatest controversy, as numerous experts believe that it should be completely eliminated. In this level, the vehicle completely controls the surrounding area and moves with no need for the attention of the driver. The controversy is related to the fact that the car may inform the "passenger" about the need to regain control of the vehicle, and if the human using the "autopilot" and not focusing on the road is suddenly interrupted, they may pose a threat to themselves and other road users. Modern trucks frequently meet the requirements of level 2 – they offer adaptive cruise control and lane centering on highways. They are also able to connect in a convoy using the V2V technology in order to continue a part of a journey synchronously. Trucks in such convoys travel with constant speeds and with fuel consumption reduced by approximately 4–5 liters per 100 km [18], resulting in higher efficiencies, lower operating costs and lower emissions of harmful gasses into the atmosphere. Although the 2016 European Truck Platooning Challenge tests of autonomous synchronized driving in a convoy were successful [2], the main goal of the international EU-supported ENSEMBLE program (introducing truck platoons to selected European public roads before the end of 2021) has not yet been accomplished. The remaining problem is for truck manufacturers to agree on standards which would allow the safe and effective multi-brand platooning.

Over the years, scientists and engineers have been pursuing options to shift the responsibility for driving a car from humans to machines. The idea dates back to the 1920s [2]. The motivation behind the early attempts made in the U.S. has not changed – to improve safety and reduce the number of fatal accidents. Currently, car manufacturers compete in developing self-driving technologies also for prestige which allows them to draw specific clients and offer them services not offered by the competition. The first automated guided vehicle (AGV) was Guide-O-Matic, which was able to follow a wire path and which was constructed in the 1950s by Arthur „Mac" Barrett, owner of Barrett Electronics [5].

## 3. Routing Protocols in Transport ("Driving Protocols")

The topology of transportation roads can be compared to a map, in which "streets" represent physical communication paths (routes), "signs" represent the result of the involved protocols (routing), and "addresses" represent a particular location. From the perspective of information technology, the analogy to the global network (the Internet) is eclectically similar, if each autonomous vehicle (AV) is understood to be in fact a host. Each device connected to the global network needs to acquire a unique IP address, and the rapid growth of the number of devices operating within the Internet of Everything (IoE) necessitates the use of the IPv6 protocol as the communication tool.

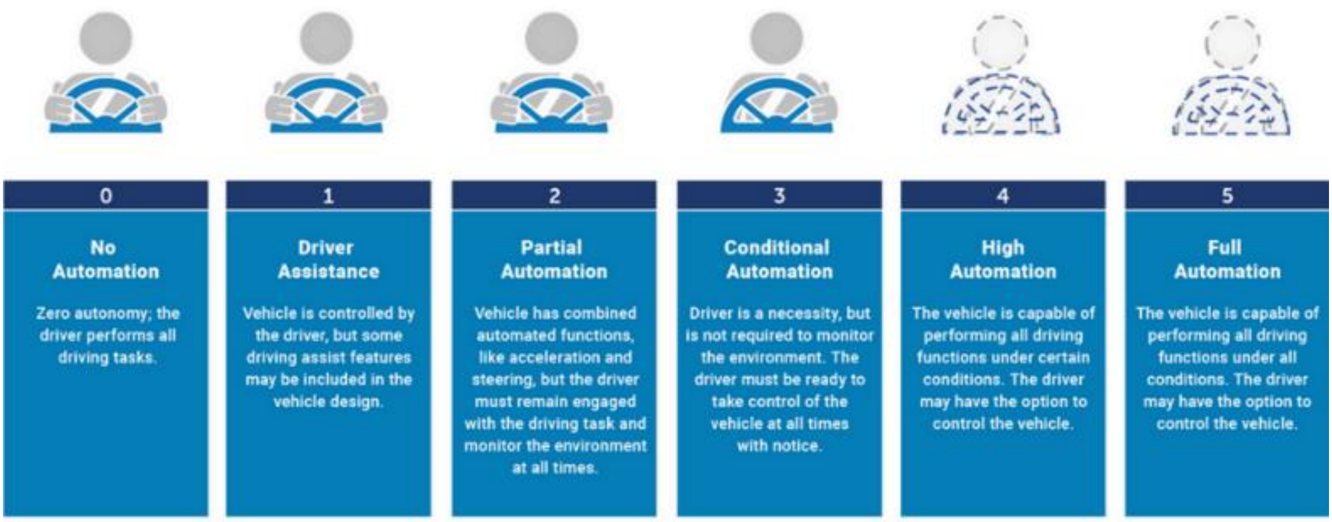


Fig. 1. Driving automation levels as defined by SAE [17]

In order for AVs to reach global markets on a mass scale, the number of available IP addresses should be sufficient both at present and in the future perspective. The IPv6 is additionally advantageous in that it allows the connected devices to be configured automatically, thus effectively limiting the number of potential mistakes and enabling an unambiguous identification of each machine [19].

Each AV regularly generates a finite portion of data, which are then processed locally and later sent to the server for interpretation. The acquired information can be classified by its usage method as:

- technical data
- crowdsourced data
- personal data.

The technical data, acquired from the sensors and preprocessed in order to remove faulty or incomplete electronic measurements, allows the vehicle to analyze its surroundings. The implementation of artificial intelligence which identifies the source of each piece of information and fuses the information in real time into one coherent and valuable unit will allow highly "intelligent" (autonomous) vehicles which will be capable of making "conscious" decisions on the road.

The crowdsourced data are acquired from the collectively shared information and will allow optimal planning of the occupied space and effective management of the road traffic. To date, such data were collected only from measurement points installed along the road infrastructure, which thus needed modification. The typical solutions include induction loops, vision cameras and microwave devices. Additional data, albeit less reliable, are also collected from commercial services based on sensor readings from fleet vehicles. Additional sensors installed in autonomous vehicles will allow the acquisition of very precise data directly from the machines. As a result, the vehicles will be able to communicate with each other in a complex, ant-robot manner, following the concept of miniature, intelligent electronic devices which act as autonomous individuals but cooperate to accomplish a set goal [20].

In the context of AVs, the above concept will lead to full cooperation between the machines and to the definition of a hierarchy between the road users (hosts). This phenomenon will be of particular importance in the transition period, when AVs will have to coexist with other "less intelligent" machines. The analysis of data incoming from other road users will allow a reduction in the number of dangerous road accidents.

Personal data are packages of information most closely related to the vehicle user. In the first stage, they will serve only to identify the user, and in the next stages – also to increase the travel comfort by means of personalization, such as selecting the preferred route or following further points on the agenda of the user.

The above solutions imply a substantial amount of data generated by an AV. It is impossible for the vehicles to exchange complete information within the autonomous system. In the case of "conscious transport" (in which AVs know about each other by exchanging information), the vehicle should be treated as a (mobile) host, (not a node!) in an ICT network. The problem of routing between hosts has already been solved in IT. A number of the so-called routing protocols have been designed to allow the exchange of information between nodes (intermediate points) following the "best" path (route) between two points. The intermediate points use the routing protocol to indicate the optimal path for the host (vehicle). The protocol running in the node calculates the "best path" by including a number of variables, such as distance, traffic intensity, blockades or priorities. The following is a short description of the three most popular open-source protocols: RIP, OSPF and EIGRP.

**Routing Information Protocol**

The first version of Routing Information Protocol (RIP) is described in document RFC 1058, which dates back to June 1988 [10]. To date, new versions have been published: RIPv2 – the second version, working with IPv4 [22] and RIPng – a version dedicated to IPv6 [24]. RIP selects the route based on the best path. In the case of RIP, the best path is the one with the smallest hop count (this metric is calculated with the graph-based Dijkstry algorithm – the best path has the smallest count, as it requires the smallest number of hops – intersections).

**OSPF protocol**

OSPF (Open Shortest Path First) is a protocol more complex than RIP – it is used in autonomous systems operating in a medium having different bandwidths (road capacity). The first document describing the OSPF protocol was published in 1989. It is currently available in two versions: OSPFv2 for IPv4 [21] and OSPFv3 for IPv6 [10]. The protocol divides the network of local routers into areas, i.e. groups of nodes, and employs the flooding technique to inform the neighbors (nodes) about changes in the topology. Each node (router) in the OSPF network maintains a routing table for its area. Border routers – which are part of one area but neighbor another area – additionally have the routing table for the neighboring area. The OSPF protocol uses an additional designated router to store all local routes.

**EIGRP protocol**

EIGRP (Enhanced Interior Gateway Routing Protocol) is a hybrid protocol which combines the features of the above-described protocols. Therefore, it is theoretically the most "intelligent" protocol of the three. Unfortunately, its more advanced algorithm causes this protocol to use more node resources. EIGRP was developed by Cisco, and its description can be found in RFC [13]. It employs a highly specialized transport protocol called RTF (Reliable Transport Protocol). The EIGRP algorithm searches for the best path to the destination using a mathematical function with variables such as bandwidth, reliability, delay, and load (in terms of transport: road capacity, current traffic intensity, accident statistics, and speed statistics, respectively).

## 4. Estimation of computing power demand from PRT

To analyze the amount of continuously flowing data generated by a vehicle, Intel "froze" their static fragment. This approach allows the application of current knowledge to the theoretical investigation of the problem. Based on the average time spent in the car by the user, Intel predicts that a single autonomous vehicle will generate approximately 4 TB of data [11].

The Mobileye autonomous vehicle has been provided with 12 cameras, 6 lidar sensors, 6 radars, a sonar and a GPS receiver, and the total amount of the generated data is provided in Table 1.

Table 1. Theoretical amount of data (optimistic variant) generated by Intel Mobileye

| Optimistic variant – vehicles generate a minimum expected amount of data | | | | |
|---|---|---|---|---|
| Source | per sec | [–] | Data sent over 1.5 h [MB] | Data sent over 1.5 h [GB] |
| Cameras | 240 | MB | 1296000 | 1265.63 |
| Radar | 60 | kB | 316.41 | 0.31 |
| Sonar | 10 | kB | 52.73 | 0.05 |
| Lidar | 60 | MB | 324000 | 316.41 |
| GPS | 50 | kB | 263.67 | 0.26 |
| | | | | SUM TOTAL: 1582.65 GB |

Table 2. Theoretical amount of data generated (pessimistic variant) by Intel Mobileye

| Pessimistic variant – vehicles generate a maximum expected amount of data | | | | |
|---|---|---|---|---|
| Source | per sec. | [–] | Data sent over 1.5 h [MB] | Data sent over 1.5 h [GB] |
| Cameras | 480 | MB | 2592000 | 2531.25 |
| Radar | 600 | kB | 316.06 | 3.09 |
| Sonar | 100 | kB | 527.34 | 0.51 |
| Lidar | 420 | MB | 2268000 | 2214.84 |
| GPS | 50 | kB | 263.67 | 0.26 |
| | | | | SUM TOTAL: 4749.96 GB |

Even in the optimistic approach, in which the amount of data is three times lower than in the pessimistic scenario, the 3 trillion vehicles estimated to be on the roads in 2050 will generate at least 12 yottabytes of information per day – a value comparable to the content of the entire Internet. The above estimation indicates a necessity for implementing driving protocols that will enable fully automated autonomous transportation.

The decision can be postponed in waiting for improved transmission medium and server solutions to be ready to accommodate the above-mentioned load. However, this progress will simultaneously apply to the equipment installed in intelligent vehicles: engineers will hesitate to implement additional modules as they will be expected to generate increased amounts of data. The potential of AVs can be fully utilized only if the scalability of this solution is increased, as optimization seems to be the missing link on the road to the global implementation of this technology [4]. Unfortunately, the current problems include the need to define which sources of data the machine will need at a particular moment or which information will enable the effective management of transportation. Therefore, all available data must be initially acquired to enable efficient management of the tested AV fleet [7]. The properly identified transmission priorities will allow a decision on which information should be sent to the server cyclically as the car is in motion, and which information can be sent later. The data for immediate transmission include GPS coordinates which allow the analysis of the local traffic and enable the cooperation with regular vehicles. The information needed by the AV to make independent decisions on the road can be given a lower priority.

## 5. Potential to compress the AV data – lidar, GPS, video

Lidar sensors emit waves continuously or cyclically, and the scattered light beams are reflected from obstacles. The analysis of the intensity of the wave recorded by the optic system allows a precise estimation of the distance to and the shape of the objects. The cloud point thus generated offers a highly accurate representation of the geometry of the surrounding objects. Unfortunately, the specific character of lidar data disqualifies them as the only source of information for an autonomous vehicle – although lidar sensors are very precise, they are sensitive to weather conditions: the signal is "lost" not only in the presence of fog and clouds, but also when touching the asphalt. The combination of lidar and other sensors will eliminate dead zones, i.e. fragments of the surroundings not visible to the vehicle from the available perspective. It will also allow an advanced correction of the measurement errors and provide information about important object features such as convexity and speed, enabling the vehicle to predict events and plan maneuvers with appropriate response time. Tests [12, 14, 15] have demonstrated that with the algorithm correctly adjusted to the type of the surroundings the file size can be considerably reduced. In urban traffic conditions, the original amount of data could be reduced by 75% without any significant loss of data quality.

Table 3. Theoretical amount of data (optimistic variant) generated by vehicle

| Optimistic variant – vehicles generate a minimum expected amount of data | | | | |
|---|---|---|---|---|
| Source | per sec. | [ ] | Data sent over 1.5 h [MB] | Data sent over 1.5 h [GB] |
| Cameras | 240 | MB | 1296000 | 1265.63 |
| Radar | 60 | kB | 316.41 | 0.31 |
| Sonar | 10 | kB | 52.73 | 0.05 |
| Lidar | 15 | MB | 81000 | 79,10 |
| GPS | 50 | kB | 263.67 | 0.26 |
| | | | | SUM TOTAL: 1345.34 GB |

Table 4. Theoretical amount of data (pessimistic variant) generated by vehicle

| Optimistic variant – vehicles generate a minimum expected amount of data | | | | |
|---|---|---|---|---|
| Source | per sec. | [ ] | Data sent over 1.5 h [MB] | Data sent over 1.5 h [GB] |
| Cameras | 240 | MB | 1296000 | 1265.63 |
| Radar | 60 | kB | 3164.06 | 3.09 |
| Sonar | 100 | kB | 527.34 | 0.51 |
| Lidar | 105 | MB | 567000 | 553.71 |
| GPS | 50 | kB | 263.67 | 0.26 |
| | | | | SUM TOTAL: 3088.82 GB |

Although it is very useful for the driver today, the 2D GPS (Glonass, Galileo) map is not a sufficient source of information for an autonomous vehicle – the data that an AV requires must be of accuracy and precision level sufficient to allow the vehicle to make a proper decision on the road. Being provided with advanced electronic systems and software, AVs will be able to use the 3D map technology.

The 3D map is a series of repeatedly taken photographs or 3D lidar scans which serve to construct a point cloud comprising objects present in the particular space. Each object has an assigned depth which is used to determine its distance from the road axis.

In order to increase precision or eliminate occlusion, the data are subjected to additional operations and subsequently to compression with the aim for the "view to be presented from the center of the roadway in perpendicular to its edge" [9]. In the DNA Roadmapping project, TomTom attempted a digital mapping solution with a positioning accuracy of up to 5 cm with respect to the road lane [25].

The basic elements of the system comprise the following layers:

- RoadDNA – a detailed point cloud for a particular location
- vertical traffic signs and horizontal lines on the roadway – adjusted to enable the positioning of a vehicle on the basis of data from its cameras
- radar – supplementary positioning data enabling the continuous view of objects scanned by sensors
- lamp posts along the road, which facilitate the positioning of a vehicle with the use of data from radar or lidar sensors, as well as from cameras
- road surface, using the reflectivity of the lidar laser beam.

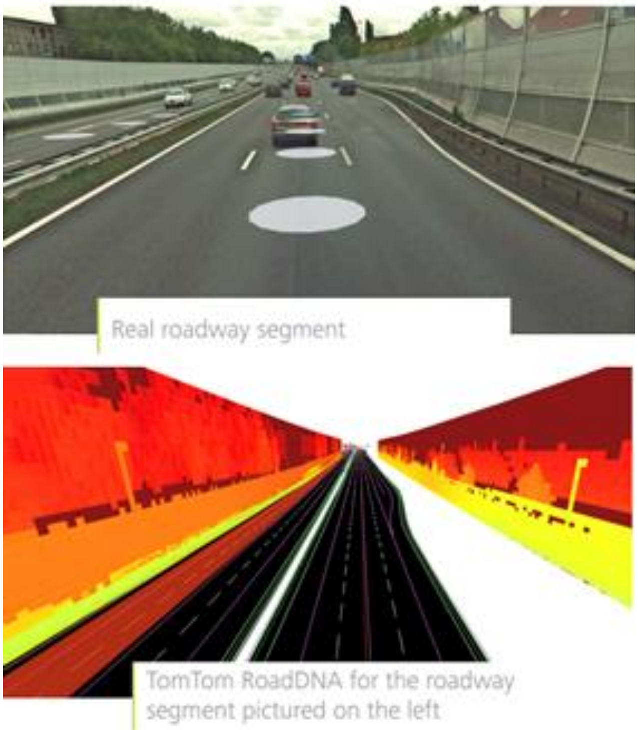


Fig. 2. RoadDNA technology developed by TomTom [25]

Intel estimates the amount of data sent by the GPS module at approx. 50 kbps and the main purpose of providing AVs with such a receiver is to build a traffic map and to analyze data for the informed development and management of the road infrastructure. However, the effectiveness of GPS can be increased by expanding its functionality with the option to read additional parameters directly from the vehicle.

Table 5. Impact of GPS data compression (Albatross) on the amount of generated data

| Optimistic variant – vehicles generate a minimum expected amount of data | | | | |
|---|---|---|---|---|
| Source | per sec. | [–] | Data sent over 1.5 h [MB] | Data sent over 1.5 h [GB] |
| Cameras | 240 | MB | 1296000 | 1265.63 |
| Radar | 60 | kB | 316.41 | 0.31 |
| Sonar | 10 | kB | 52.73 | 0.05 |
| Lidar | 15 | MB | 81000 | 79.10 |
| GPS | 0.2 | kB | 1.05 | 0.001 |
| | | | | SUM TOTAL: 1345.09 GB |

Table 6. Impact of GPS data compression (Albatross) on the amount of generated data

| Pessimistic variant – vehicles generate a maximum expected amount of data | | | | |
|---|---|---|---|---|
| Source | per sec. | [–] | Data sent over 1.5 h [MB] | Data sent over 1.5 h [GB] |
| Cameras | 480 | MB | 2592000 | 2531.25 |
| Radar | 600 | kB | 3164.06 | 3.09 |
| Sonar | 100 | kB | 527.34 | 0.51 |
| Lidar | 105 | MB | 567000 | 553.71 |
| GPS | 0.2 | kB | 1.05 | 0.001 |
| | | | | SUM TOTAL: 3088.57 GB |

With high-resolution (UHD or 4K) devices, the imaging ("video") function will allow a 360-degree representation of the surroundings and a full view of the situation on the road. Proper recognition of the color space ensures that objects are correctly identified in different light conditions, and a high frame-per-second rate reduces the response time of the vehicle. However, the disadvantage of modern solutions lies in the size of the output file, which may hinder the effective transmission of the material to the server. A proper video compression may facilitate the information transmission over the network. However, video compression, based on a series of the so-called codecs and continuously developed protocols, will not be able to meet the demand resulting from the amount of data generated by new versions of imaging technologies. The above problem is of significance, as this type of sensors is currently the basis for the local autonomy of vehicles (although not all of the information needs to be transmitted).

We cannot forget about possible additional diagnostics, which will result from the vehicle's supply method (e.g. control of electricity flow in the vehicle [23]) and the use of this information to place the vehicle in the charging queue.

## 6. Conclusions

Although intelligent transport systems are still in the test phase, public administration should already regulate and support the development of new standards by building a uniform digital infrastructure for numerous and various economic entities. The purpose of tests performed across the world is not only to prepare societies for the broad deployment of autonomous vehicles but most importantly to identify the potential problems and eliminate them at an early stage. From this perspective, Sweden is the leading country, with a range of legal acts regulating the use of AVs and their tests on public roads.

To date, discussions on the future of vehicles and their propulsion systems have focused on two aspects: either the type of motor or the emissivity [1]. Vehicle autonomy seems an underestimated issue, regarded as a curiosity rather than a (practically certain) direction of development. Research units and the automotive industry view vehicle autonomy from the perspective of its commercial potential – as an opportunity to demonstrate their ability by creating a mechatronic device with a certain autonomy. However, several completely new problems have meanwhile appeared: how to control a group of AVs in an autonomous system? How to process the amount of data generated by AVs over a single day – an amount equivalent to the content of the entire Internet? Should such data be processed locally or globally? The above questions can be answered from the perspective of the current IT resources: the technology will not be able to accommodate the traffic generated by the AV fleet.

The problem has not yet been addressed on a wide scale (except stress tests by Intel), while the challenges posed by the autonomous transport of the future include not only the propulsion system and the emissivity.

## Nomenclature

| | |
|---|---|
| AGV | Automated Guided Vehicles |
| AV | Autonomous Vehicle |
| EIGRP | Enhanced Interior Gateway Routing Protocol |
| GPS | Global Positioning System |
| ICT | Information and Communication Technologies |
| INS | Inertial Navigation System |
| IoE | Internet of Everything |
| IPv4 | Internet Protocol version 4 |
| IPv6 | Internet Protocol version 4 |
| IT | Information Technology |
| LiDAR | Light Detection and Ranging |
| OSPF | Open Shortest Path First |
| PRT | Personal Rapid Transit |
| RFC | Request for comments |
| RIP | Routing Information Protocol |
| RTF | Reliable Transport Protocol |
| WHO | World Health Organization |

## Bibliography


[1] Andrych-Zalewska M. Research of pollutant emissions from automotive internal combustion engines in conditions corresponding to the actual use of vehicles. Combustion Engines. 2023;193(2):64-70. https:// doi.org/10.19206/CE-162621

[2] Andrych-Zalewska M, Chłopek J, Merkisz J, Pielecha J. Investigations of exhaust emissions from a combustion engine under simulated actual operating conditions in real driving emissions test. Energies. 2021;14:1-20. https://doi.org/10.3390/en14040935

[3] Barker K, Cioara J. TCP/IP IPv6 – Networking Training. CBT Nuggets; 2019.

[4] Caillet P, Dupuis Y. Efficient LiDAR data compression for embedded V2I or V2V data handling. Arvics 2019.

[5] Choromański W, Grabarek I, Kozłowski M, Czerepicki A, Marczuk K. Pojazdy autonomiczne i systemy transportu autonomicznego. PWN, Warsaw 2020.

[6] Dimitrakopoulos G, Tsakanikas A, Panagiotopoulos E. Autonomous Vehicles Technologies, Regulations, and Societal Impacts. Elsevier 2021. https://doi.org/10.1016/C2020-0-02875-6

[7] Gościewski D. Application of RLE recompression to reduce the size of grid files (in Polish). Technical Journal of the Cracow University of Technology. 2008

[8] Igliński H. Pros and cons of autonomization of trucks (in Polish). Transport and forwarding (June–July); 2018.

[9] Intel automatic driving informations. https://newsroom.intel.com/editorials/krzanich-the-future-of-automated-driving

[10] Internet Engineering Task Force, RFC 1058. https://datatracker.ietf.org/doc/html/rfc1058

[11] Internet Engineering Task Force, RFC 2080. https://datatracker.ietf.org/doc/html/rfc2080

[12] Internet Engineering Task Force, RFC 2328. https://datatracker.ietf.org/doc/html/rfc2328

[13] Internet Engineering Task Force, RFC 2453. https://datatracker.ietf.org/doc/html/rfc2453

[14] Internet Engineering Task Force, RFC 5340. https://datatracker.ietf.org/doc/html/rfc5340

[15] Internet Engineering Task Force, RFC 7868. https://datatracker.ietf.org/doc/html/rfc7868

[16] Isenburg M. LASzip: lossless compression of LiDAR data. Photogrammetric engineering and remote sensing. February 2013.

[17] Kij M. Difficult adolescence (in Polish). Truck&Van. 2020;6.

[18] Lyamin N, Dengy Q, Vinel A. Study of the platooning fuel efficiency under ETSI ITS-G5 communications. IEEE 2016:551-556. https://doi.org/10.1109/ITSC.2016.7795608

[19] Markowski A. Psychological basis of road accidents (in Polish). Time for transportation. 2017;9.

[20] Pobocha B. Robo-ants (in Polish). Connected life (May/June). 2015.

[21] Processing in autonomous vehicles. https://www.thedrive.com/tech/20553/the-language-of-self-driving-cars-is-dangerous-heres-how-to-fix-it

[22] Statistics of Polish Police. https://statystyka.policja.pl

[23] Szałek A, Pielecha I, Cieślik W. Fuel cell electric vehicle (FCEV) energy flow analysis in real driving conditions (RDC). Energies. 2021;14:4. https://doi.org/10.3390/en14165018

[24] The first Polish autonomous public transport bus. https://www.transport-publiczny.pl/wiadomosci/gdansk-tworcy-autonomicznego-busika-spodobal-sie-62612.html

[25] Tom–Tom HD maps. https://www.tomtom.com/products/hd-map

Prof. Radosław Wróbel, DSc., DEng. – Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Poland.
e-mail: *radoslaw.wrobel@pwr.edu.pl*

Prof. Zbigniew Sroka, DSc., DEng. – Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Poland
e-mail: *zbigniew.sroka@pwr.edu.pl*

Gustaw Sierzputowski, DEng. – Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Poland.
e-mail: *gustaw.sierzputowski@pwr.edu.pl*

Radostin Dimitrov, DEng. – Faculty of Mechanical Engineering, Technical University of Varna, Bulgaria.
e-mail: *r_dimitrov@tu-varna.bg*

Veselin Mihaylov, DEng. – Faculty of Mechanical Engineering, Technical University of Varna, Bulgaria.
e-mail; *v_mihaylov@tu-varna.bg*

Daniel Ivanov, MEng. – Faculty of Mechanical Engineering, Technical University of Varna, Bulgaria.
e-mail: *dan.ivanov@tu-varna.bg*