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V2I Data Standpoint within the Smart Mobility Concept

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Abstract

The aim of this article is to describe data intensity estimates and data aspects of vehicle-to-infrastructure (V2I) communication in the Smart Mobility concept. The goal of vehicle fabrics is to constantly increase driving comfort and the use of multiple sensors to detect the vehicle's surroundings, as well as to help the driver in critical situations avoid danger. The growing number of sensors is directly related to the amount of data generated by the vehicle. In the automotive industry, it is crucial for the decision-making process that autonomous vehicles can process data in real time or be precisely located. To meet these requirements, we will describe HD maps as a key segment of autonomous management. It draws the reader's attention to the need to address the issue of big data processing in real time, which is an important role in the concept of Smart Mobility.

Keywords: smart mobility; V2I; autonomous vehicles; HD maps.

Introduction

The usability and availability of sensors and camera modules in the vehicle changes the orientation of the automotive industry mainly to the data level. The data obtained from the sensors in combination with computer technology transform the data into the execution of autonomous vehicle decisions. The question that remains unanswered is how much data such a vehicle produces?

The continual increase of the total number of vehicles is causing daily traffic congestion and accidents, which often result in serious injuries. Improper management of a critical traffic situation causes further inconveniences. This transformation is part of the Smart Mobility concept [1].

According to [2], up to 50% (approximately 3.3 billion) of all people in the world live in cities. It is estimated that this number will increase to 5 billion by 2030. As the population increase, the demands on the transport infrastructure grows. It is necessary to ensure quality and reliable data transmission of information. This information will also be used in communication between transport infrastructure and vehicles (V2I).

Currently, the most modern commercial vehicles on the market fall into the third level of autonomy according to the Society of Automotive Engineers (SAE International) and are awaiting regulatory approval. However, even vehicles at a lower level of autonomy generate approximately 25 GB/h of data. Each higher level directly correlates with the number of sensors in the vehicle, which causes a higher amount of data produced [3]. The usability and availability of sensors and camera modules in the vehicle changes the orientation of the automotive industry mainly into the data viewpoint. The data obtained from sensors combined with computing transforms data to make decisions of an autonomous vehicle.

According to calculations by Stan Dmitrieva in 2017 [3], whose article was updated by Simon Wright, after combining the estimated amount of data from individual vehicle sensors from the third level of autonomy, the total amount of data transmitted is approximately 19 TB/h. For vehicles that fall into the lower category of autonomy, the estimated amount of data produced is about 1.4 TB/h (Figure 1). According to the American Automobile Association (AAA), the average person spends 17,600 minutes a year behind the wheel, which is about 293 hours. After counting the calculated values, we can estimate that one vehicle produces more than 5500 TB of data per year [3].

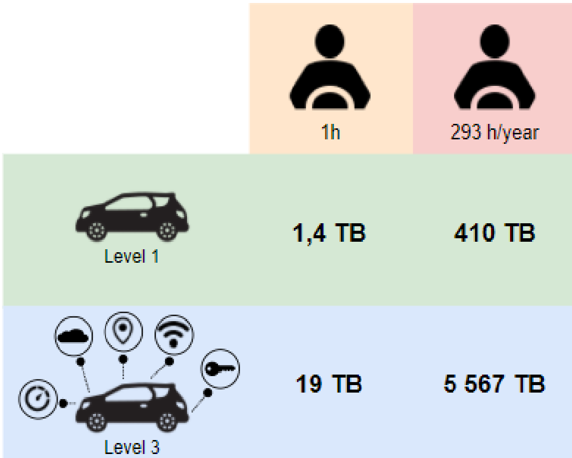

Figure 1 – Comparison of total vehicle data production by autonomy level according to [3]

The scope of this paper is focused on data requirements in V2I communication. We also discuss the effectiveness of existing solutions in relation to such an enormous amount of data which needs to be stored, transformed, and processed in Smart Mobility concept, specifically V2I communication. At the end of the article, we will describe HD maps and their use for autonomous vehicle. We describe the theoretical estimated amount of data transferred between the central server and the vehicle.

Some of the key issues with the large volumes of data were their management in traditional data warehouses and knowledge acquisition using Data mining and statistical analysis techniques [4]. The solution to this problem was the development of Big Data, a data analysis methodology that allows the storage and analysis of big volume of data using a new generation of technologies and architecture [5]. According to [5], Big Data and Cloud computing complement each other, and their combination provides many benefits that neither technology would be able to provide on its own.

Many of the tasks performed by IoT devices are time sensitive and the use of Cloud is not a suitable solution for them. The data must be uploaded to centralized servers and the results are sent back to the IoT devices after making the necessary calculations. These results are often needed in less time than can be provided with Cloud computing. The solution to this problem may be the use of Edge computing. It allows to process data closer to the device and end-user, thus also reducing the time it takes to transfer data. Thanks to distributed deployment, balanced network traffic is ensured, and traffic peaks are avoided. It also makes latency and energy consumption lower. However, unlike the Cloud, Edge.

As well as the inclusion of autonomous vehicles in normal traffic with the ability to communicate with the surroundings, the design of the processing architecture and the way data is stored in real time, are currently a major challenge for the entire Smart Mobility concept.

Development of the Smart Mobility

The concept of smart mobility has been a popular topic in recent years, not only in scientific fields but it is also interest of people outside the scientific area, as it brings benefits that will enable cities to manage traffic efficiently combined with sustainability.

Smart mobility is seen as a new way of thinking about transportation of people and goods as it has evolved over the years from the convergence of the digital revolution with transport. With the advent of modern technologies such as fast data connections, reliable sensor systems, powerful mobile devices, the advent of automated and autonomous vehicles, intelligent mobility concepts are becoming an increasingly common part of transport systems [6].

The continual increase in urbanization needs additional road infrastructure. The problem of the growing number of passenger cars has so far been addressed by adding new roads to meet the requirements [6]. The construction of additional roads in cities should ease the unmanageable traffic situation. However, it does not provide a sufficient solution to the problem as this method reaches its limits due to existing urban infrastructure.

Meeting the objectives defined in the Smart Mobility concept will bring several key solutions that should ensure a higher level of traffic using advanced information and communication technologies. Travel will be easier and smoother, traffic management efficiency will be increased, information on traffic intensity will be provided over time, which will allow prediction and optimization of planning, information on free parking spaces will be available. The overall architecture and mode of shared transport will be proposed, which will affect every single inhabitant of the city. The aim of the transformation is primarily to turn transport as a product into a mobility service (Mobility-as-a-Service).

The definition of autonomous vehicle (AV) can be understood as a vehicle capable of sensing the surrounding environment, evaluating the traffic situation, and performing activities and maneuvers without the need for human intervention. It is not at all necessary for a person to take control of the vehicle or to be in the vehicle at all. AV can drive on the same roads, evaluate traffic situations (react more quickly in crisis situations), do everything as an experienced human driver. The SAE has defined 6 levels of driving automation – from level 0 (fully manual) to level 5 (full autonomy) [7]. These 6 categories are divided into 2 groups of three levels. The first group consists of levels (0-2 inclusive) where the driver monitors the environment around him. The second group are levels (levels 3-5 inclusive) where the environment is monitored by an automated system capable of reacting in time based on the information obtained.

V2I communication

Efficient data communication between individual traffic entities is one of the basic pillars of Smart Mobility. At the very top of the communication hierarchy is the V2X (Vehicle-to-Everything) communication. Vehicle-to-Everything (V2X) communication is a paradigm of intelligent transport system (ITS). ITS is used to increase the efficiency and reliability of data transmission. Within V2X we distinguish several subcategories, such as:

- Vehicle-to-vehicle (V2V).
- Vehicle-to-network (V2N).
- Vehicle-to-pedestrian (V2P).
- Vehicle-to-infrastructure (V2I).

Definition

Communication between vehicles and road infrastructure equipment is referred to as vehicle-to-infrastructure (V2I) [8]. According to [9], there are several V2I system architectures that match in key components, namely:

- Vehicle On-Board Unit or Equipment (OBU or OBE).
- Roadside Unit or Equipment (RSU or RSE).
- Safe Communication Channel.

The vehicle is represented by the OBU in V2I communication. This component ensures communication between the vehicle and other vehicles in its vicinity, as well as between the vehicle and the RSUs. RSU represents infrastructure in V2I communication. The device is connected to a network designed for V2I communication and can be located at intersections, petrol stations, pedestrian crossings or other locations. In addition to receiving and sending messages, its tasks may include prioritizing messages sent to and from vehicles [9].

Based on memory capacity and communication capabilities, OBUs collect data at regular intervals, with the oldest data being overwritten. OBUs send "status messages" to other OBUs to ensure safety and at the same time they transmit vehicle data together with GPS data to RSUs [9]. The main idea of V2I communication is to provide local information on real-time safety, such as speed limitation, safe spacing between vehicles, accident warning or safety at intersections [10]. The purpose of providing this information to the driver or vehicle in real time is to try to avoid traffic collisions and increase mobility, thus ensuring smooth traffic [8]. To secure smooth traffic, V2I applications can be used, for example, for dynamic control of light signals at intersections or early notification of traffic congestion.

Data categorization

Data collected within V2I communications can be categorized in several ways according to (Figure 2):

- the source
- the method of collection,
- character [6].

Figure 2. Categorization of data collected within V2I

Data categorization by source

A source that can share useful information for V2I communication to work properly can provide a variety of data. These sources include, for example, reports from people, information provided by the vehicle manufacturer. Information from third parties is also useful, as is known today. The last example is a state-owned system that could provide comprehensive information for V2I communication [6].

Data categorization by method of collection

Another way we can categorize data for V2I communication is according to the way the data is collected. The amount of data is collected through sensors in intelligent infrastructure, such as camera systems, temperature sensors, barometric pressure meters, traffic censuses and others. These sensors are not movable, so data from them is always evaluated against the same location [6].

Unlike sensors in the infrastructure, the vehicle dynamically changes its position and changes the location with which the data is correlated. This location is detected through GNSS/GPS sensors. Vehicle location data is often also obtained from online navigation systems or mobile applications, such as Google Maps or Waze.

Relevant information may also be obtained from information systems. For example, we can obtain information on mobile signal road coverage through the GIS. Monitoring systems shall provide data on, for example, the number of available parking spaces [6].

Data categorization by character

The character of the data is defined by the level of detail of the temporal and spatial area it represents. According to this character, we divide the data into operational, tactical, strategic [6].

Operational data is provided in real time, focuses on a short period of time. These relate only to the area in which the vehicle is located and its immediate surroundings. The information contained in this data relates to actual traffic accidents, impassable road sections or other problems which need immediate decisions to be made [6].

Tactical data has a medium level of detail, providing information about traffic situations affecting the entire location. Unlike operational data, tactical data may not be provided in real time but at larger time intervals. However, it is necessary that the data must be up-to-date and provide the recipient with the information to make tactical decisions, such as choosing to bypass a traffic jam [6].

Strategic data have the smallest level of detail. In terms of time, it is a period of at least one month. In terms of space, the minimum size of the district. However, their analysis can provide information that deals with traffic density in individual sections and thus helps in making strategic decisions, such as building infrastructure [6].

HD maps

One of the goals of Smart Mobility are fully autonomous vehicles. In order to do that, vehicles need to have an overview of the traffic situation in the vicinity, and they also need to have road infrastructure information. At the same time, they need information even outside of the shared data between the different participants in the V2X communication in order to cover all the above areas. One possible solution is to use High-Definition Maps (High-Definition Map), as part of the way the vehicle is oriented on the road. In general, we can mark HD maps as high-resolution maps that have information and accuracy at centimeter level. They contain information whether static or dynamic, such as:

- map documents,
- traffic situations,
- traffic signs and intersections,
- weather reports,
- urban facilities on city streets [11].

According to the Automotive Edge Computing Consortium (AECC), the use of HD maps is a key issue in Mobility as a Service, ADAS (Advanced Driver Assistance System) and autonomous driving [11].

HD map layers

Based on available information, the AECC has produced preliminary estimates of the operation HD maps and the overall network occupancy that occurs when a vehicle contributes data to HD maps.

The AECC divided the different layers of HD maps into dynamic and static (permanent). Static maps represent today's famous maps of the territory. We divide dynamic maps into 4 categories, based on updating information according to the time interval (Figure 3) [11].

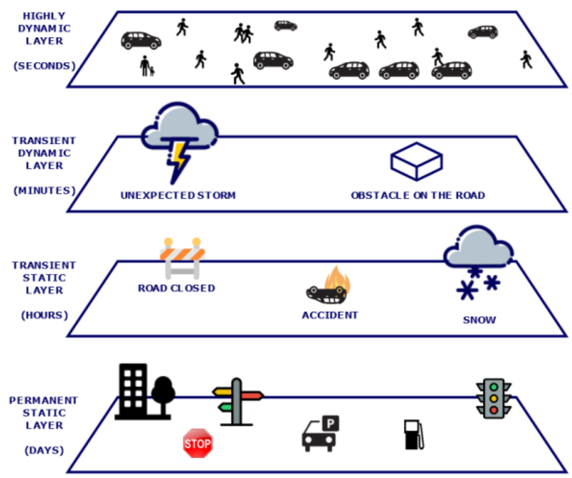

Figure 3. HD maps layers based on [11]

These are:

- Permanent Static Layer contains information that has the lowest data frequency of updates of the order of days and more - information about intersections or traffic signs.
- Transient Static Layer updates data on an hourly basis - work on the streets, risk accidents, closures.
- In Transient Dynamic Layer, the information is changed in minutes - weather data, illegally parked cars, dirt on the streets.

- Highly Dynamic Layer is the most frequent layer. The information is changed in unit of seconds - vehicles, pedestrians, or cyclists [11].

The overall flow of information from the vehicle to the complete updating of HD maps depends on the determined strategy of processing the obtained data. The expected process begins with obtaining source data from the vehicle's sensors, followed by data processing and analysis. In the last phase, the HD maps are updated, and the information is sent back to the vehicle

Network occupancy of updating HD maps

In the section "Introduction" we showed estimates of data difficulty for vehicles of lower and medium levels of autonomy. The estimated information consisted of statistics from the United States of America. The AECC has produced its own estimates, including the processing, and updating of HD maps, which they consider to be a key aspect of autonomous management. Certain constants, such as the total length of journeys, the number of illegally parked vehicles are obtained from Tokyo.

The individual indicators that are included in the calculation of the estimate of the total amount of data transferred according to pattern B are:

- **Data Upload/Download Frequency** – A frequency defined as the number of detected changes in the Transient Dynamic Layer and HD map updates.
- **Upload/Download Data Volume (per vehicle system)** – represents the total amount of data transferred between the vehicle and MSP Edge/Cloud Server.
- **Upload/Download Data Volume (in total)** – represents the total amount of transmitted data, categorized according to the number and type of connected vehicle.
- **Latency** – Latency is defined as the time it takes to transfer information from the sensor to update the HD map [11].

The estimate includes 2 types of vehicles – Economy Model Cars and Mid-range Model Cars. Economy Cars are vehicles that are commonly available and contain several cameras and radars. Mid-range vehicles have more sensors than the Economy model (for example LiDAR).

Data frequency		97.9 times/day	
Data volume per vehicle system		2.2 GB/day	24.8 MB/day
Data volume in total	2022 5 milions economy model cars 0 mid-range model cars	10.8 PB/day	123.8 TB/day
	2027 20 milions economy model cars 5 milions mid-range model cars	91.7 PB/day	743.1 TB/day
	2032 40 milions economy model cars 10 milions mid-range model cars	183.4 PB/day	1.5 PB/day
Latency		10 seconds	

Figure 4. The calculated amount of transferred data based on [11]

The calculated data is categorized based on the number of Economy Model Cars (EMC) and Mid-range Model Cars (MRMC), where they focus on the total amount of data transmitted from the Upload/Download perspective (Figure 4).

On the left side, we can see the total amount of data sent to MSP Edge/Central Server, where the estimated generated data by 2022 represents a value of approximately 10.8 Petabytes per day. In terms of data received, it is 123 Terabytes per day. The idea of generating data in the next ten years is about 1/10 of the total data production of the world's population, which is growing every year, and the latest estimates show that this value will increase rapidly [12].

Conclusion

This paper provides a data viewpoint on Smart Mobility, specifically V2I communication. In order to successfully implement smart mobility into everyday life, it is necessary to solve several basic issues concerning the data level of this concept. Many of the technologies that are essential for smart mobility are still at the beginning of normal / daily use in many countries, e.g., 5G, Edge computing or HD maps.

The V2I communications elements, vehicles, and infrastructure, contain a number of devices that generate data. This data needs to be processed and analyzed. The processing time of operational data should be minimal so that the vehicle has enough time to respond adequately. The question therefore remains which architecture should be chosen.

These values already show a significant amount of data for transmission as well as processing for the various car manufacturers involved in advancing autonomous driving. The challenge for transport leaders as well as the professional community is to achieve reliability and meet the required hardware need to store the necessary data in the vehicle. However, we already know that traditional database systems such as relational databases, data processing in data warehouses as well as data storage and analysis in these systems are not sufficient [12]. Likewise, it is questionable whether systems (Hadoop, NoSQL, MapReduce, and others), which are designed to process Big Data, are sufficient for storing, processing, and transmitting data depending on efficiency and time.

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