Electric cars as environmental monitoring IoT Network

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Abstract. With the intensification of traffic in large urban agglomerations, the need for monitoring of environmental parameters is increasingly being observed and more and more efficient solutions are being sought for taking over and processing these data. It is proposed to build a network of sensors mounted on electric vehicles to be used to create an interactive map of environmental pollution in urban areas. It has often been observed that motorized air quality monitoring platforms are propelled by conventional gasoline or diesel engines and therefore also produce significant pollution factors that can alter data taken over by the sensor network. The use of an electrical monitoring system has as a major benefit greater accuracy in retrieving data from pollution detectors as it does not appear in the data taken and the influence of classic monitoring system pollution using a classic propulsion platform. It is also proposed that efficient communication algorithms be made between the sensor networks to take data on the quality of the environment.

1. Background
The alarm signal in the development of an internal combustion engine car has given its pollution in the urban area. The annual report of 9 February 1989 by the World Watch Institute in Washington draws the attention to mankind that if the level of release of pollutants in the atmosphere is not reduced, there is a risk that the Earth's inhabitants will trigger the global warming phenomenon. Increasing amounts of carbon dioxide (with an annual increase of 0.4%), nitrogen oxides, carbon oxides, lead vapours, chlorofluorocarbons (5% annual gas) contribute to the warming of the atmosphere by destroying the ozone layer that protects the planet from ultraviolet radiation. In addition to the chemical pollution of the atmosphere, another great damaging product that the car is guilty of against the environment is noise. By acting on the cerebral cortex, noise causes nerve irritation that accelerates fatigue, weakens attention and mental reactions. Thus, the obvious opportunity to use a non-polluting and quiet vehicle in urban traffic is the one that, in the early 60's, reopened electric cars subject. The research then received a new impetus at the peak of a new phenomenon: the energy crisis, a phenomenon of exploitation, which in 1973 highlighted the problem of oil reserves, causing the world's states to move to concrete research and development programs. Each country is looking for alternatives to crude oil, depending on indigenous sources of energy, natural gas (reserves that are almost exhaustible as crude oil), coal such as methanol, hydrogen, renewable energy, etc [1, 2].

The use of electricity is favourable because the necessary infrastructure, in the form of public distribution systems, is already available and can be used with small changes. Also, electricity, unlike alcohols or synthetic gasoline, can be produced from all known primary energy sources, which is an essential factor in the event that one of these forms becomes deficient. Compared to vehicles propelled
by internal combustion engines, electric vehicles powered by electric accumulators show higher power efficiency. While for vehicles in the first category only 14% of the total energy is used for traction, the electric vehicles energy used is 50% of the total energy [2, 3].

2. Electric vehicles
The development of electric vehicles is closely linked to the evolution of electricity and electromechanical energy conversion technologies. In the early 1800s, the means of transport were propelled only by the power of steam, because the laws of electromagnetic induction, and hence the motors and electric generators, were not yet discovered. Faraday discovered the law of electromagnetic induction in 1831 and soon invented the DC motor. The first vehicles equipped with non-rechargeable batteries were tested in 1834 and 1851. Lead electric batteries were made in 1859 and in 1874 they were used on an electric vehicle.

There are currently several different types of electric cars. When talking about cars, one can distinguish between battery-powered electric vehicles - powered by an electric motor only - and different types of rechargeable hybrid vehicles that have both an electric motor and an internal combustion engine.

There are other types of vehicles that can work with electricity. We see more and more bikes, vans and electric buses in traffic. As for other means of transport, we also have electric locomotives, ferries and boats [4].

Nearly a quarter of greenhouse gas emissions come from transport activities and urban mobility accounts for 40% of all CO2 emissions from road transport. In addition, it is estimated that 9 out of 10 European citizens are exposed to harmful particulate emissions exceeding acceptable levels. Electric engines pollute incomparably less than thermal motors. Indeed, in fact, to generate electricity generates a high degree of pollution and there are studies that already address this problem. The use of electric power to propel vehicles does not directly create pollution.

Thermal engines use the so-called "tread train" to adapt and transmit the power of the engine to the wheels. The "tread train" may have different components, depending on the desired performance. The gearbox is the most important component and has the role of turning torque and engine speed and distributing this torque to the wheels. Differentials participate in this process and improve this engine-driven torque process and at the same time increase the controllability of the vehicle. In the case of electric cars, the "tread train" looks different and contains different components. There is no need for these systems that contain a lot of moving parts. Many moving parts can be removed by using electric motors. Basically, the electric power to wheel path is: Battery - Power Electrical Convertor - Transmission – Wheels, as can be seen in Figure 1 [4, 5].

![Figure 1. Block diagram of an electric car.](image-url)
Looking at the whole, electric motors can have an efficiency of about 90% compared to engines fuelled with diesel or petrol. This superior efficiency of electric motors compared to thermal motors is due to the fact that most of the components used to power electric vehicles are more efficiently created. Thermal motors besides the energy needed to move produce more heat. To increase the efficiency of a vehicle, most of the energy has to be produced to move the vehicle, not to produce heat. And electric motors and their peripheral systems produce heat and other types of losses, but they are much smaller than thermal ones. An electric motor car can have instantaneous acceleration like the fastest car series or less often even as racing cars.

This happens because an electric motor can produce the maximum torque from zero, while the thermal engine produces this maximum torque only at a certain speed. An electric car has fewer moving parts than a machine with a thermal engine, so its maintenance is easier and cheaper. Indeed, electric cars are relatively new on the consumer market, where they can be repaired or maintained are little compared to those where the thermal engines are repaired and maintained. This will change due to the need for such services that provide services for electric cars that will be more and more. Due to the fact that in the case of electric cars the variant in which each deck has its own electric motor is preferable, the mass of the machine is evenly distributed. In the case of thermal engine engines, the location of the engine has influenced for certain types of impact the increase in material damage and the loss of human life. In electric vehicles because the propulsion system consists of several modules that are mounted in several areas of the machine, a different behaviour of the vehicle was found in the event of an accident. At the same time, the danger of fire due to ignition of fuel or pipes in high temperature areas is more or less non-existent [4, 5].

The autonomy of electric car is considerably improved with new technologies that allow more power to be stored in the batteries in the car. Top electric cars have a range of about 500 km with fully charged batteries. It seems a little, but there are cars (and not a few) that, due to the high fuel consumption or the small tanks, can make as many miles with a full amount of fuel. At the same time, the autonomy will not increase in proportion to the number of accumulators in the car. The biggest impact on machine autonomy is in general the mass of the machines and with the increase in the number of batteries, the mass of the machine will increase. If a car with conventional fuels (gasoline, gas oil) the feed time can be less than 10 minutes, it increases for electric cars. For electric motor cars, this theme is treated differently. Charging time depends a lot on how much electricity can be delivered to the machine. There are "overload" systems that operate at high voltages and deliver about 45 minutes of energy to travel over 250 km. There are also cases when a full battery charge can take up more than 8 hours. A positive aspect of the power supply is that it can be powered from home by a 220 V / 110V power supply [6, 7].

Although the electric motors, from the point of view of precision, are clearly superior to the thermal ones or the hydraulic control systems, this performance comes with a cost. To make a comparison for controlling electrical systems, nanosecond time units are used. One second is one billion nanoseconds. For mechanical systems, time is measured to be measured in milliseconds. In a second there are 1000 milliseconds. Hydraulic systems use times that are measured in seconds. In order to be able to control the electrical systems with the necessary precision, they use high performance computing systems which in turn consume energy and produce heat, so they have to be cooled. Without the technological advances in electronics, electric motors could not become a viable and efficient solution to build cars.

Although the electric machine itself does not pollute, in some cases it is used as raw material for coal to produce the necessary electrical energy. Coal power generation produces pollution. Increasing the need for electricity that comes up with the increasing number of electric cars could lead to conventional electricity production. The impact of the increase in the need for electric power to power electric cars will lead to the need to invest in clean electricity sources that could lead to higher electricity prices [6-8].
3. System design

This paper presents a new concept of implementing new communication and data acquisition technologies on the quality of environmental factors in a city. Thus, it is proposed in a city, a concept of using electric vehicles that can interact with each other through revolutionary vehicle to vehicle technology (V2V). Each of the vehicles also has several categories of sensors that can retrieve different data on geographic position and environmental parameters. These data form a blockchain and are stored in a cloud, and based on these data, an environmental map of the city is made in real time. In Figure 2 is presented the conceptual diagram of the system [9, 10].

![Conceptual diagram of the system.](image)

3.1. Wireless Sensor Network

Of the many sensor network topologies one can find after a quick perusing of the scientific literature we consider the most appropriate for the purpose of this paper is that of a sensor network consisting of a group of a large number of sensor nodes, which are logically inter-linked and have the ability to collect data from an area where they are positioned and can communicate information via wireless links [11].

The importance and advantages of any Wireless Sensor Networks (WSNs) is connected to the size of the network, size expressed usually by the number of nodes (sensors), and the ability of the network to change information among the nodes. Of equal importance is the architecture of the network (the topology) and some characteristics of these nodes. One of these characteristics is latency, which denotes the necessary time for a packet of data to get from the sensor node to the gateway node, or back. Largely speaking, latency reveals the speed of the network, for example a fast network has low latency [12]. Another important characteristic is the throughput, which describes the quantity of data that can go through a network in a time unit.

The fault resiliency would be the third characteristic of a network and it refers to the degree with which a wireless network, if interrupted, will recuperate and deliver the amount of data to the destination. The fourth important characteristic is scalability, i.e. the number of nodes which are contained in a single network.

A hop is part of the path between source and destination. The number of hops represents the number of devices through which data passes between source and destination. Network range is the distance that a complete network can have. The interval of a node is the distance from one node to another. Depending on the task of the WSNs, the sensors will be carefully chosen in order to accomplish the necessities in functional terms, but similarly to handle the essential environment
factors. The processing unit is selected based on the concrete functional assignment of the nodes and on the architecture of the network, the fence off of the information processing and on the power requirements and availabilities. Numerous networks are planned to operate in full, independent mode, with wireless connectivity and in such a case, the low power requirement is essential [13].

In a network of wireless sensors, the choice of network topology must take into account consumed energy, latency, computational resources and the quality of communication. In addition, topology characteristically outlines the dimensions of a group, what to do if new sensors are connected to the network, or how to deal with the nodes which are no longer active. If we are paying attention to the basic network topology, more effective routing schemes can be realized. Additionally, the network topology in WSNs can be easily changed by changing the nodes’ transferring ranges and also by adjusting the wake/sleep plan of the nodes. Consequently, more energy can be kept if the network topology is preserved in an optimal mode [11].

To establish the proper networking technology for the goal of this paper, it is decisive to understand the network topology. The networking standards which are used currently in WSN can be grouped into five basic topologies: point-to-point, star, tree, mesh and hybrid as can be seen in Figure 3.

![Network topology diagram](image)

**Figure 3.** Network topology.

The point-to-point topology establishes in a simple way a high-capacity wireless direct connection between two sensor nodes. This simple topology was most commonly used in traditional wireless sensor networks (a Bluetooth connection between a mobile phone and a headset). The advantages of a point-to-point connection are simplicity and low cost. One of the restrictions originates from the one-to-one connection that exists between two devices; the network is not able to scale beyond the two nodes. The range of these networks consists of a single hop and is defined by the transmission range of a single device.

A star network involves one central hub (gateway node), to which all nodes (the sensors) are connected. This central hub represents a common connection point for all other nodes in the network. All marginal nodes can communicate with all others nodes by transmitting to, and receiving from, the central hub only. An example of this type of topology is the Wi-Fi network hub in our homes. The hub is usually connected to the outside world as well.

One of the advantages of a star topology in WSN is the low power consumption. The performance of star networks is steady, liable and fast (low latency and high throughput). Another advantage is that in this topology it’s easy to increase the number of nodes; this topology is scalable. In a star network a
data packet travels maximum two hops to get to its destination, which results in a very low and predictable network latency [11].

Nevertheless, there are also some disadvantages of a star topology, similar to the point-to-point network, like the fact that communication is not reliable due to a single point of failure and it is impossible to find an alternate route in this arrangement of any node.

A mesh network contains three types of nodes:
- A gateway node as in a star network
- Simple sensors nodes
- Repeater/routing capability sensor/router nodes

The nodes initially disseminate their own data, but also serve as relays for other nodes. These nodes cooperate with the following nodes in the network to transmit the data.

Mesh network nodes are ordered in a way, that each node is inside the transmission range of at least one other sensor/router node. Data packets pass through multiple nodes until they reach the central node. This topology is used mainly where necessary a wide coverage area. Since the network range is not constrained to the transmission range of a single device, the network range can be very broad. Mesh networks can have up to thousands of nodes, having as a result a high density of coverage with an extensive variety of sensors and devices.

The first limitation of mesh networks is its complexity - they are more complex than point-to-point or star network topologies and this could lead to difficulties [11]. Similarly, there is higher network latency due to multiple network hops typically from the sensor to gateway.

In the tree topology the sensors are positioned in such a way that they are constructing a logical tree. In this architecture they are two categories of nodes: the parent node and the leaf node. Data packets are efficiently transmitted from a leaf node to the parent nodes. Instead, a receiver node receives data in the parent node of the receiver only after checking its own data [14, 15].

The main advantage of this topology is that it consumes less energy than other topologies. One of the difficulties with tree topology is that if a parent node has a problem, then its complete sub-tree fails. In the hybrid topology the sensors are positioned in a star topology beside the routers and the routers are organized in a mesh topology.

3.2. Blockchain
Blockchain, from a general perspective, is a decentralized registry, not located in one place, and many actors who have a copy of certain information that can not be changed later. It is a digital register in which any information entered is encrypted in mathematical formulas and cryptic data, and each mathematical formula authenticates and validates another mathematical formula that contains other encrypted data. This decentralized database contains all information about all possible transactions that involve material values and which are encrypted in the block of blocks with permission to verify at any time their authenticity. A blockchain is a chain of interconnected blocks, each node containing the hash key of the previous node, except for the first block called genesis.

Normally, the block structure is made up of two main components: a header and a body. The header includes the current block version, the block of the previous block, the hash key of the current block, a time signature, a counter, and target bits, and the body consists of transactions.

A hash function applied to an object helps to get a sequence of characters called the hash key, which is the digital signature of the object. A hash key is unique and can only be reproduced if all the original components from which it was obtained are known.

For each participant to be able to get in touch with the distributed data, the mining concept was introduced. It is necessary to limit the number of block generations over a period of time as inconsistencies may occur. Also, a very small generation time can compromise a chain.

As for Bitcoin, mining is used to generate new currencies, but the main purpose remains to provide data consistency.

For each participant to have access to the data, they must be mined for a specified period of time. This mining is very expensive in terms of hardware resources.
Each participant has access to this blockchain, but each block in the blockchain may also represent another blockchain, so there is communication between different areas and domains. Transactions made are transparent, questionable and incorruptible.

One of the biggest advantages that blockchain offers is the protection and data control. People do not need to trust only other people but also, they need to have trust in mobile devices, robots or vehicles.

Sensors are built in daily objects as mobiles, electrical applications, cars, industrial machineries. All these sensors send data without intermittence, related to the status of the devices to which they are applied to and allow these devices to communicate with each other via internet.

Blockchain can be use in different fields, and among this we can use this technology in managing a network of connected sensors that collect and exchange data. Platforms compatible with this kind of networks are a normal network that permits sensors to send and receive their data and a protocol that allows these sensors to exchange information between them, permitting users to use them to their advantage [16].

Normally this network of connected sensors is dependent of an architecture which is not at all decentralized. The data is exchanged between the sensors and the cloud and it is processed using analytics. With a big number of sensors or devices to join this kind of network, this type of system, seems not be very scalable, and it is vulnerable to many threats, compromising the network security. Nevertheless, another weak point is the fact that becomes more expensive if suppliers need to check and approve every transaction between sensors. Using blockchain in the model presented in this paper, was not done before but taking it to a large scale we need to analyze well the benefits of using this technology. Blockchain can bring innovation and has a big potential. What it is sure, it is that with this technology information cannot be modified and there is a history of all events, a permanent archive of the actions taken in the blockchain.

We think that on a large scale blockchain can be use in the data transmission from and to sensors, bringing a more secured environment [17].

3.3. Vehicle to vehicle communication protocol

Cellular-V2X communications are based on device-to-device (D2D) communications defined as part of ProSe services in Release 12 and later in Release 13 of the 3GPP specifications. Sidelink aims to enable D2D communications within legacy cellular-based LTE radio access networks.

The C-V2X protocol is designed to enable vehicles to communicate directly with each other (Vehicle-to-Vehicle or V2V) or with pedestrians (Vehicle-to-Pedestrians or V2P) or with infrastructure (Vehicle-to-Infrastructure or V2I) without any support from network operators. The C-V2X is also designed to make it easier for vehicles to communicate directly with a cloud server via the mobile network (Vehicle-to-Network or V2N) when needed and if the situation requires it. Each C-V2X chipset is equipped with an accurate GNSS sensor (simultaneously multiple positioning signals from GPS / GLONASS / BeiDou / Galileo / QZSS) for combining collected data with positioning information. [18]

The V2V, V2I, and V2P interactions use C-V2X direct communication technology to increase active safety and awareness of the situation at any time by detecting and directly exchanging information among all traffic participants using low-latency transmission as a communication protocol without not based at all on the mobile network coverage.

V2N interactions use C-V2X network communication technology to support advanced information sharing and highly secure information protection with 4G and 5G emerging wireless networks on a licensed spectrum. The notion of Vehicle-to-Vehicle Communication Protocol (V2V) includes a wireless communication network within which traffic information vehicles are exchanged. The transmitted information reflects the running speed, location, route chosen, deceleration (braking) and vehicle stability. Data transmission is provided by WI-FI (one of the frequencies used is even 5.9GHz) with short-range communication (DSRC - dedicated short-range communications) - with a maximum communication distance of up to 300 meters away from a motorway running in highway mode in
about 10 seconds. DSRC transmission is a standard set up by the Federal Communications Commission (FCC), ISO (International Organization for Standardization) and IEEE (IEEE 802.11p) [18, 19].

The V2V communication networks will be designed as mesh networks, meaning that each node (vehicle, smart road indicator, etc.) will be able to transmit, capture and retransmit signals to any networked node. Analysing information from nodes with 5 or even 10 positions in front will provide an overview of the traffic conditions that occur in the next mileage. This can generate warning and guidance reports that cannot be ignored by even the most impatient driver. Other examples of implementation of V2X technology can be seen in Table 1 [18].

Table 1. Examples of implementation of V2X technology.

|                  |                                                                 |
|------------------|-----------------------------------------------------------------|
| **Vehicles**     | It is possible for a car to communicate directly with other cars |
|                  | Vehicles can exchange information such as current position or major traffic alerts in case of accidents |
| **Infrastructure** | Make it possible communication between cars and road infrastructure |
|                  | Vehicles and traffic lights are connected with smart grid to avoid traffic jams |
| **Devices**      | The car can communicate with any electronic device |
|                  | A car can detect the presence of cyclists through their smartphones |
| **Pedestrians**  | Communication between cars and pedestrians is possible |
|                  | The pedestrian smartwatch warns if a car is approaching high speed |
| **Smart home**   | Communication between the vehicle and the smart home of the driver can be created |
|                  | The intelligent house receives a signal when the car approaches and opens the garage |
| **Smart city**   | Allows data collection from transport infrastructure and then the creation of pollution or traffic maps that are permanently updated and available on any fixed or mobile device |

5GAA (5G Automotive Association) is actively driving the development of such technology and it is constantly pushing the manufacturers for demonstrating its capabilities. On April 15, 2019 in Klettwitz, Germany, 5GAA announced that several technology vendors from Cellular-V2X (C-V2X) achieved the first successful results in the standardization process. This demonstrates the great progress that industry made to come a step close to commercial readiness.

Electric vehicles with pollution sensors on board and equipped with C-V2X technology could transfer their collected data to infrastructure elements, like lamp posts or traffic lights which are fixed elements, using V2I technology. Each infrastructure element, having a fixed position, could upload the data to the cloud for post-processing.

The communication between these elements is done completely autonomous based on proximity criteria. By using this technology and collected data, some big data processing algorithms could create an interactive and always up to date pollution map of any city, no matter how dense or complicated the city is. Another approach would be for each electric vehicle to upload its collected data, by using V2N, together with GNSS positioning information. By combining all collected data and the positioning information, the interactive map it’s just a matter of big data analysis [20].
4. Conclusions
Electric vehicles have become more and more visible in urban traffic and thanks to new technologies for producing electric accumulators, they allow greater autonomy to travel at a lower cost. In the context of monitoring environmental factors in an urban agglomeration, it is proposed to use electric vehicles equipped with a number of sensors able to retrieve data about the geographic position and the level of pollution existing at a given moment in a certain area. These electric cars form up a network of sensors. The use of electric vehicles for monitoring pollution factors in an urban agglomeration is more efficient than using classic motor vehicles because sensors mounted on electric cars will take the data more accurately because no harmful effects will arise from the operation of powered vehicles classic used as a monitoring platform. The revolutionary concept described in this paper presents the use in an urban agglomeration exclusively of electric vehicles that have on the platform some sensors that can retrieve data on the quality of the environmental factors. Each of the electric vehicles communicates with each other using vehicle to vehicle technology (V2V). Data retrieved from the sensor network is transmitted using blockchain technology to a central cloud server. With all data taken from the sensor network, an interactive map of pollution from a city accessible via a software platform can be created.

5. References
[1] Casals Canals L, Martinez-Laserna E, Amante G and Nieto N 2016 J. Clean. Prod. 1 425
[2] Jochem P, Babrowski S and Fichtner W 2015 Transportation Research Part A: Policy and Practice 78 68
[3] Moro A, Lonza L 2018 Transportation Research Part D: Transport and Environment 64 5
[4] Yong J Y, Ramachandaramurthy V K, Tan K M and Mithulananthan N 2015 Renew. Sust. Energ. Rev. 49 365
[5] Xuedong L, Lin H, Minkang H and Wei Y 2018 IOP Conf. Ser.: Mater. Sci. Eng. 452 032083
[6] Aswin A and Senthilmurugan S 2018 IOP Conf. Ser.: Mater. Sci. Eng. 402 012154
[7] Karpukhin K, Terchenko A and Kolbasov A 2018 IOP Conf. Ser.: Earth Environ. Sci. 159 012043
[8] Leba M, Ionica A, Dobra R and Pasculescu V 2014 Environmental Engineering and Management Journal 13 1535
[9] Rosca S, Riurean S, Leba M and Ionica A 2018 Advances in Intelligent Systems and Computing 850 235
[10] Rus C, Leba M and Ionica A 2018 Proc. 17th edition International Technical-Scientific Conference, Modern Technologies for the 3rd Millennium (March, Oradea, Romania) p 351
[11] Shamneesh S, Dinesh K, Eshav K 2013 International Journal of Computer Sciences and Engineering 1 19
[12] Gutiérrez D, Toral S L, Barrero F and Bessis N 2013 Internet of Things and Inter-cooperative Computational Technologies for Collective Intelligence p 89
[13] Aleksandrovics V, Filicevs F, Kampars J 2016 Information Technology and Management Science p 78
[14] Rus C, Negru N, Leba M and Ionica A 2018 Proc. Int. Conf. GLOREP (Timisoara, Rom.) p 237
[15] Patrascoiu N and Rus C 2019 Quality - Access to Success 20 347
[16] Junjun L, Qichao Z, Zhuyun Q and Kai L 2018 Proceedings of 1st IEEE International Conference on Hot Information-Centric Networking (HotICN 2018) p 141
[17] Rebrisoreanu M, Rus C, Leba M and Ionica A 2018 International Journal Of Systems Applications, Engineering & Development 12 164
[18] Chandra Deya K, Rayamajhib K, Chowdhury C, Bhavsard P and Martine J 2016 Transportation Research Part C: Emerging Technologies 68 168
[19] Patrascoiu N and Rus C 2018 Proc. 19th International Carpathian Control Conference p 318
[20] Ganesh E N 2017 International Journal of Advanced Research 5 964