Remote Maintenance and Software Update Methods for Connected Vehicles

Erkan Demir, Habib Kaymaz, Ilker Yildiz*

Abstract— **While building smart living areas, the main purpose is to increase the quality and comfort of life without compromising health and safety. With the increase of new technologies used in growing and updated modern living areas, we witness that the needs are shaped and changed with this change. The primary purpose of each new technology is to offer more safety, health, comfort and convenience to the person, organization or structure that it addresses. The basic means of the connected vehicles has been to ensure the safety of the user in the best way, and people expect more than vehicle. With the widespread use of autonomous vehicles, that is without driver assistant, in the near future, vehicles are expected to connect and communicate with the ecosystem structured for the future and among themselves. Thanks to this communication that the vehicles have, the traffic flow on the route, the road condition, the location of the pedestrians around, possible malfunctions and failures that may occur and all such information will be shared by the vehicle with each other and the future ecosystem. On the other hand, while the vehicles are becoming more connected with any of useful technologies, thanks to the remote connection provided by their technology, manufacturers can easily develop their vehicles without recalling. In this study, information was given about the connected vehicles, the remote connection infrastructure and methods. The advantages provided by these systems are explained.**

Index Terms— **Connected Vehicles, Over The Air (OTA), Firmware Over the Air (FOTA), Software Over the Air (SOTA), Remote maintenance**

I. INTRODUCTION

THE WORLD'S leading automakers and communications infrastructure providers, Mercedes-Benz, BMW, Audi, Volvo, Toyota, TIM, and Telstra, describe the importance of connectivity in cars and the ecosystem required to support connected vehicles [1]. According to Mercedes-Benz, "connecting vehicles is laying the foundation to offer new kinds of services for comfort, safety, and entertainment in a new dimension". For BMW, "the highly-developed smart city is characterized by all-encompassing networking, and cars are becoming a part of inner-city networking in this smart city" [2]. Audi thinks that 5G to make software downloads more reliable and faster for an increasing demand from a huge number of vehicles. For Volvo, connectivity was once a feature only, but now it is an essential part of all cars they offer. According to Toyota, "the challenge for connected cars receives and sends large amounts of data from the cloud". TIM forecasts, there will be an estimated 100 million connected vehicles on the road in 2025. Telstra considers that the possibilities are endless when all cars can communicate with each other, with the surrounding infrastructure and pedestrians.

Mercedes-Benz has unveiled its concept vehicle, Vision AVTR as shown in Fig. 1, which is directly correlated with Mercedes-Benz's plans for the future. The company designed the car to connect seamlessly with its passengers, and it embodies the vision of near future for mobility in the. A new era of the car, "The Vision AVTR shows a completely new interaction between human, machine, and nature," the automaker claims. We can see the future by looking at this car; it will become such a natural part of our lives in the near future.

Fig.1. Mercedes-Benz's VISION AVTR [3]

II. CONNECTED VEHICLE

Connected vehicle is a vehicle that can communicate bidirectional with other external objects, structures, and systems inside or outside. In this way, the vehicle can share

ERKAN DEMIR, is with Department of Electrical and Electronics Engineering, Faculty of Technology, Marmara University, Istanbul, Turkey, (e-mail: erkan.demir@marun.edu.tr).

https://orcid.org/0000-0002-4832-5889

HABIB KAYMAZ is with Mercedes Benz Türk AŞ, Otobus Gelistirme, Esenyurt, Turkey, (e-mail: habib.kaymaz@gmail.com).

https://orcid.org/0000-0002-8338-004X

İLKER YILDIZ is with Ministry of National Education, İstanbul, Turkey, (e-mail: ilkeryildiz2000@hotmail.com).

https://orcid.org/0009-0004-9021-5909

Manuscript received Apr 19, 2023; accepted April 28, 2023.
DOI: 10.17694/bajece.1285919

the information, which it has with other structures inside and outside of the vehicle or use the information from other structures [4]. It is expected to improve people safety and traffic management by adding communication to a vehicle [5].

General Motors as an automaker offered its connected vehicle features to the end-user market in 1996. The company developed its technology called OnStart in 1996 and introduced it to the public usage in order to ensure the safety of drivers and passengers [6]. General Motors firstly adopted OnStar technology on its Cadillac DeVille, Sevilla, and Eldorado models and improved it later. The primary purpose of using this technology in vehicles was safety and emergency assistance to the vehicle in the event of an accident. If the medical aid and support arrive at the scene as earlier as fastest in the event of an accident, the higher the likelihood that drivers and passengers will survive.

Thanks to OnStar technology, the connected vehicle transmits the help call to the emergency center, which will provide assistance to the vehicle via the phone integrated into the vehicle during the accident and enables communication between passengers and emergency centers.

After the success of General Motors in OnStar, many car manufacturers have included similar safety practices in new cars. And nowadays, after March 31, 2019, new EU-approved car models must have an emergency call assistant as a default function as figured out in Fig. 2.

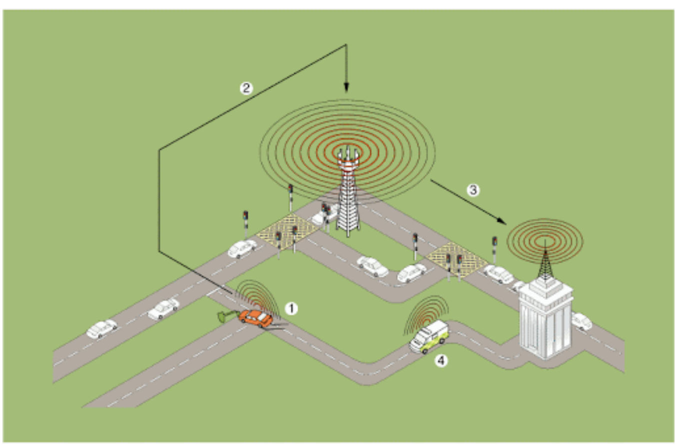


Fig.2. Emergency call system on vehicle [6]

Initially, this technology only provides voice calls via the phone, with the addition of data communication to the phone communication in 1999, GPS location signals have also been transmitted to the emergency center. However, since 2000, by adding the functionality of the GPS system to vehicles, GPS not only took the navigation technology to a new upper level, but also contributed to safety by monitoring and tracking the stolen vehicles [7,8].

III. CONNECTION TYPES

All these new technologies used in vehicles, while offer driver, passenger and vehicle safety, also support building a reliable relation between the end-user and manufacturer or service. For example, the connected vehicle diagnoses a non-critical but needs to be checked and informs the vehicle user as well as the service company. And a specialist person or system would give more detailed information about the vehicle status to the user, so that the user can drive safely. In this way, the user will be provided with more reliable details of the vehicle and driving, and a long-term reliable relationship will be established between the manufacturer and the user.

As simulated in Fig. 3 there are 5 ways for a vehicle to connect around of it and communicate with them:

- V2I "Vehicle to Infrastructure": communication between vehicle and its environment
- V2V "Vehicle to Vehicle": a vehicle communicates with other vehicles, such as information about the speed and location of the surrounding vehicles
- V2N "Vehicle to Network": data communication between vehicle and cloud-connected structures
- V2P "Vehicle to Pedestrian": communication between vehicle pedestrians for environmental safety
- V2X "Vehicle to Everything": this is a summary of other connectivity’s; communication between vehicle and all kinds of vehicles and structures (vehicles, trains, ships, aircraft etc.)

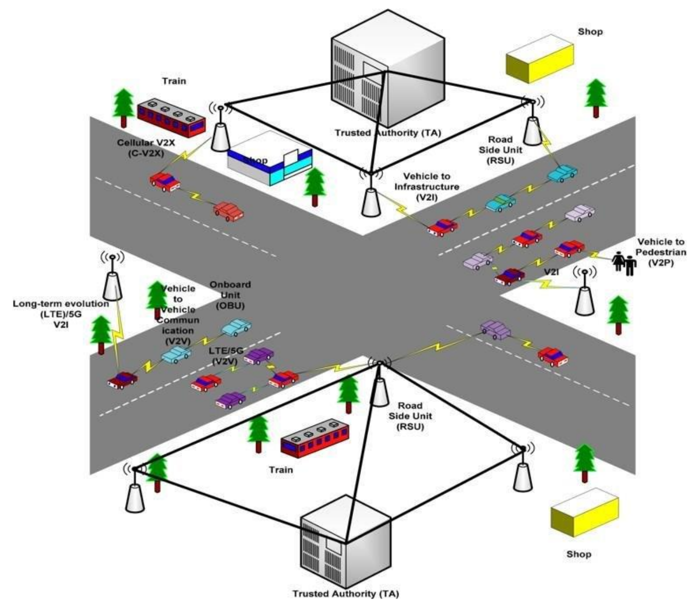


Fig.3. Vehicle to around [9]

The communication standard V2X as a protocol, that allows the connected vehicles to connect with each other and includes all other vehicle communication systems as a framework protocol where data can be transferred in real time at high speed and low loss [10].

Inter-vehicle connection network is one of the main technologies that can be used in the smart transportation system to provide wireless connection between vehicles, roadside drivers, passengers and pedestrians. Despite considerable potential market opportunities and gains, V2X communication technology is still in the field trial phase in general and new advanced algorithms should be developed for this type of communication [11].

Applications in vehicle networks; due to the different performance requirements, it can be classified according to passenger and road safety, traffic flow efficiency and infotainment types. However, as an important point here is that road safety applications in vehicle-to-vehicle (V2V) communication require low latency and high reliability [12]. And due to safety reasons, priority must be given to minimize especially security risks of communication on the connected vehicle [13].

IV. COMMUNICATION INFRASTRUCTURE

Various applications in the vehicle network pose specific requirements and challenges in the wireless communication technology and it is needed multiple security control techniques to secure privacy sensitive data [14] and privacy of the ecosystem [15]. To provide the communication infrastructure required by vehicle communication as shown in Fig. 4, various wireless communication technologies are available, such as Wi-Fi, cellular network systems and IEEE 802.11p.

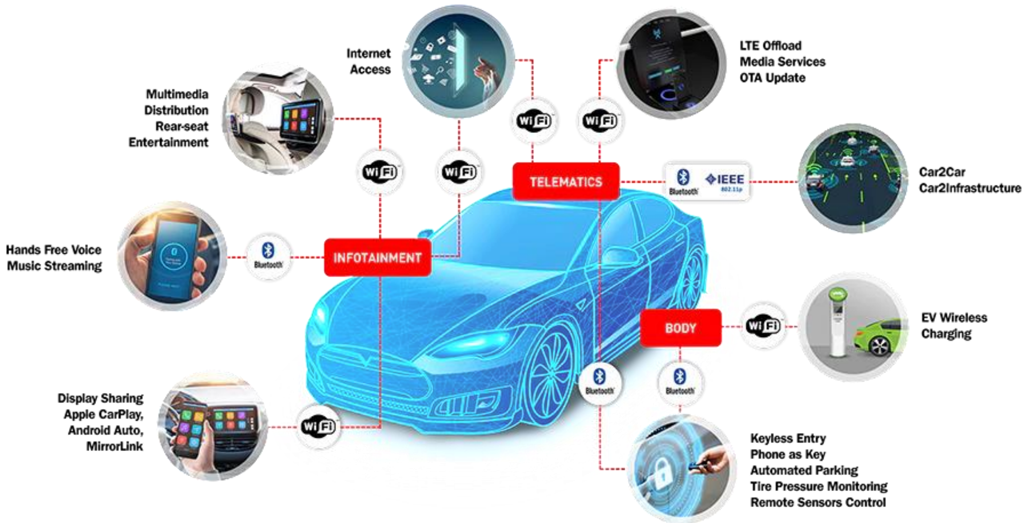


Fig.4. Communication technologies on the connection vehicle [16]

Wi-Fi communication is not suitable to support high mobility due to its short range. Although IEEE 802.11p is considered the first wireless technology standard specifically designed for road communication, it has obvious disadvantages such as low reliability, hidden node problem and unlimited latency. The widespread use of IEEE 802.11p requires major investments in network infrastructure. Due to these disadvantages of IEEE 802.11p, new efforts have been made to use 5G in the long-term evolution (LTE) as an optimal potential wireless access technology to support vehicle applications.

It is vital that the communication must take place instantly and without delay. At this point, it is very rational to look for the solution at 5G since the 4/4.5G technology we are currently using is insufficient. We face the importance of 5G for connected vehicles and IoT at this point.

5G technology, one of the indispensable technologies for connected vehicles, is extremely critical with its ultra-fast data transfer and latency below 1ms. Intel predicts that connected vehicles will spend unbelievable data.

The figures are hard to believe. Connected vehicles are expected to consume 4 TB of data per vehicle in a day when it enters our lives completely! Each vehicle will exchange about 4 TB of data, and this data traffic is only possible with 5G [16].

The challenge is how data can be continuously sent and received from the cloud. The volume of data is very important. To realize sending and receiving huge amount of data, new technologies and new infrastructures are needed.

While the connected vehicles have many important features and benefits brings to next life, we will focus on easy function upgrade and maintenance of these connected vehicles via such processes like remote monitor and control.

According to BMW, “first remote-controlled function is used 2001. Vehicle diagnostics, also known as remote diagnosis, have produced a connection between users and their cars across vast distances since 2001. With vehicle diagnostics, vehicle manufacturers can examine the system’s functionality and, if there are any problems, potentially recognize the cause more quickly”.

A. Remote maintenance methods

OTA, which is a process of the data transmission and reception for application-related information in a wireless communication system. OTA was initially associated with consumer electronics such as television and later it started entering every industry from telecommunication to household appliances and the automotive industry.

In the automotive industry, OTA process has some delivery solution ways. Software provider and manufacturer can coordinate in a system architecture [18]. In this system architecture data can be sent to the vehicle from a cloud-based server via a wireless network as shown in Fig. 5a, or mobile network directly to the vehicle as shown in Fig. 5b, or to the vehicle owner's mobile device and then installed directly to vehicle from mobile device via a wireless connection such as Bluetooth as shown in Fig. 5c.

Along with the prevalence of connected vehicle technology, a usage of over the air software update is also progressing for easy function upgrade and maintenance [19].

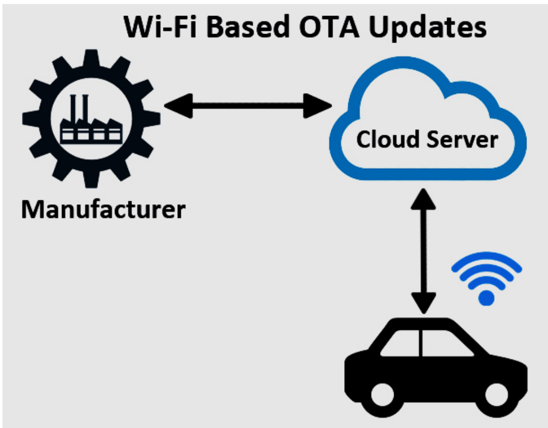


Fig.5a. Wi-Fi based solution delivery model for OTA updates [19]

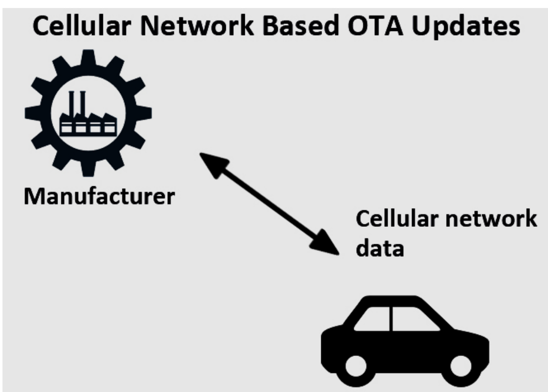


Fig.5b. Cellular network-based solution delivery model for OTA updates [19]

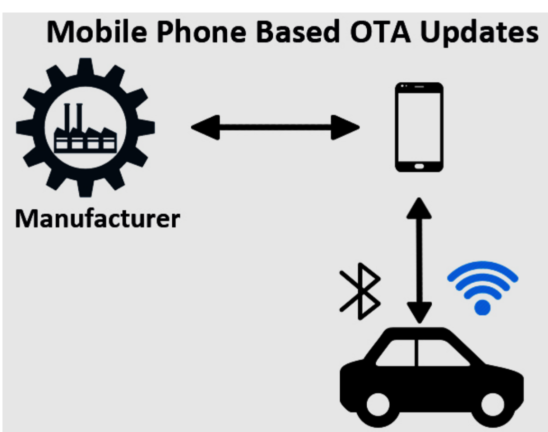


Fig.5c. Mobile phone-based solution delivery model for OTA updates [19]

OTA connection and updating process is critical and should be robust and reliable, both in terms of security and user safety. Thus, it needs detailed security architecture while the updating process [20]. When a vehicle's firmware or default software have a software-related security bug or vulnerability, it must be corrected immediately. This kind of correction by OTA updates is also convenient and comfortable for vehicle owners because by this way no longer need to go a service center to receive the updated software [21]. All of the vehicle's software related its system must be up to date for security reasons [22]. So that, OTA updates are main issue for the safety and keeping vehicle's features and functions up to date.

Developers try to fix known software bugs or integrate several numbers of new additional features to the vehicle by software updates. The complexity of automotive software has made it more difficult to verify software updates. A strong and reliable verification methodology is required during this process. Firstly, software update source must be verified [20], second, it is ensured that any bug fixes are implemented correctly, then it is ensured that the new additional features are running correctly, and finally it is ensured that the entire software update does not harm any other functions [21].

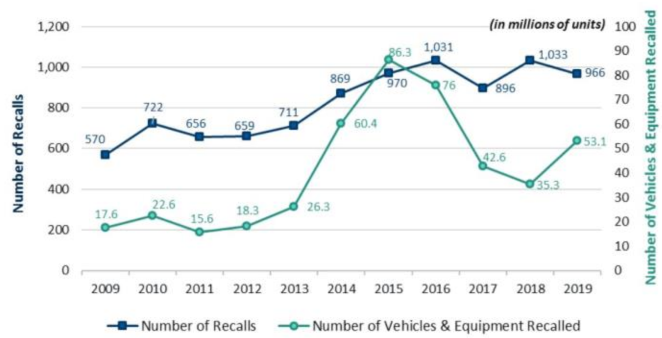


Fig.6. Comparison of recall issues with recalled vehicles [24]

Software dependency of vehicles increasing more and more regarding electronic components used on the vehicles. Because of the complexity of these hardware and software infrastructures, the amount of recalling has risen dramatically. As a comparison of the number of recalls with the number of recalled vehicles regarding various faults, bugs in the software, etc. by the period of 2009 to 2019 are shown in Fig. 6. It is prominently displayed on the figure, the number of issues and the number of vehicles related recalling has increased since 2013. While there is approximately 60 million increase in Overall recalled vehicle number from 2013 to 2016, there is approximately 51 million decrease from 2016 to 2018 [24]. Many manufacturers recalled such number of vehicles due to software issues. Remote OTA updates provide many benefits to keep the vehicle and its functions up to date. All these recalls could have been eliminated by the implementation of remote OTA software updates. As a valuable result of avoiding recalls sustainable consumer satisfaction could be built-in self.

OTA process offers two types of methods, one is SOTA and the other is the FOTA.

SOTA is the meaning of sending a software file from cloud to vehicle. The communication between cloud and vehicle can be implemented in some ways, wireless communication or mobile communication can be used to download the software file to the vehicle.

Instead of sending a full image of the software installation file, SOTA updates can be downloaded as a part of the whole file. Thus, the developer can forward only a part of a file, which is needed to be fixed on the vehicle. While this can reduce download time and make it safer with the reduction of traffic on the communication data line.

The installation file may contain several files to update different hardware and software on the vehicle. Especially critical hardware of vehicle must be considered while doing SOTA updates [25]. SOTA must be cyber-safe, making sure that car manufacturers only apply the appropriate updates to their vehicles. Updates, which can be sent by the SOTA method may include changes to software that controls the physical parts of the vehicle and to user interface software such as infotainment screens or instrument panels. The SOTA update method enables automotive manufacturers to fix, maintain, and check for disruptions in vehicles, also to improve them for future needs through remote software updates sent to the vehicle from a cloud-based server. These kinds of improvement-based technologies can offer both cost savings and revenue earnings to the manufacturers, while also improving customer satisfaction and brand value with remedies, modifications and enhancements that are applied remotely, timely and comfortably.

Vehicle that need fixing, upgrading, and maintenance are likely to pay attention to their software as if it's a mechanical thing; in this case SOTA eliminates the need to go to service center. SOTA will also provide an opportunity to be quickly updated and corrected when a problem arises that can pose major security concerns.

Remote enabled SOTA and FOTA include such kind of OTA enabled segments, such as navigation map, infotainment applications, telematics control unit (TCU) and electronics control unit (ECU) updates. Every functions of vehicle must be implemented individually for security reasons [26].

TCU updates are carried over FOTA in real time, subject to the condition that the TCU is connected to the server. FOTA checks for the correct update package and then finishes the process of updating the vehicle remotely, thereby reducing the correction cycle time. SOTA offers such updates as below:

- Updates based on applications
  - ➢ Navigation Updates
  - ➢ Head Unit Display Updates
  - ➢ Telematics System Updates
- Updates based on software platforms (infotainment operating system and operating platform)
  - ➢ Embedded Applications
  - ➢ Featured Software
  - ➢ Infotainment Software

FOTA offers updates such as TCU and ECU.

By 2022, analysts expect vehicle manufacturers to realize approximately 350 million software updates regarding application based, infotainment software platforms and telematic services for their customers' vehicles by using software SOTA process. And another point of view, ABI Research, leading in market intelligence, forecasts nearly 203 million OTA enabled vehicles will be produced with approximately number of 180 million vehicles featured with SOTA and approximately number of 22 million vehicles featured with FOTA by 2022. Components of OTA can be classified like that:

- Application providers
- Solution providers
- OTA Platform Providers
- Infrastructure providers;
  - ➢ Cloud infrastructure; such as Microsoft, Sierra Wireless
  - ➢ Communication infrastructure; such as AT&T, Verizon
  - ➢ Cyber security solution providers; such as Visual Threat, Airbiquity, Gemalto, Escrypt, Infineon
  - ➢ Component manufacturers

In the vehicle industry, many of the manufacturers are already involved with these structures, and telematics and electronic control units are going to be the primary focus areas in the future. For example, Hyundai has proof of many concept systems in terms of OTA map updates, on the other side BMW, Audi and Tesla have already started rolling out OTA procedures for updating navigation maps, Ford's Sync 3, which is interactive touch screen system, will be accomplished through an OTA using Wi-Fi. Autonomous car manufacturer, Tesla use OTA, their vehicles regularly receive over the air software updates which add new features and functionality.

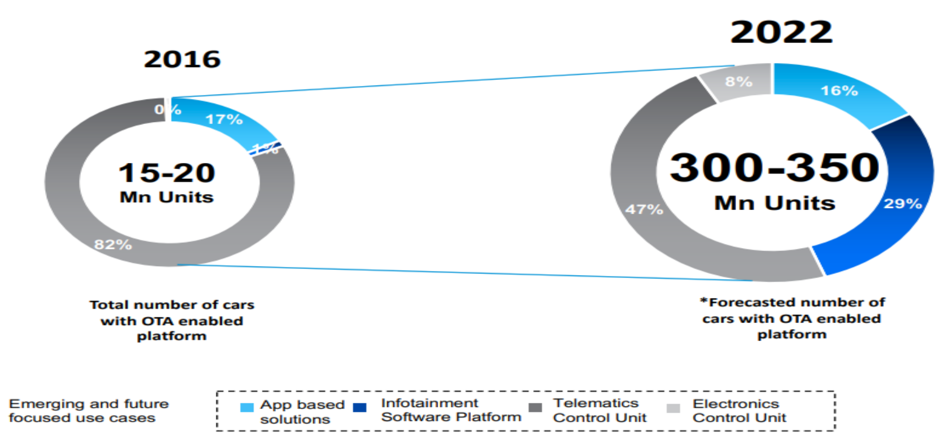


Fig.7. Total market size in terms of the number of vehicles [27]

Total market size in terms of the number of vehicles is curated from the IHS market report and GEIP platform data (source: DRAUP).

Fig. 7 shows the number of vehicle units that include OTA updates related to application-based solutions, infotainment software platforms, TCU and ECU. These OTA enabling updates will see the highest interest in the number of vehicles. Application-based solution programs take up less space in total core memory when compare to others and have low-level security issues; therefore, it can be implemented easily as OTA enabled platform.

Infotainment software OTA updates are complex because the programs can be quite large. These updates can take place over Wi-Fi communication instead of mobile communication because of the mobile network limitations.

Types of updates include binary files for ECUs or other firmware updates, mapping data for onboard navigation, user-generated contents such as music, videos and photos, operating systems, applications and software package updates, and such kind of other updates.

According to the benefits of OTA processes, total worldwide OEM cost savings from OTA software update events is forecasted by growing from 2.7 billion USD in 2015 to more than 35 billion USD in 2022 [28]. When comparing with others, telematics control unit and infotainment software platform updates are contributing most to these figures to become alive. It shows that value-added cost savings by OTA updates will be the most valuable part of this kind of new future solution. There are some success stories, which will be useful to mention:

- MinVolkswagen

Denmark based Connected Cars company, which is founded in 2016, aims to provide smart and effective tracking of vehicles for workshops and fleet managers, as well as a better driving and service experience for vehicle owner.

The software they developed as simulated in Fig. 8, helped Volkswagen Denmark to improve customer satisfaction and add a new life to the customers' old cars. Free connection service was offered to the customers with a Volkswagen model year 2008 and later vehicles. This allows vehicle owners to see the status and usage of their vehicles at first a glance and enables direct communication between the service and customers via chat and exchange of information. In addition, the services know the status of their customers' vehicles almost in real time and can proactively help them.

Fig.8. Mobile application for vehicle status [29]

Developed software called MinVolkswagen is a digital service which is offered to Volkswagen customers [29]. It aims to ensure that users are connected and under control of their vehicles. This technology also serves the service workshops, enabling the services to follow customer vehicles technically, to be more productive in production and service quality and to offer the highest level of customer satisfaction.

- Mercedes PRO Connect

Mercedes-Benz plans to offer a wide range of digital services to the fleet customers by a platform, called Mercedes PRO connect [30], which one makes the van transparent and allows it to be used even more efficiently by collecting vehicle data via a digital vehicle log. The communication equipment required for the internet connection is integrated into the vehicle hardware as a default component when the vehicle is manufactured. So, all fleet customers will be able to make the best use of Mercedes PRO connect in the future. Thanks to the web-based service, it provides fleet managers with an overview of their vehicles, for example, they can manage orders in real time, check which vehicle is where, whether it needs refueling or not, or go into the workshop for maintenance.

V. CONCLUSION

While remote connection technologies offer huge opportunities for the automotive industry, these will require manufacturers to review their plans, redesign their processes and release new software updates to bring these new technologies to life.

There will also be issues to be concerned and overcome. For example, manufacturers may be concerned about remote connection safety, because there may be security issues when new technologies become alive. While the vehicles are becoming more connected with any of useful technology, which has the ability to connect each other and everywhere on its ecosystem, a reassuring security infrastructure is needed to ensure the privacy and security of the vehicle and its occupants.

Nevertheless, as the advantages of OTA technology and the potential opportunities it brings to the manufacturer are noticed, the investments in this technology will increase and the obstacles we mentioned will be overcome easily. As connected vehicles' dependency to the software will increase, OTA will become an indispensable necessity.

On the other hand, OTA can help manufacturers to improve their vehicles without calling back it. For example, manufacturers can release OTA updates where a vehicle has the opportunity to improve the quality of reducing fuel consumption. Manufacturers can also use SOTA or FOTA for customer satisfaction, for example, to keep vehicle functions up to date with new software and firmware releases and vehicle infotainment services.

OTA technology has the ability of bidirectional communication from vehicle to manufacturer or vice versa. Manufacturers could collect data from vehicles for their production quality analyses for future improvements or to help vehicle owners by applying of any immediate correction of bugs to prevent failures before occurring.

REFERENCES

[1] Ericsson < https://www.ericsson.com/en/internet-of-things/automotive>, Accessed: 24 March 2023.

[2] BMW <https://www.bmw.com/en/innovation/connected-car.html>, Accessed: 24 March 2023.

[3] https://www.mercedes-benz.com/en/vehicles/passenger-cars/mercedes-benz-concept-cars/vision-avtr/ Accessed: 24 March 2023.

[4] E. Uhlemann. "Introducing Connected Vehicles." [Connected Vehicles] in IEEE Vehicular Technology Magazine, vol. 10, no. 1, pp. 23-31, March 2015, doi: 10.1109/MVT.2015.2390920.

[5] B. Masini, G. Ferrari, C. Silva, I. Thibault. "Connected Vehicles: Applications and Communication Challenges." Mobile Information Systems. 2017. 1-2. 10.1155/2017/1082183.

[6] G. S. Vasilash. "OnStar: 10 Years After." Automotive Design and Production, 2006.

[7] K. R. Chen, L. Chun-Chung, H. Cheng-Hung H. "Vehicle burglar alarm system with GPS recognition." U.S. Patent No. 7,151,441. 19.

[8] S. Lee, G. Tewolde, J. Kwon. "Design and implementation of vehicle tracking system using GPS/GSM/GPRS technology and smartphone application." IEEE World Forum on Internet of Things (WF-IoT), Seoul, 2014, pp. 353-358, doi: 10.1109/WF-IoT.2014.6803187.

[9] Kiran, Jonnalagadda Surya, and Pranay Reddy Jakkala. "Cyber Security and Risk Analysis on Connected Autonomous Vehicles." Solid State Technology (2020): 10161-10176.

[10] S. K. Datta, R. Costa, J. Härri, C. Bonnet. "Integrating connected vehicles in Internet of Things ecosystems: Challenges and solutions." 1-6. 10.1109/WoWMoM.2016.7523574.

[11] J. He, A. Radford, Z. Xiong, Z. Tang, X. Fu, S. Leng, F. Wu, K. Huang, J. Huang, J. Zhang, Y. Zhang. "Cooperative Connected Autonomous Vehicles (CAV): Research, Applications and Challenges." 1-6. 10.1109/ICNP.2019.8888126, 2019.

[12] M. Bennis, M. Debbah, H. V. Poor. "Ultrareliable and low-latency wireless communication: Tail, risk, and scale." Proceedings of the IEEE, 106(10), 1834-1853, 2018.

[13] S. Parkinson, P. Ward, K. Wilson, J. Miller. "Cyber Threats Facing Autonomous and Connected Vehicles: Future Challenges." IEEE Transactions on Intelligent Transportation Systems, vol. 18, no. 11, pp. 2898-2915, Nov. 2017, doi: 10.1109/TITS.2017.2665968.

[14] T. Nawrath, D. Fischer, B. Markscheffel. "Privacy-sensitive data in connected cars." 11th International Conference for Internet Technology and Secured Transactions (ICITST), Barcelona, 2016, pp. 392-393, doi: 10.1109/ICITST.2016.7856736.

[15] S. Chen, J. Hu, Y. Shi. "LTE-V: A TD-LTE based V2X Solution for Future Vehicular Network." IEEE Internet of Things Journal. PP. 1-1. 10.1109/JIOT.2016.2611605.

[16] https://www.cypress.com/blog/corporate/driving-connected-car-revolution Accessed: 24 March 2023.

[17] Karel <https://www.karel.com.tr/blog/5g-ve-iot-otonom-araclar-icin-neden-onemli>, Accessed: 01 May 2020.

[18] Y. Zhou, X. Wu, P. Wang. "Secure Software Updates for Intelligent Connected Vehicles." Electrical Engineering and Computer Science (EECS), 3, 109-112.

[19] A. Kanda, T. Kurafuji, K. Takeda, T. Ogawa, Y. Taito, K. Yoshihara, M. Nakano, T. Ito, H. Kondo, T. Kono. "A 24MB Embedded Flash System Based on 28nm SG-MONOS Featuring 240MHz Read Operations and Robust Over-The-Air Software Update for Automotive Applications." IEEE Solid-State Circuits Letters. PP. 1-1. 10.1109/LSSC.2019.2948813.

[20] M. Steger, A. Dorri, S. Kanhere, K. Römer, R. Jurdak, M. Karner. "Secure Wireless Automotive Software Up-dates using Blockchains – A Proof of Concept."

[21] D. Coe, J. Kulick, A. Milenkovic, L. Etzkorn. "Virtualized In Situ Software Update Verification: Verification of Over-the-Air Automotive Software Updates." IEEE Vehicular Technology Magazine. PP. 10.1109/MVT.2019.2954302.

[22] Ş. Okul, M. A. Aydin, F. Keleş. "Security Problems and Attacks on Smart Cars." In: Boyaci A., Ekti A., Aydin M., Yarkan S. (eds) International Telecommunications Conference. Lecture Notes in Electrical Engineering, vol 504. Springer, Singapore.

[23] K. Mayilsamy, N. Ramachandran, V. Raj. "An integrated approach for data security in vehicle diagnostics over internet protocol and software update over the air." Computers & Electrical Engineering. 71. 578-593. 10.1016/j.compeleceng.2018.08.002.

[24] Motor Vehicle Safety: Issues for Congress <https://sgp.fas.org/crs/misc/R46398.pdf> 24 March 2023.

[25] A. Freiwald, G. Hwang. "Safe and Secure Software Updates Over The Air for Electronic Brake Control Systems." SAE International Journal of Passenger Cars - Electronic and Electrical Systems. 10. 10.4271/2016-01-1948.

[26] A. Camek, C. Buckl, A. Knoll, A. "Future cars: necessity for an adaptive and distributed multiple independent levels of security architecture." 17-24. 10.1145/2461446.2461450.

[27] https://www.abiresearch.com/press/abi-research-anticipates-accelerated-adoption-auto/ Accessed: 24 March 2023.

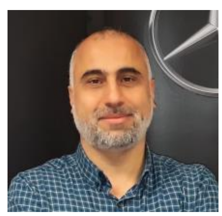
[28] M. Khurram, H. Kumar, A. Chandak, V. Sarwade, N. Arora, T. Quach. "Enhancing connected car adoption: Security and over the air update framework." IEEE 3rd World Forum on Internet of Things (WF-IoT), Reston, VA, 2016, pp. 194-198, doi: 10.1109/WF-IoT.2016.7845430.

[29] Connectedcars <https://connectedcars.dk/>, Accessed: 24 March 2023.

[30] Daimler <https://www.daimler.com/products/vans/advance.html >, Accessed: 24 March 2023.

BIOGRAPHIES

ERKAN DEMIR received his B.S. in Electronics Engineering from the University of Erciyes, Kayseri, Turkey, in 2004. His research interests include automotive electronics and solutions.



HABİB KAYMAZ Kasımpaşa, İstanbul, in 1970. He received the B.S. and M.S. degrees in Electric Education from the University of Marmara. He has been working for Mercedes Benz Türk AŞ, Bus Development as a lead test engineer since 1997. He earned his doctorate degree with the study of "Development of Driving Cycle for Hybrid and Electrical BRT vehicle" in Marmara University Institute for Graduate Studies in Pure and Applied Sciences in 2018.

His research interests include Automotive Electric-Electronic Systems, Automotive Testing, Life Test, Reliability, Connectivity, Hybrid/Electrical Powertrains, Measurement Systems and Sensors, Data Acquisition, Data Mining and Analyzing.

İLKER YILDIZ received his M.S. degree in Institute of Turkic Studies from the University of Marmara, İstanbul, Turkey, in 2002. His research interests include History of Technology.