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Evolution of IoT-enabled connectivity and applications in automotive industry: A review

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A B S T R A C T

Emerging Internet of Things (IoT) is considered as blessings for the automotive industry to offer vast opportunities to inventively create, develop, and enhance seamless services for the comfort of the users. Over time, IoT has significantly expanded and evolved in a numerous variety of automotive applications. Motivated by this growing importance of automotive IoT, this paper presents a critical literature survey on the utilization of IoT technology in the automotive industry, emphasizing the evolution of technology-enabling connectivity and applications. Initially, a review of the transformation and development of IoT-enabled smart systems for the vehicle is presented along with an extensive evaluation of the evolution of technology enabling IoT connectivity and applications. This then follows by the formulation of a comprehensive application scope of IoT technology and a general conceptual framework of IoT applications in the automotive industry. Detailed investigation of the benefits and challenges associated with deploying IoT applications is subsequently discussed together with proper identification of current and future technological challenges in the automotive industry. Furthermore, this study also focuses on assessing various connectivity types embedded in the sensor node functionalities and linked them with associated applications to reveal technical challenges for future automotive IoT advancement. This work is envisaged to shape the future perspectives of IoT technology in the automotive industry and impact the development of IoT platforms devised by the automotive industry-academia community. The promise of this technology will be realized through addressing new research challenges in the vehicular IoT paradigm, and the design of highly-efficient communication technology with minimum cost and efforts.

1. Introduction

The remarkable advancement in information and communication technology hardware and software has paved the way for promoting innovative, priorly unimaginable connectivity and interaction between humans and their physical surroundings. This phenomenon is well captured by the increasingly popular terminology of *Internet of Things (IoT)* [1,2]. IoT represents converging embedded systems and networking infrastructure that interconnect physical objects with a designated end-user system to access, accumulate, process, and transfer data with the assistance of the internet. To accomplish this purpose, IoT encapsulates several vital functionalities, including the sensors and identification elements, software intelligence, and a universal internet connection [3]. IoT was found extensive applications in various sectors, including healthcare [4], smart cities, building [5], energy and smart grid, manufacturing industry, weather forecasting, and environmental monitoring, logistics and resource management, agriculture [6], smart shopping [7], automotive [8] and so forth due to its ubiquity and pervasiveness characteristics. Since the last decade, the market analyses have forecasted 26 billion [9] to 30.73 billion [10] things to be associated with the internet as IoT-enabled devices by the end of 2020, which will increase to a 75.44 billion figures by 2025 [10].

One of the fastest-growing sectors for IoT development is the automotive industry [8,11,12]. Market analysts have predicted that there will be around 250 million IoT-enabled vehicles by 2020 [13].

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In terms of economic values, a report on Global Automotive IoT Market by Reuters showed a significant projected growth of the IoT Market value from $20.49 billion in the year 2016 to $100.93 billion in the year 2023 [14]. In this context, IoT can play a significant role in enhancing the overall transportation efficiency and comfort in traveling activities through an intelligent transportation system (ITS) to minimize the travel disruption and accidental rate by proper information sharing among the vehicle users and other related authorities [15]. Additionally, IoT can act as an enabler for real-time remote vehicular performance monitoring [16], for instructive vehicular irregularities diagnosis and maintenance [17], and for productivity improvement within smart automotive manufacturing [18]. As a result, the applications of IoT technology proliferate in the automotive industry, exemplified by vehicle condition monitoring, intelligent traffic management, and industrial activity monitoring. For instance, in the case of the industrial processes, a prominent option is extensive adoption of sophisticated connectivity technologies for monitoring and speeding up the manufacturing activities, raw materials, spare parts inventory management, sales management, and after-sales services of automotive products [19].

Intelligent processing and decision-making is a central part within an automotive IoT ecosystem to offer value-added services. This is possible through incorporation of key functional elements, namely the sensing layer, connecting layer, analyzing layer [3], data transferring/aggregating devices [20], and interfacing layer [21]. Herein the sensing element is sensors or similar objects to receive physical information and transfer it to other devices by an electrical signal. This element has a crucial role in collecting data from the designated points [3,22]. Radiofrequency identification (RFID) and the camera can also serve as a sensing device [21]. Sensing devices are widely used in vehicles to collect information about the engine heat, light, radiator heat, tire pressure, vehicle motion, and so forth [23]. The connecting layer is responsible for establishing the connection between receiving and transferring terminals for carrying collected, and analyzed data from the delivery points to the desired destination points such as internet and cloud-fog computing [24]. This layer consists of relevant connectivity technologies suitable for the automotive ecosystem. Analyzing tool is used to analyze useful information and patterns from the collected data supplied by the sensor as per given pre-defined instructions and computational models [3,21]. Data transferring/aggregating devices are responsible for data aggregation, and transmission by establishing interconnections among sensors, end-user terminals like displays, remote routers [20]. The interface layer is employed to show relevant outputs after data transfer and analysis. Many appliances to support its functionality covers mobile displays, personal computers, printers, and so forth [21,24].

This review paper is motivated by the exciting recent progress of IoT adoption and its future research advancement, including real-time vehicles vulnerable parts/operations observation, real-time environmental pollution observation, sophisticated energy-efficient vehicular communication networks, and smooth industrial operations in the automotive industry with minimum expenses. This paper specifically proposes a comprehensive review of the IoT technology in the automotive industry with full emphasis on enabling techniques for IoT connectivity and high-layer applications. In particular, this paper covers the following:

1. Providing fundamental information about automotive IoT technology;
2. A critical review of the transformation and development of IoT-enabled smart systems in the automotive sector;
3. Extensive examination on the evolution of technology enabling IoT connectivity and applications for vehicular structural health observation, industrial management and traffic management;
4. Formulating a comprehensive application scope of IoT technology and a general conceptual framework of IoT applications in the automotive sector;
5. Detailed investigation on the benefits and challenges associated with deploying IoT applications in the automotive industry;
6. Expanding the areas of future research on IoT technology as driven by proper identification of current and projected future technological challenges in the automotive industry.

Moreover, this paper differentiates from various recent review works as it emphasizes on the evolution of automotive IoT applications with the corresponding available communication technologies. This is done by gathering the required information from the latest research works, and conceptualizing directions for future research work. For instances, earlier review works on IoT for the automotive industry were concentrated on specific issues such as review study on the intra-vehicular network [25], the survey on crucial technologies and concise description of limited automotive IoT applications [26] and review on car parking systems [27]. This paper takes a step forward by comprehensively gathering a wide range of automotive IoT applications and combining them with other experimental articles i.e., accidental position detection [28], important vehicle tracking [29], vehicle burglary prevention [30], smart city traffic management [31], vehicles performance observation [32], automotive industrial management [33], and so forth. This work is anticipated to capture emerging and diversifying applications of IoT in the automotive sector to serve as a foundation to advance the recent adoption of IoT in the automotive industry, moving towards Industry 4.0.

The remaining sections of this paper are organized as follows. Section 2 is devoted to highlight evolving IoT technology in the automotive industry, available connectivity techniques for implementing IoT technology in automotive products, and current vehicular IoT applications. Section 3 presents elaborated discussion on vehicular IoT applications in industrial cases of automotive vehicles. Section 4 discusses the general conceptual framework of automotive IoT applications underpinning real-time vehicular monitoring, automotive industrial and commercial observation, and transportation management. Section 5 describes the importance and challenges of deploying IoT technology in the automotive sector encompassing both products and processes. Section 6 outlines open research issues and possible future research directions of IoT in the automotive industry. Finally, Section 7 concludes this review work by highlighting key contributions and remarks.

2. Background of IoT applications in automotive sector

2.1. Evolution of IoT technology for automotive applications

Since the mid of the 1960s up until now, there have been tremendous efforts of advancing and developing smartness and intelligence in vehicles and cars, including connected IoT technology, to enrich two-way interactions between humans and automotive vehicles. This evolving progress is manifested in the context of Research and Development Era (1966 to 1995) and a later advancement achieved by New Mobility Era (anticipated starting in 2020). This transformation has been bridged via Embedded Era (1995 to 2002), Infotainment Era (2007 to 2012), and Vehicle-to-Everything (V2X) Era (2012 to till now (2020)) [34]. Recent developments of this evolution are depicted in Table 1 to capture IoT-enabled intelligence progresses from Infotainment Era to New Mobility Era.

Concisely, the transformation of smartness and intelligence in vehicles has driven the evolution of IoT technology and applications in the automotive industry. IoT has initially enabled RFID technology as a prerequisite communication instrument [52]. Harris County Toll Road Authority mounted a toll collection and traffic

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Table 1
Available smart facilities in the vehicle from infotainment era to new mobility era.

Infotainment Era	V2X Era	New Mobility Era
Monitor/display for entertainment facility in vehicle [35]	Eco-navigation [36]	Autonomous vehicle [13]
BlackBerry's QNX tool [13]	Smart charging and charging safety by V2H and V2G [37]	Autonomous shared vehicle [38]
Real-time vehicle navigation systems [39]	Ride-sharing [40]	Self-driven shared vehicle [41]
Vehicle cockpit [42]	Collision and accident avoidance [43]	Vehicular environment by LTE [44]
Wireless internet access in the car [45]	Pedestrians safety alerts from the vehicle [46]	
Data streaming to the vehicle with the help of USB and Bluetooth connectivity [13]	Smart traffic management [47]	NB-IoT and LoRa for vehicular connectivity [48]
Speech-recognition interface for car [49]	Traffic congestion avoidance alert [50]	
	Internet of Vehicle technology [51]	

Table 2
RFID reader category and their application according to the frequency.

RFID Reader Frequency Type	RFID Reader Frequency Range	RFID Reader Application	Covering Distance Capacity
Low frequency	9-135 kHz [62,64]	Access control [62], Animal identification [64]	Only a few centimeters [64]
High frequency	13.56 MHz [62,64]	Library books, access and security control [62]	1 cm to 1.5 m [64]
Ultra-high frequency	868 to 928 MHz [60,62]	Supply chain management [65], Logistics [62]	50 cm to 5 m [65]
Microwave frequency	2.40 to 5.8 GHz [60,64]	Asset tracking, toll collection, vehicle tracking [55]	Maximum 10 m [65]

management system using RFID technology [53], which shape a new dimension for the evolution of IoT in the automotive sector. This communication system was further enhanced by the introduction of GPS [54], Bluetooth [55], and Wi-Fi [56]. Since around 2011, the automotive community realized the importance of IoT technology to monitor vehicular malfunctions remotely, which can be leveraged to mitigate various related issues [57]. This is then being followed up in the subsequent years through the introduction of automobile manufacturing "IoT" to ensure the smooth automobile manufacturing process [18] and V2X technology as the backbone of automotive IoT platforms that demonstrates the integration of vehicle connectivity and internet [58]. The specific internet-connecting platform for vehicles is often referred to as the Internet of Vehicles (IoV) [8,59]. In addition to that, the dedicated short-range communication (DSRC) devices were integrated with the V2X communication system after 2012 to improve the performance of IoT for sharing data and communications with vehicles [13]. Applications of IoT technology in the automotive industry have significantly expanded, paving the way for future seamless human-vehicle interactions. The deployment of IoT to connect vehicles and "everything" marks the beginning of the new era of mobility, envisioned with great autonomy and self-learning capabilities of the vehicles.

2.2. IoT connectivity technology in the automotive industry

2.2.1. Radio frequency identification (RFID)

RFID described as a technology to identify the object automatically and collect information with the help of a reader by using electromagnetic signals from an adhesive sticker called transceiver microchip [60]. Generally, the attached tag contains information electronically as an electronic product code [58,61]. According to reference [62], the frequency of RFID is classified into four categories shown in Table 2. The RFID tag also categorized into three groups, namely Active RFID, Passive RFID, and Semi-passive RFID [61]. Due to a convenient data transfer facility, the RFID technology was thought as a significant IoT connectivity component in vehicles for monitoring primary parameters remotely and ensuring smooth traffic management. This technology is also suitable for the automotive manufacturing industry to ensure smooth production facilities by improving the efficient utilization of raw materials, equipment, and tools [63]. Over the years, the thinking has evolved as various techniques are now available with more efficient performance than RFID for the automotive sector [58]. These techniques are captured in the following sub-sections together with their relevance for the automotive vehicle, proper traffic management, and industrial management in automotive manufacturing organizations.

2.2.2. Bluetooth and Wi-Fi

Bluetooth is a universal radio interface technology to establish a connection to another device wirelessly based on short-range communications and ad-hoc networks [66]. Toshiba, IBM, Ericsson, Nokia, and Intel formed Bluetooth Special Interest Group for producing standard radio interface to ensure smooth and quick connection among a wide range of devices [67]. The applications of Bluetooth in our daily life are substantial, including a vehicle inter entertainment facility, vehicular engine health and parameters monitoring, traffic management, vehicle relative positioning, bar code scanners, medical services [68], and so on. On the other hand, the significance of Wi-Fi (Wireless Fidelity) in the automotive sector has been rising, particularly for monitoring the vehicle health, traffic management, automobile manufacturing, and after-sales process [69]. As a result, it broadens the opportunities of varying use-cases and offers the possibilities of productive automotive manufacturing organizations through a unified track using the IoT concept. In this context, a complete manufacturing process ranges from monitoring production, managing raw materials to maintaining after-sales activity [18] and so forth. The data transfer rate of Wi-Fi is comparatively much higher than Bluetooth and ZigBee, which is 54 Mbps maximum [70], and the transfer range is around 305 meters [71].

2.2.3. Ultra-wideband and ZigBee

Ultra-Wideband (UWB) corresponds to a radio technology that operates between 3.10 to 10.6 GHz [72]. The data transfer rate of UWB is around 480 Mbps with low energy consumption [73]. The WiMedia Alliance has adopted a physical layer technology based on the ECMA-368 standard for UWB, which has a promising performance to support the establishment of an intra-vehicular communication system of wireless sensors [74]. Besides this, ZigBee is another popular communication technology for IoT, which is designed based on the IEEE 802.15.4 standard with high-level protocols consuming low power with minimum expense [75]. It was developed by the ZigBee Alliance to provide better networking facilities, excellent security, and user-friendly application layers [76]. It is capable of establishing communications among less than 65,000 devices/cells at a time in a network with satisfactory performance [73]. The data transfer rate is around 250 kbps and comparatively lower than Bluetooth, Wi-Fi [70], UWB [74]. So, it makes ZigBee preferable for small data rate applications, e.g., au-

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tomotive fitness monitoring and establishing communication with other vehicles [73] and so on. Despite some limitations, ZigBee is considered as a feasible and promising option to implement wireless intra-vehicular sensor networks [74].

2.2.4. Vehicular communication networks

There are various vehicular communication networks available to ensure the safety and security of passengers, providing traffic information, notifying the driver about vehicle conditions and positioning, contributing to the traffic management as well as reducing accidents. The most popular vehicular communication paradigms are V2V, V2I, vehicular ad-hoc networks (VANETs), and so forth [8,77]. However, the V2V communication system allows for sharing required information among the vehicles for avoiding accidents, traffic congestion, and emergency braking. On the other hand, V2I systems collect and share the data between the vehicle and roadside infrastructure units (RSUs) by internet access. Moreover, both V2V and V2I are part of V2X by utilizing emerging IoT technology for sharing information from anywhere to anything [78]. VANETs defined as the fundamental part of ITS, which featured efficient communications between available internet facilities and vehicles [79]. Besides, VANETs are the subform of Mobile ad-hoc networks (MANETs) to develop using moving vehicles as nodes to establish a mobile network [80]. Here MANETs can be defined as the type of ad-hoc network that can configure itself with the change of positions. So, it turns all participating vehicles into individual wireless nodes and establishes an extensive range network by connecting vehicle nodes for ensuring traffic safety [81]. Moreover, traffic safety for users becomes more robust and reliable in the automotive sector by introducing IoV technology through the incorporation of VANETs and IoT [82]. MANETs mainly used for exchanging information by connecting wireless nodes with the temporary network. The mobile phones, laptops, MP3 players, personal digital assistants, digital cameras, and many others considered as network nodes for MANETs [81]. It designed by taking low energy consumption issues, and usually, these nodes are operated by battery [77].

2.2.5. Automotive ethernet

Automotive Ethernet is another technology introduced for the automotive to assist drivers in transferring a massive amount of data by establishing a better communication network in the vehicle [83]. The modern vehicles are constructed with a lot of advanced tools and equipment such as big sized embedded electronic control units (ECUs) and a considerable number of sensors and actuators to collect all vehicular information and other facilities. Automotive ethernet technology was shown as an excellent option for functional safety, reliability, and data security in the vehicle [84]. However, in automotive ethernet, all actuators, and sensors connected with embedded ECUs using lots of serial buses. In this system, the HU (Head Unit) and CCU (Communication Control Unit) share the aggregated information to the outside medium as an accessible interface [85].

2.2.6. Wireless sensor networks

Wireless sensor networks (WSNs) can be defined as a network comprised of various nodes as a sensor that works cooperatively to sense, compute, and communicate with another node to share the data. There are different types of sensors used to build the network inside the vehicle, such as vibration, pressure, humidity, heat sensor, and many others [7,73]. Mostly, WSN has low power radios, numerous smart sensors, as well as embedded central processing units [86]. Nowadays, it has extensive applications in numerous sectors, and the automotive industry is one of them [87]. Moreover, the automotive sector has a significant WSN future research scope involving intra-vehicular WSNs (IVWSNs) instead of the controller area network (CAN). Otherwise, the performance of IVWSNs has recently been studied under the framework of IoT [73].

2.2.7. 4G-LTE and 5G

Long term evolution (LTE) has low latency mobile access with higher throughput for a very high amount of data transfer by broadcast and multicast media deployment using the 4th generation network over the world [88]. The integrated 4G-LTE network with IoV technology establishes long term evolution–vehicle (LTE-V) to ensure the highest traffic efficiency and road safety by an effective and efficient vehicular communication system. However, it has ubiquitous coverage with the highest reliability and low latency among the different infrastructures and vehicles with a large number of users. This network was developed using the framework of heterogeneous vehicular networks of IoV [89]. As a result, LTE-V can fully utilize the available base stations over the world with the fast deployment of the required instrument and minimum expenses [8]. Again, for IoV connectivity, the demand for technological advancement is rising tremendously because of low latency, supreme reliability, and exceptionally high bandwidth to connect the vehicle with anything at anywhere, anytime, and anyhow with the most top security [90]. By considering these matters, a 5th generation (5G) mobile communication system is an excellent option to buildup the IoV environment to ensure the outstanding vehicular network performance as well as improving transportation infrastructure efficiencies for different purposes. Furthermore, recent research predicted that the future of IoV mostly depends on the 5G due to the colossal number of connected vehicle networks [91]. 5G is anticipated to be much more efficient than 4G-LTE as well as the earlier network generations [92]. A typical constraint of cellular networks is given by the flexibility since they use a licensed frequency spectrum and often have constrained communication ranges. There is a hope that incorporation of the non-licensed spectrum within 5G will facilitate industrial-grade 5G communication goals to enhance the real-time vehicular health monitoring, automobile manufacturing activities, and ITS [93,94].

2.2.8. Cloud-based technologies

The importance of enhanced traffic management, passenger safety, and improved infotainment issues are increasing with raising the number of vehicles. To fulfill these demands, the existing system facing lots of technical challenges like scalability, poor connectivity, less flexibility, and faulty intelligence. Therefore, IoV cloud computing technologies are becoming a significant matter to overcome these complexities by analyzing, storing, and providing effective decisions of massive data for the vast number of connected vehicles [95]. However, the conventional cloud computing is infeasible to provide decisions with low latency, high mobility, and real-time connectivity to the neighboring vehicles lead to collateral damage [96]. To solve these difficulties for enhanced IoV, the edge cloud computing (ECC) is the best option instead of conventional cloud computing [97]. On the other hand, there are three types of ECC (such as fog computing, mobile edge computing, and cloudlets) to establish a secure bridge connection in the space between conventional cloud computing and IoV edge devices [96]. Fog computing usually functions between the connected heterogeneous objects and cloud to ensure security and interoperability to link with end-users and enormous data processing as well as management with low latency [98].

To advance the vehicular services and transportation management by a robust vehicular network based on the cloud are acting like a favorable paradigm. However, the constraints are the remote cloud, offloading data latency, and the uncertainty of the communication system of existing vehicular networks rise [97]. The mobile edge computing (MEC) is an outstanding choice due to the IoV paradigm for mitigating these problems. MEC ensures the maximum resource utilization and performing excellent computation by using available neighboring RSUs, base stations, vehicles, as well as cloud via the multi-access networks system as a radio access network for mobile vehicle terminals [99]. Shortly, IoV, MEC, and 5G cellular networks serve excellent vehicular management services over the world [96]. Cloudlets are another ECC technology by taking consideration of end-to-end latency with mobile computing technology for the hostile environment [2]. Permanently, the cloudlets placed the middle tier among three hierarchy tiers represents as a proxy of the original cloud, such as mobile devices, cloudlets, and clouds. However, it works like a cloud by keeping the absence of the real cloud in a hostile moment and finally preserve the data to the cloud as nearby edge objects [96,100].

2.2.9. NB-IoT and LoRa technology

The dependency on wireless connectivity is rising tremendously for robust vehicular communication to ensure the safety of vehicle users and pedestrians. As a result, robust connectivity technologies are essential to cover the broad area wirelessly. Narrowband-IoT (NB-IoT) and Long-range (LoRa) are outstanding options for extending vehicular wireless connectivity with the maximum number of nodes and minimum energy consumption. Both of these connectivity technologies have a prominent scope in automotive manufacturing industries to expedite the production and raw materials handling using long-distance data transfers. In this case, these will help establish nationwide coverage for sharing essential and useful information from anywhere at anytime whilst ensuring organizational privacy [101]. NB-IoT connectivity works based on narrowband radio technology and a 3rd generation partnership project (3GPP) standards using existing cellular networks like LTE [6]. On the other hand, LoRa, as an emerging connectivity technology, operated based on a non-licensed channel band and may vary location-wise [48]. Moreover, in some cases, NB-IoT is not suitable compared to LoRa because of NB-IoT deployment is limited to 4G-LTE and for suburban and rural areas quite complicated to get the coverage of 4G-LTE [101]. However, LoRa has flexibility and the ability to establish extend connectivity in any location. Besides, the power consumption of NB-IoT is comparatively higher than LoRa because of continuous synchronization [6]. Again, NB-IoT is suitable for low latency and good quality of service (QoS) than LoRa [101].

2.3. Applications of IoT technology in the automotive industry

As an intelligent technology, IoT has a high magnitude of importance that can be straightforwardly realized by its promised benefits in various sectors and projected future adoption [1]. However, in the automotive sector, IoT has an extensive application scope to emphasize types of communication technology, data sensing, collection tools, and analyzing tools encapsulated within the IoT paradigm for multiple purposes. The importance of the diverse and widespread applications in the automotive industry will be presented in the following sub-sections.

2.3.1. Real-time vehicle navigation

The significance of a real-time vehicle navigation system using IoT has an enormous impact on ensuring a safe and smart transportation facility [102]. It has desirable features to help the driver by following live maps on microHD screens in any location. On the other hand, an IoT-enabled model using the SKM53 GPS module and Haversine formula to notify the nearest rescue team for urgent help and rapid aid to the victims when a vehicle faces emergency difficulties like an accident [28]. Beyond real-time personal vehicle navigation, IoT technology also finds applications in the school bus tracking [29], public transport tracking for passengers [103], and so forth.

2.3.2. Traffic management and toll collection system

The traffic management system has a significant role in making the robust economic stability of a nation [104]. A lack of proper traffic management can generate traffic congestion and unusual movement of the vehicle, which leads to severe road accidents, clogging the road, and affects the national economic growth. A smart traffic management system is promising to relieve from these situations [105]. As the quantity of vehicles on the road is gradually growing, it is possible to manage by intelligent timing of traffic signal based on vehicle density with the help of IoT, locally installed RSUs [31], and surveillance camera [106]. In the case of an emergency, the central system can help to detect the accident zone and inform the nearest rescue team [104]. It also helps the driver to know about the road conditions (asphalt, wet, and snow), traffic situation, and accidental information on the road and provide information about emergency parking locations [107]. Development of intelligent traffic management can be traced back to as early as 1992 where the first RFID technology application was utilized to collect charges of the road toll [53]. Nowadays, IoT technology helps improve this system by providing security, a convenient working environment, and improved traffic management via traffic congestion reduction and hassle-free payment [108]. The system is also able to deduce the vehicle's physical characteristics before imposing a toll charge through a web/database query mechanism [109].

2.3.3. Security and anti-theft system

The anti-theft features for the vehicles are a conventional technique to protect it from burglary. Nowadays, these features are advanced by adding IoT technology to make the vehicle more cost-effective, secure, and reliable [110]. Benefiting from an IoT-aided anti-theft system, the owner of a stolen vehicle can quickly track its accurate location with the help of the internet accessible smartphone. This technology ensures more dependability because of the starting features that can be remotely controlled by the owner using an embedded smartphone application as well as a steering embedded camera that can capture the photo of the perpetrator as digital evidence [30].

2.3.4. IoT-enabled black box and event data recorder

Black Box is installed as an electronic footage collecting device to record various information during operational mode for future investigation. Unfortunately, in many previous cases, the black box could have lost forever due to unanticipated deadly accidents, and, as a result, the investigators failed to dig up the actual reason behind road events [111]. Motivated by this undesirable limitation, IoT-enabled black box introduced in the car for future profound analysis [112]. With the help of IoT technology, the system can capture the image, record video, collect location coordinates, perform data processing using analysis tools. It then transfers the required information to the cloud server and shares it with the designated responsible person via email and SMS [111]. Besides, another advanced gadget with excellent features also devised for data storage and transmitted through IoT technology during the accident, which helps to dig up the fact for the unexpected incidents, and that is called event data recorder (EDR) [113]. Because of the prominent beneficial aspect, EDR is mandatory in recent years for installing inside the car to record accidental information for post accidental forensic reports [114].

2.3.5. Emergency vehicles management system

Around the world, traffic congestion is a significant problem that can lead to the loss of lives and property due to the unavailability of emergency vehicles (EV) at the right time to ensure emergency services [50]. Around 24% of sudden cardiac arrested patient's lives are possible to save by reducing response time by at least one minute [31]. Therefore, it is conceivable how essential to facilitate the EV for ensuring required medical services. Given the necessity and unique identity of EV to travel across a long traffic bottleneck, installing a suitable IoT platform that exploits sensors, V2I and V2V can automatically detect EV based on a predefined priority [115] and then send a notification to the traffic authority [116]. The administration manages alternative shortest passage to reach the desired destination to provide emergency services [31]. This IoT technology ensures avoidance of EV road accidents in road intersections and other places by providing emergency notification to the road users about the EV approach as well as ensuring security [117]. As a result, the hacker's group will not be able to entertain this facility.

2.3.6. Pollution monitoring system

According to the World Health Organization, around 2.4 million persons die annually due to factors that can directly be attributed to air pollution [118]. Therefore, air pollution is a vital problem as a result of the emission of various gases and dust from the vehicle, industry, and volatile chemical compounds. In this case, the transport sector is significantly responsible for air pollution and contributes from 12% to 70% of air pollution [119]. Hence, continuous monitoring is essential to control excessive emissions from obsolete vehicles. In this case, IoT technology deployed to measure the magnitude of vehicular exhaust pollutants and notify the vehicle owner and administration about the emission-quality, as well as recommend further action [120]. IoT is also applicable for monitoring the air pollution level at various points over the country [121].

2.3.7. Driver physical condition monitoring system

The vehicle driving carries heavy responsibility for ensuring the road safety of all users, including the driver, passengers, pedestrian, and others [122]. The driver behaviors constitute the most substantial factor for committing an accident on the road [123]. In many cases, the accident caused by the driver is often a result of the lack of satisfactory physical and mental health criteria for driving. IoT technology can be used to observe the driver's physical condition. The driver physical conditions include Electroencephalogram (EEG), Electromyogram (EMG), Electrocardiogram (ECG), and heart rate using a sensor integrated module inside the driver seat, as well as other health issues such as eye/face tracking devices putting in the suitable position from the driver to observe physical abnormality [124]. This information then forms a stream of data for a notification to desired persons with the help of IoT technology. This technology can also enhance alcoholic detection facilities to avoid unexpected accidents and save the lives of drivers, passengers, and road users [125].

2.3.8. Vehicle performance monitoring

Vehicle performance and engine conditions monitoring is the most critical issue because of the engine temperature, speed, and tire pressure correspond to the essential components of a vehicle. When the engine temperature was gone increasingly high, then it raised fuel consumption, exhaust emission rate, affect turbocharger compressor efficiency, and seize the engine [126]. Correspondingly, the engine speed and tire pressure have a unique effect on vehicle performance and safety purposes, respectively. IoT technology has a promising capability to monitor engine temperature [32], engine speed [16], and tire pressure [69] as well as provide real-time information to the vehicle owner through the IoT technology.

3. Emerging applications of IoT in automotive industries

With IoT technology being used for various purposes, both in-vehicle and a wider automotive industrial sectors, it is imperative to state IoT as an emerging technology paradigm. Nowadays, it captivates industrial attention and its application in the automobile industry for a wide communication range, i.e., P2P (Peer to Peer), P2M (Peer to Machine) and M2M (machine to machine) is desirable along with improvement opportunities through performance, productivity, dependability, safety, and privacy. This technology has another lucrative feature that gives the capability to connect heterogeneous networks and devices through the internet [21]. In the following, we review IoT applications in a wider domain of the automotive industry.

3.1. Supply chain management

For the industrial case, a supply chain management (SCM) system is a critical factor in achieving strategic goals. In the present time, IoT based SCM creates a new paradigm by providing dependability, interoperability, trustworthiness, and effectiveness in industrial operations [127]. Therefore, IoT enabled SCM to have a remarkable impact on improving the overall economy by efficiently utilizing resources and sharing information among manufacturers, suppliers, and consumers in the automotive industry. Again, IoT technology within the materials procurement system of SCM opens up a new gateway to close the distance between the raw materials suppliers and automotive manufacturers [33]. The automotive manufacturer shares information about forecasted vehicle demand to the raw materials supplier by using collaborative planning, forecasting, and replenishment (CFPR). As per requirement, the supplier delivers the raw materials and components instantly, which leads to continuous production due to the availability of these materials. Hence, IoT-driven CFPR is a promising way for raw materials procurement by saving the cost through intended collaboration in the automotive sector. There has already been developed on robust collaborative planning and forecasting processes by Toyota through trustful buyer-supplier affiliation using CPFR [128].

About thousands of parts are connected sequentially to assemble a new vehicle. Hence, the proper inventory and distribution of vehicle parts are sophisticated tasks to build a new vehicle. An IoT-based inventory management system facilitates information acquisition and exchange on the available quantity in the database to prepare for the demand forecast [129]. The parts can also be tracked quickly by using RFID for successive distribution to the assembly line while in the warehouse. Besides the inventory management, logistics support is a significant part of the automotive industry to carry the raw materials for continuing the production process and deliver finished products to the customers' door. An RFID unit can be installed along with IoT technology to collect dynamic tracking information and share essential data about logistics. As a result, this technology helps to increase customer satisfaction and reliability by delivering the desired product within a specified time, along with improving management dedication for better services [33].

3.2. Manufacturing system

IoT based automotive manufacturing system in the automotive industry infers about the attachment of electronic tags on spare parts in the warehouse to monitor and track various operations. Such as semi-finished or finished product preparation, safety condition during production, quality checking information, finished product storing, and sales information [18]. Moreover, IoT-enabled RFID technology as an electronic tag ensures real-time information sharing in the manufacturing processes [130]. For the case of safety and security in the working premises, when anyone moves through a hazardous point, then the system can detect with the help of installed sensors, laser scanning, and data analysis through the incorporation of IoT [131].

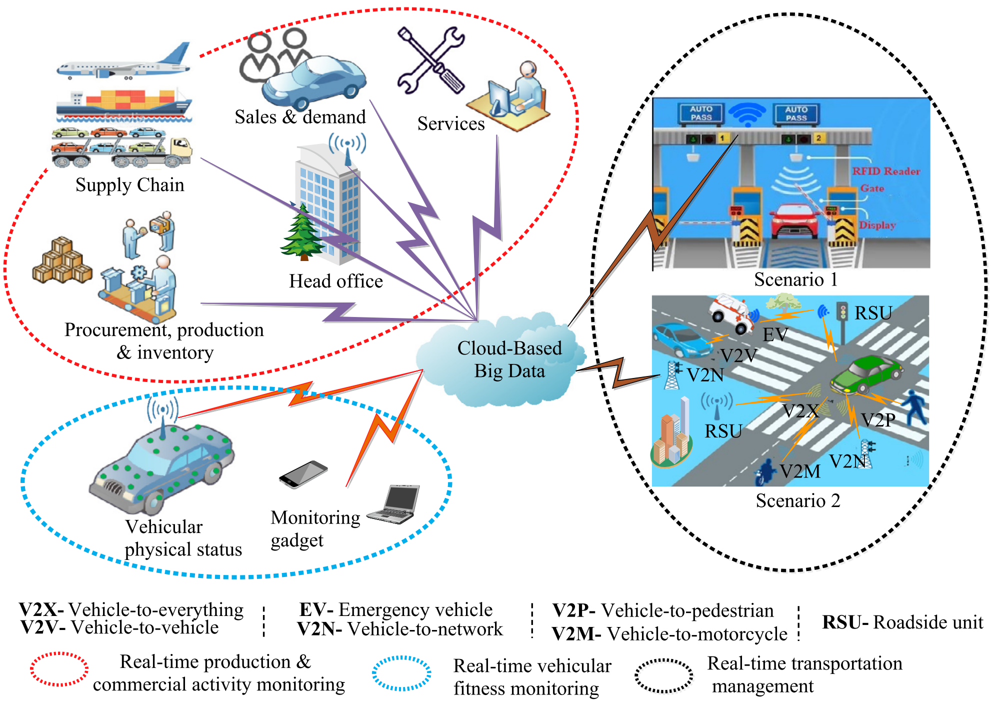

Fig. 1. Conceptual framework of IoT applications in the automotive sector. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

3.3. *After sales service system*

The most vital factor to be a successful organization is the after-sales service. Similarly, the after-sales service has a significant impact on product acceptance by the customers for the automotive industry. The IoT technology-based after-sales service system can keep an outstanding contribution to acquire feedback and suggestion about the marketed vehicle from the customers. Based on the analyzed data of the customers' feedback, technical support, and necessary initiatives for customer satisfaction lead the automotive manufacturing industry to advance in a competitive vehicle market [33]. On the other hand, IoT enabled RFID technology ensures real-time notification about maintenance requirements for the awaiting people to get maintenance service [130].

4. Conceptual framework of IoT application in automotive sector

The present and future applications of IoT in the automotive sector can be classified into three sections, such as real-time vehicular monitoring purpose, real-time industrial and commercial observation purpose, and real-time transportation management purpose. The conceptual idea depicted to bring automotive-related all activity under real-time monitoring by using IoT technology. It will help to minimize operational and maintenance cost, reduce time consumption, improve productivity, ensure organizational transparency and security, ensure pedestrian and vehicle user's safety as well as comfortability, and many other beneficial issues. However, Fig. 1 presents the conceptual idea of IoT application in the automotive sector.

4.1. *Real-time vehicular monitoring purpose*

The development of IoT has given perfection to the real-time vehicular monitoring system in today's world. We have proposed a new conceptual framework to make the real-time vehicular monitoring system more elaborate and efficient. Fig. 2 presents the conceptual framework of the real-time vehicular monitoring system. Information requester in the figure involves demands to know information about the vehicle. The vehicle users, manufacturers, and maintenance engineers are represented as a requester for information through the decision engine based on a fuzzy logic approach [132]. The requested requirements will be categorized, and there will be followed up with actions to deliver information after collecting data from the information providers such as sensors and devices. As the information provider, a set of vehicle-dependent sensors (S_1, S_2, S_3 … S_n) are introduced, such as position sensor, motion sensor, force sensor, pressure sensor, flow sensor, acoustic sensor, humidity sensor, light sensor, temperature sensor, chemical sensor, brake sensor, door sensor, heat sensor, fuel level sensor, parking sensor, lane detection sensor, RFID and so forth [23]. At the same time, a set of vehicle-independent devices (D_1, D_2, D_3 … D_n) are also defined as other information providers by gathering the additional required information, including the driver's physical condition. There are a few external devices to be installed, such as EEG sensor, EMG sensor, ECG sensor, heartbeat sensor, eye, and face-tracking camera [124]. In addition to those, the navigation devices, actuators, anti-locking brakes, fuel injection controllers, airbag systems, and many others also play a role as information providers. These devices and sensors are responsible for providing information to the Fuzzy logic-based decision engine as per requester demand besides collecting real-time data. In this system, a bulk amount of data will generate continuously and share among the requester based on their demand. So the data extraction and reduction of storage data is the most crucial factor, and the Machine Learning/ Deep learning technique Enabled Big Data Analytics concept may help for processing and extraction efficiently to conceal the useful information from these collected data [133].

However, the decision engine act as an integral part of the conceptual framework of the vehicular monitoring. It is synchronized with an existing vehicular engine control unit to gather the full system information and be subsequently programmed based on Fuzzy logic. It is also responsible for accumulating, verifying, and transferring the selected data to the cloud storage system. On the other hand, the data verifying process is expedited and ensures

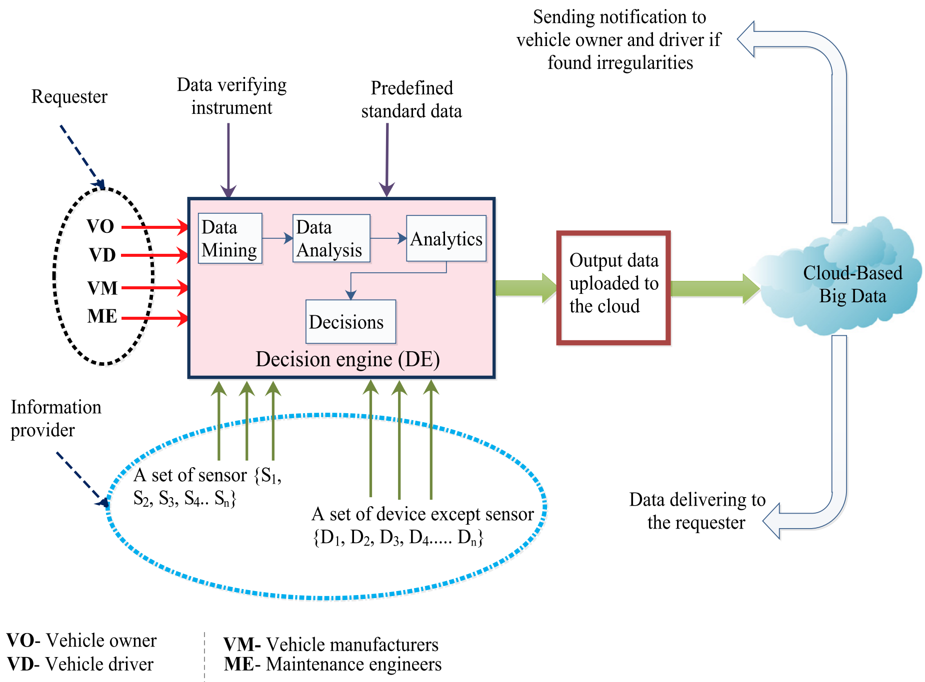

Fig. 2. Conceptual idea of IoT applications for vehicular monitoring system.

accuracy by comparing the gathered data with predefined standard information. The standard information is the vehicle exhaust standard, allowable engine oil data, engine oil change information, maintenance details, vehicle health, engine information, and many others as per requester demands. After processing, the accepted data is stored into the cloud as well as transferred in real-time to the designated person using the available network. For instance, the vehicle manufacturers (warranty period), maintenance personnel (maintenance-related information), the vehicle users can obtain details using IoT technology as per request.

4.2. Real-time industrial and commercial observation purpose

In the automotive industrial and commercial cases, IoT technology has attracted attention to improving operational smoothness and efficiency. It is included the supply chain management, after-sales services, market demand forecasting, real-time materials handling, manufacturing, parts identifying, and maintenance schedules. Mostly, the corporate office can easily monitor all the processes and then the strategic plan necessary actions and recommend suggestions rapidly with the help of IoT technology. Fig. 3 presents an IoT conceptual framework to capture a generic working principle for industrial and commercial purposes. It mostly shares similar characteristics to the vehicle monitoring, however, with different specific functionalities. The information requester works identical fashion as of vehicle monitoring. Nevertheless, the category and types of requesters are different since this concept is mainly driven by the expansion of automotive manufacturing scope and productivity improvement measures. Therefore, after-sales service units, supply chain management, production section, and governmental units are considered as the information requesters. For instance, the customer may have an enormous query about the purchased vehicles, for the service team may have a query about the maintainable vehicle. The head office may have a query about the customer comment aligning with monitoring after-sales matters. Similarly, supply chain management, head office, and supplier can place their demands about desired issues through the decision engine. On the other hand, the government may place a request through the decision engine to check all the government-related activities for audit as well as monitoring the transparency activity. For this system, it would be predictable that this system will generate a massive quantity of data. So, in this case, similar to the real-time vehicular monitoring system, the Machine Learning/ Deep learning technique Enabled Big Data Analytics concept may help for processing and extracting useful data from these massive amounts of generated data [133].

The central organizational server is connected with the decision engine besides individual information providers. More specifically, the individual information providers are included after-sales services information (real-time maintenance progress and parts requirement and maintenance work schedule), real-time finished product, raw materials delivery details, real-time production status, inventory, and procurement status, customer demand, and headquarters real-time required information. The information providers and central servers are responsible for providing demanded and stored information to the Fuzzy logic-based decision engine [132]. Although the functionality of the decision engine works slightly different as compared to the above-mentioned vehicle monitoring system. In this case, the decision engine is connected with information requester, information provider, and the central organizational server. It then delivers the demanded information to the requester after data collection and proper analysis. The decision engine ensures an authentic entry of requester and protects it from the intruder. The sufficient information transects since the application of IoT technology considered for industrial purposes. On the other hand, the past industry data usually needed for the jurisdiction of industry conditions as well as comparison productivity and other issues. Thus, this technology ensures fast data collection and solutions for anytime-anywhere to store data to the cloud storage system and deliver to the requester as much as quick possible after getting the decision from the decision engine.

4.3. Real-time transportation management purpose

Transportation management is an enormous issue, and numerous research carried out an effective way to mitigate this issue. In this direction, an IoT-enabled transport controlling system has the potential to create an excellent threshold to maintain the traffic

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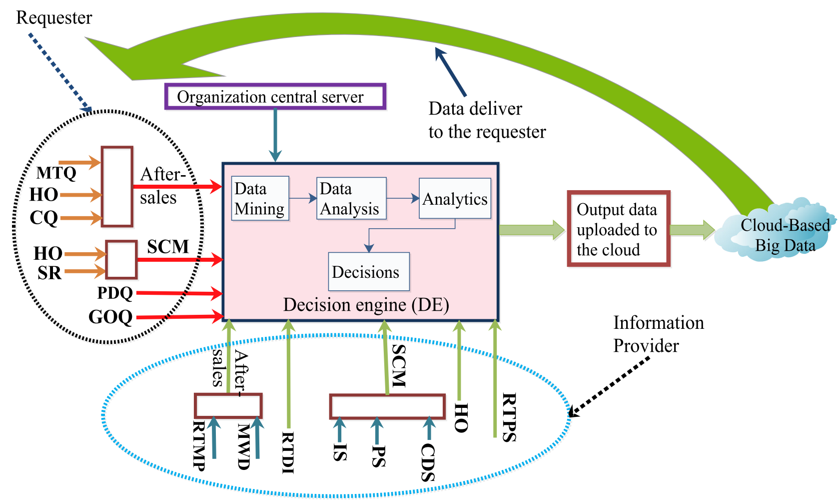
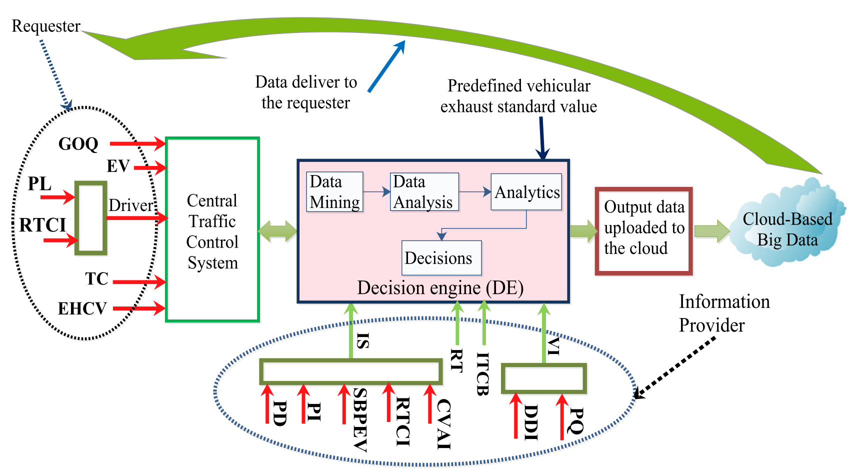


MTQ- Maintenance team query
HO- Head office
CQ- Customer query
SR- Supplier request
PDQ- Production dept. query
GOQ- Govt. organization query
SCM- Supply chain management
RTMP- Real-time maintenance progress
MWD- Maintenance work details
RTDI- Real-time delivery information
IS- Inventory status
PS- Procurement status
CDS- Customer demand status
RTPS- Real-time production status

Fig. 3. Conceptual idea of IoT applications in the automotive industries for real-time monitoring.



GOQ- Govt. organization query
PL- Parking location
TC-Toll collection information
PI- Parking information
PQ- Pollutant quantity
VI- Vehicular information
RT- Rescuing team
PD- Pedestrian detection
SBPEV- Suggestion about best path for EV
EV- Emergency Vehicle (Ambulance & Fire brigade)
IS- Information sharing using GPS, V2X
CVAI- Crushed vehicle accidental information
EHCV- Emergency help for crushed vehicle
RTCI- Road & traffic condition information
ITCB- Information from all toll collection booth
DDI-Drivers detail information (Driving license, road permit, tax, insurance, owner details, etc.)

Fig. 4. Conceptual idea of IoT applications in real-time transportation management.

system at a busy intersection. It aims to help move the vehicle safely, actively, and efficiently by leveraging upon GPS, V2N, V2V, V2P, and V2I communication systems embedded within automotive IoT technology. Fig. 4 proposes an IoT-driven conceptual framework for the vehicular transportation management system. The information requester is the first phase of the real-time transportation management framework. In this case, the toll collection, vehicle driver (information on road and traffic condition, parking location), government traffic control agency (help for traffic accidents), emergency vehicles (ambulance, fire brigade) and many others will seek for information, assistance or services as an information requester. In this system, they will able to send their queries to the central traffic control system instead of the decision engine.

The central traffic control system is incorporated to provide all traffic information across the covered area accurately. It also helped scrutinize query validity and forwarded it to further analysis. The decision engine provides return notification to the central server about the inconsistent query. The central server and decision engine work together to reject the request when a fake ambulance or any emergency vehicle sends a request. In this case, feedback also issued and transmitted to the driver by using available communication technologies in the IoT networks. Further action may include blacklisting the plate number and putting consideration for the subsequent references. An information supplier is another critical factor in the transportation management system. The whole system may malfunction when a particular party avoids sharing the information. The proposed framework is con-

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sidered connectivity techniques (such as GPS, V2N, V2V, V2P, and V2I) to help for sharing information about current road conditions and suggest the best route, best parking location, pedestrian detection and so forth. In addition to that, the toll payment information, vehicular information, rescuing team responses, government organizations, and many others can play a role as information providers. They share their data through the Fuzzy logic-based decision engine, depending on the requester demand through the central traffic control system [132]. Moreover, for resourceful data processing and extraction from these colossal quantity data, the Machine Learning/ Deep learning technique Enabled Big Data Analytics concept will help to open a new threshold in the real-time transportation management system [133].

In this framework, the Fuzzy logic-based decision engine is considered to synchronize, analyze as well as collect the desired information from sources, i.e., the information providers, before forwarding through the internet cloud. It also works with the central traffic control system to ensure fast, secure, and optimal traffic management and services to the users. Similarly, it can compare exhaust quality with a predefined standard value and command to notify a higher authority to take action when it remains above the standard level. Cloud storage is the last phase of the proposed transportation management framework. After analyzing the user request, the information is stored in the cloud and instantly delivered the required information to the users and governing authorities through IoT networks. The use of cloud storage is to ensure a ubiquitous and reliable storage system. As a result, the requester gets the required information at anytime-anywhere based on decision engine command.

5. Benefits of IoV, limitations and Its challenges

IoT applications in the automotive sector have revolved for various reasons. Although IoT technology has a significant impact on transforming the automotive sector, it comes with shortcomings. We provide elaboration on the benefits, shortcomings, and challenges to deploy the IoT technology in the automotive sector.

5.1. Benefits

The developed IoT system able to collect diverse data by using sensing devices with the highest accuracy [23,134] to assist a vehicle for quick navigation [135], accident avoidance [136], and detection of the road condition [106]. These features appeal to the users and industry manufacturers for upgrading the vehicle with updated IoT-enabled devices. IoT technology is enhanced by comprising with a heterogeneous features for vehicular communication [134] and able to connect any other devices instantly [8] for helping the vehicle users by gathering traffic conditions information [137]. As a result, it helps to save travel time and fuel as well as protect the environment by reducing exhaust emission. The IoT system also has fast data collection ability compared to a conventional process [138]. It instantly provides a decision outcome by analyzing a vast amount of collected data in real-time [139]. Therefore, IoT-enabled traffic management systems help to find an alternative way for an emergency vehicle and suggest others to avoid traffic jams, accidents, and clashes with another vehicle. Besides, this technology ensures a smart traffic management system over the city with minimal human assistance by collecting and analyzing gathered data, i.e., vehicle parking [140], parking location detection [141], traffic signal management [104], and so forth. It helps improve the overall quality of life for the city residents through smart interaction with transportation. Again, IoT technology is also able to detect emergency vehicles and provides a rapid solution by controlling the traffic system [142] and find out an alternative shortest path [31]. Moreover, it also provides a mechanism to considerably reduce the death rate by allowing faster response to those with critical health situations. For the case of security of the vehicle, IoT technology facilitates an anti-theft protection and tracking system sophisticatedly by sending a notification to the driver [143]. This system thus restricts unauthorized uses as well as prevents the vehicular burglary.

About the driver's physical condition, the IoT system has the capability of determining whether the driver able to drive along with notifying the owner of the vehicle through email and SMS instantly [124]. Thus, it is reducing the road accident through the incorporation of IoT-enabled technology for monitoring the driver's physical disorderliness in the vehicle. IoT technology facilitates the cloud server to store data for future investigation evidence. In such a case, all data used for forensics investigation purposes [112] to minimize the chance of missing evidence due to a lack of field monitoring data. Besides these positive aspects, we can gain benefits in saving the environment pollution control through the deployment of IoT-enabled vehicle emission monitoring system that provides real data about the vehicular exhaust [120]. The same data further exploited to monitor vehicle performance for reducing fuel consumption [126]. IoT is also playing a significant role in improving productivity in the automotive industry by minimizing human interfaces in different areas such as inventory management [129], raw materials, and finished product details information sharing, manufacturing process monitoring, and controlling [130]. As well as this technology created a new dimension for company administrative information storing, processing and sharing, customer services and logistics management [134] activities. Again, the adoption of it in the automotive industry can help to reduce labor costs as well as improve productivity [144].

5.2. Limitations

Skilled and well-trained operators are required to operate IoT in the automotive vehicle, which is currently difficult to obtain. Due to the diversified nature of automotive IoT applications and facilities, vehicle owners and automotive industrialists attracted by this technology, as well as the demand of IoT experts increase proportionately. It is well evidenced that qualified staff can handle the upcoming challenges more smoothly compared to the new staff [134]. Again, in order to establish communications as an integral part of the IoT, the system has to seek consent from the vehicle owners, who may be reluctant to share their information with other vehicles and devices. This concern is relevant since there is a strong possibility of the abuse of personal information, which is a sensitive matter [145]. Due to additional devices, having IoT certainly increases the expenses of the vehicle and maintenance costs of the roadside infrastructure. From the manufacturer's perspective, to operate the IoT-enabled industrial plant require the employment of digitally-skilled specialists and operators, which also incurs extra costs.

IoT is a very complex system with different components working harmoniously to achieve a common goal [134]. A massive amount of devices connected to the same network compete with the limited radio and network resources for transmission. Without a proper design, this complex system can also be sensitive towards a single point of failure that can damage the whole system [146]. Besides, network failure is another critical drawback that can impact the functionality of the IoT system [147]. This technology is often unusable in a remote area due to the lack of internet or network availability. Again, for the adoption of IoT technology, the investigator needs to completely depend on the cloud to obtain necessary data and evidence for forensic investigation. It is inconceivable to manage the required information in the context of a limited network for emergency cases. Although it is clear that the

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benefits of adopting IoT in the automotive are enormous, limitations as mentioned earlier, have put the contextual challenges of IoV development.

5.3. Challenges

As an integrated vehicular network, there are a lot of possible malicious and intrusion activities due linked to pervasive and ubiquitous information sharing and communications among the vehicles, pedestrians, and roadside infrastructures. The users may reveal their identities, vehicular information, and exact location due to the data sharing [148]. Therefore, users may disrupt the vehicular communication system by spreading malware and hindering information sharing using a smartphone and other devices when the intruders decide to eavesdrop and hijack the sessions [59]. However, it is quite challenging to protect all aspects from intruder intervention and cyber-attacks without robust safeguard strategies.

In an IoT-based traffic management system, the overall communication network is established by various connectivity techniques such as V2V, V2I, V2P, and V2N and other control devices. Such a large system requires an enormous amount of electrical power to sustain its operation with a certain level of power supply continuity. The whole traffic management system may enter a chaotic situation as a result of the absence of data for decision making when a sufficient amount of electricity fails to be supplied [149]. The certainty of continuous power supply for the whole system is also a big challenge. Therefore, an alternative source of power and conservation system, including solar power and battery, should be considered to overcome this unexpected situation. Besides these challenging issues, a well-trained and skilled team are required to monitor the field conditions and provide interventive actions to operate the whole system efficiently. Developing an experienced operation and maintenance team to be challenging and often requires proper continuous training and practical engagement with the fieldwork.

Exchanged data complexity is another challenge in the automotive IoT platform. It can lead to a dysfunctioning system when the shared data is not understandable to others. As a result, end-users may lose their interest in adopting IoT technology in the automotive vehicle. Concurrently, monitoring the accuracy of shared data is often challenging due to the malfunctioning of sensing devices. The system may sometimes share erroneous data, which decreases the trustworthiness, dependability, and interest of users about this technology [150]. Also, traveling in a remote area may present difficulty in accessing the network. It is understood that excellent internet facilities with robust IoT technology can assist in navigating the vehicle, sharing present road conditions, monitoring engine health, navigate the nearest refueling station, and so forth. Therefore, a lack of reliable networks with high-speed internet connectivity can impact functionalities and broader inclusion of IoT technology to provide appropriate services for the seamless travel experience.

6. Issues, potential solutions and future research

After carefully evaluating the evolution of IoT technology in the automotive industry, we have identified several issues related to research opportunities that can shape directions for future research. The detailed description of issues and potential solutions for the different concerns will be presented in the following subsections.

6.1. Vehicle vulnerable parts monitoring

One of the widely-considered IoT-enabled development covers the area of monitoring vehicle conditions such as engine speed, radiator conditions, engine heat, fuel flow, tire pressure, vehicle exhaust quality, and so forth. Subsequently, there exists a vast scope of further research in monitoring and diagnosing defects of vehicular vulnerable parts, and engine conditions. The future works may follow supervisory function development incorporating a Hidden Markov model (HMM) and Empirical Mode Decomposition (EMD) to monitor vehicular engine conditions [151]. In addition to this, engine sensors with different measurement properties for monitoring lubricating oil condition can be employed and interconnected through an IoT platform to facilitate data fusion and collaborative decision making [152].

6.2. Sound pollution monitoring and energy-efficient technology

Since the era of industrialization, sound pollution has been one of the significant contributing factors in the overall environmental pollution [153]. In recent years, it has emerged as a dangerous pollutant that severely impacts the neurocognitive ability of humans. A dominant sound pollutant comes from the emission of noise from the moving vehicle, given the ever-increasing traffic intensity on the road [154]. Despite the dynamic impact of the vehicle noise pollutant on the environment, very little research work carried out to monitor the sound pollution produced in the automotive sector using IoT technology. It offers outstanding opportunities for future research and development work in applying sophisticated IoT-enabled devices and big data analytics methods to monitor the noise level of the vehicle accurately and control the pollution. For accomplishing, the follow-up works may consider the utilization of a central server to IoT technology with updated and high-performance instruments. It will then be used by the environmental authority to gather pollution data, make inferences, and initiate actions against faulty vehicles that emit intolerable levels of sound pollution.

6.3. Advanced transport system design

Although a variety of research advancements have materialized for the smart transportation system [155–157], a broader future research scope is to be explored for advancing this system using IoT technology. For long and short travel routes, future research can address the development of advanced tracking devices to track, screen, and spot, e.g., stolen vehicles, lane violations, traffic rules disobeying vehicles, drug trafficker vehicles, emergency assistance, smart toll collection, and so forth. Besides these, IoT-enabled smart highway lighting is another significant issue to avoid unexpected incidents in dark conditions. But energy issue is a great problem, and to overcome it, some researcher carried these experiment concisely instead large extent [158]. So, for the automotive sector as part of transportation system advancement, in this case, it has a huge scope to conduct extensive research for the long route using IoT.

6.4. Energy-efficient technology and alternative energy source

Motivated by the worldwide concern of carbon production, and energy-efficient IoT-enabled traffic management system seen as a promising way for forthcoming study in intelligent transportation [107]. The challenge of such a system is comprised of a large-scale network containing a massive number of vehicles, backbone servers, adaptive intelligent energy-efficient devices, and analytics machines. Concurrently, future works shall incorporate extensive development of techniques for managing alternative green-energy sources [158]. Such as solar panels, uninterruptible power supply, instant power supply, and so on for supporting the operation of the traffic management system.

6.5. Cost minimization and upgradation industrial sales management system

Cost minimization is a big concern in improving the rate of adoption of IoT technology in the automotive sector by end-users. The cost reduction of IoT platforms by developing low-cost sensing devices, analytics machines, networking tools, and cost-efficient network architecture [139]. Another possibility is through investigating novel, cost-effective material design with maximum reliability. The design optimization from the perspectives of material, embedded hardware, networking system, and applications can help to reduce the deployment cost dramatically and appeal to the users for IoT technology [102]. On the other hand, in an IoT-enabled sales management system, the automobile industry has the opportunities to further exploit the captured big IoT data stream through acquiring updated sales information, forecasting demands of vehicles, and their corresponding parts [159,160]. The real-time notification can be fed forward through a reporting mechanism to the relevant stakeholders and higher authority. As a result, it helps increase the production quality and yield, customer satisfaction, and sales performance as well as inform the higher officials with present and future market awareness of this industry.

6.6. Cybersecurity

The automotive market is full of competition among automobile manufacturers, which accomplishment gradually attracted to the broader deployment of IoT for various tasks in expediting the production process. However, the leakage of sensitive information such as demand forecasts, financial and customer information, and production details have a high possibility of occurring due to more connected through IoT [145]. In order to circumvent this issue, one of the most prevalent research directions is automobile industrial cybersecurity. In this case, the researchers can employ two-factor and biometric authentication access and intruder detection with coordinate localization by extensive research. Additionally, they can think about the industrial cyber-physical system for providing data security in the automotive industry [160].

On the other hand, the market analysts and researchers have predicted that IoT-enabled devices will reach around 20 billion by the year 2023 [161]. Given the massive scale of data exchange, provisioning proper security, and controlling privacy from invader attacks are receiving growing interest in traffic management and various vehicle communication systems. Bio-metric identification using iris recognition systems can be invoked to ensure security and halt the abuse of user's privacy [145]. This technology enhances the functionalities of IoT technology and will it help to detect automotive cybercriminals.

6.7. Standby sensing instrument use

Existing works considered only a single sensing device to collect data from a single measurement point in the vehicle, such as engine speed, fuel flow, tire pressure monitoring, and so forth [22]. When these devices fail to work correctly due to aging and other factors, then they erroneously deliver wrong monitoring data and challenging also to overcome it. However, in this case, the utilization of standby sensing devices and their corresponding synchronization can motivate further work in the technical area of accurate and reliable in-situ data collection. Such research may exploit various vehicular communications for data sharing and facilitating multiple observations [8,74,77].

6.8. Trusted data evaluation

When performing data sharing, some intruders may try to bruise out the whole system for unlawful personal purposes by providing malfunctioned data. Therefore, data screening is mandatory for maintaining reliable services via guaranteeing trusted and useful data. It can play a crucial role, e.g., critical accident-related data such as real-time accident occurrence time, information provider distance from the incident point, information provider reputation, and so forth [137]. For this purpose, data accuracy, reliability, and trusted data evaluation still leave plenty of research challenges due to the advance in state-of-the-art automotive cyber-attacks. However, for trusted data, the researcher can follow the research work Trustworthy and Secured Data Collection process [160].

6.9. Overseas tracking system

To expand the automobile business in all over the world, and to ensure proper customer service, the vehicle delivery real-time location, estimated time to reach the desired destination and product details. The product details, including batch no, production time and date, quality details, quantity, are among the most important things to inform customers since the users help forecast about various activities. Therefore, there is a relevant research direction on overseas real-time tracking and seaway real-time tracking using IoT-enabled advanced technology. Motivated by its promise for improving the supply chain and tracking [162]. This technology can also be anticipated to help the manufacturers to monitor their supplied vehicle performance as well as customer's feedback about it and the maintenance services.

7. Conclusion

The ultimate purpose of deploying IoT technology in the automotive sector is to administer a higher level of vehicle comfort by using state-of-the-art vehicular communications and improve travel experience with minimum travel disruptions and unexpected incidents through intelligent computerized processing. This paper has comprehensively provided a review on clear evolving roles and applications of IoT in the automotive industry, converging diverse communication technologies to support the envisaged massive IoT connectivity as well as the progressive conceptual framework of designing IoT applications in the automotive sector. Based on this review, developmental issues have been examined along with potential solutions for future research. We conclude that, as an evolving technology, IoT with its inherent sophisticated devices and communication technology has enormous scope to expand its applications in both the automotive vehicles and the broader industrial processes. This technology has been envisioned to play a pivotal role in increasing the economic growth of the automotive sector. Therefore, lucidly, IoT technology does not only provide the necessary technical assistance, relevant notifications, security, and safety functionalities to the stakeholders but also helps grow the economy by creating new businesses through innovative uses cases. However, this potential might be hampered by new research challenges in the vehicular IoT paradigm, including the management of the massive number of sophisticated devices and the design of highly-efficient communication technology. Harmonizing future research efforts would be a key step going forward to realize the promises which the IoT technology has brought upon.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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