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Internet Of Things (IoT) In The Smart Automotive Sector: A Review

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Abstract: *The Internet of Things (IoT) is a new wave of Internet that is expected to transform our lives. Internet has connected people and now it is connecting 'Things' to make seamless communication and intelligence pooling. IoT is a disruptive technology that has tremendous potential to change the world and is changing the way we live. It uses low cost Internet connected devices and sensors that create new possibilities. Not long ago, the idea of IoT in the automotive sector was being seen as a futuristic theoretical concept and today we are already seeing possibilities of connected cars, driverless cars and application of IoT in the car ecosystem covering parking, environment, supply chain and transport governing bodies. This paper discusses the evolution and developments on Internet of Things with regard to the automotive sector to provide a perspective on the various areas such as- Connected Car services/applications, Vehicle communications, IoT in Intelligent Transportation, IoT based Supply Chain Management in Automotive Industry and New Generation Cars, where tangible progress is being made.*

Keywords: *Automotive Industry, Connected Cars, Internet of Things (IoT)*

I. Introduction

IoT is a disruptive technology where cyber world meets the physical world. It is autonomous communication between inanimate objects [28], in order to benefit human beings. IoT encompasses all technologies in SMAC (Social, Mobile, Analytics and Cloud). Automotive industry is on course to a disruptive transformation using developments around smarter vehicles and related infrastructure. IoT is at the heart of this digital transformation in Auto sector. It connects people, machines, vehicles, auto parts, and services to streamline the flow of data, enable real-time decisions, and improve automotive experiences [25]. Leading automotive manufacturers, suppliers, and dealers have started investing heavily in Internet of Things and are gaining returns in the form of ultra-efficient inventory management, real time promotions that grow sales, reduced operational expenses and increase in revenue. They are beginning to change their business processes and recognize that, in time, IoT will touch every area of automotive operations and customer engagement [27].

Tesla motors is a big example in the Internet of Things domain. In addition to being a luxury car, performance vehicle, the car is one big IoT device with a lot of IoT properties inbuilt. Applications are developed that use data collected by connected cars [30] in many ways. For example, traffic control systems can provide real-time data collected from connected cars to avoid traffic jams and accidents, Automotive components manufacturers can benefit from data about wear and tear to pre-order the components to be replaced and notify customers before there are equipment failures. Car sharing mobile apps can use real-time location data to encourage car pools. Also, in insurance systems, premium rates would be based on geolocation of vehicles and driving behavior of drivers. Figure 1 shows these and many more developments on IoT in Automotive sector.

1.1Connected Car Ecosystem

IoT has a significant impact on Automotive industry. Automobile manufacturing companies, telecommunication service providers [33] and software companies are coming together to build the Connected Car. A connected car is a car which using its onboard sensors and internet connectivity enhances the in-car experience of its users [3]. Connected car, just doesn't mean the capacity to surf the internet on the move, but the communication between cars, communication of cars with other devices. As of date, there are only a small number of cars which are internet enabled but it is expected that the number will rise considerably in less than a decade's time. And seeing the lifestyle experiences required by today's generation and the exposure to smartphones will definitely help the connected cars market to grow exponentially. The Connected car services and applications along with other developments on IoT in Automotive sector are discussed below.

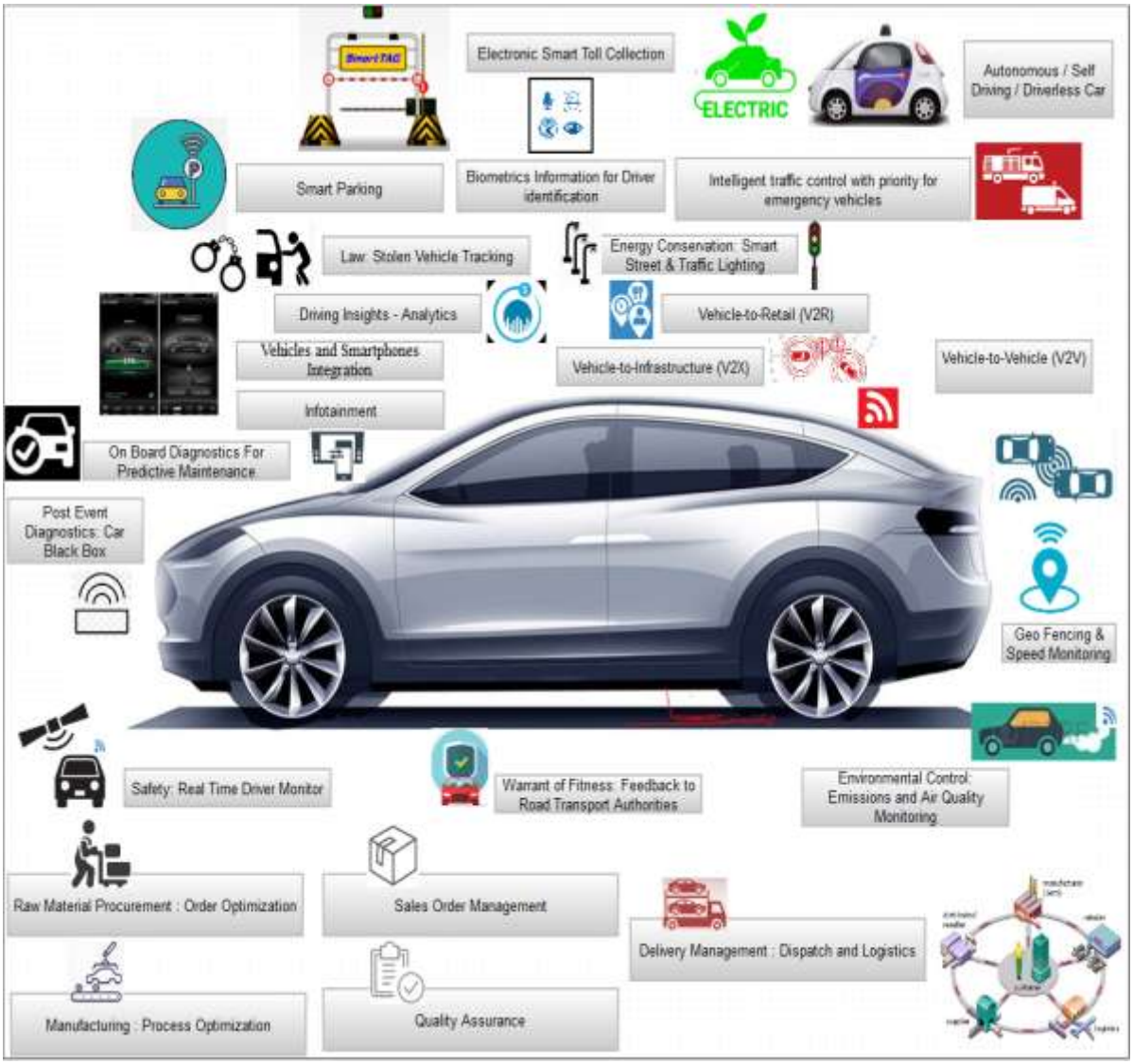


Figure 1 Developments on IoT in Automotive sector

II. Connected Car Services/Applications

*2.1*Infotainment

Infotainment refers to a system in vehicles that delivers a combination of information and entertainment [9] content/services. Typical features of an In-Vehicle-Infotainment (IVI) system are – providing navigation features while driving, managing audio/visual entertainment content, delivering rear-seat entertainment, connectivity with smart phones for hands free experience with the help of voice commands [2]. Infotainment Options should create a Safer In-Car Experience [26] helping drivers keep their eyes on the road and their hands on the wheel. Infotainment options like apps and menus need to be well organized and accessing features should be very intuitive to avoid drivers' distraction. Also, voice and audio commands needs to anchor the in-car app platform and drivers should be able to navigate menus or create messages using voice commands. Audio should be the primary way to accept commands from the users. With rapid growth in smart phone and Cloud technologies, consumers are demanding for live streaming of music and Internet radio. Ideas for advanced infotainment features integrate both user behavior and the next level of cloud based infotainment systems [29]. Some of the examples of smartphone apps integration software units are Car Play, Google Projected Mode, Mirror Link etc.

2.2Vehicles and Smartphones Integration

In today's fast-paced world, people need to be both mobile and online for most of the time with no exception when it comes to being onboard of a car or even when being the driver [31]. Using the On-Board Diagnostics OBD/OBD-II port, (which is like computer which monitors emissions, mileage, speed, and other useful data) information regarding engine and other crucial vehicle parameters can be displayed on the driver's smartphones and same can be sent to service provider for analysis [2]. Alerts related to the car like Open doors, Lights ON and Hand brake ON and performing actions on certain vehicle parts such as Lock/Un-lock vehicle doors, roll windows up/down and AC temperature +/- are becoming seamless.

2.3Driving Insights - Analytics

Smartphones sensors such as GPS, Gyroscope or Orientation sensor and Accelerometer can be used to model the driving behaviour. By mounting the smartphone in the vehicle, data from these sensors can be used to detect driving patterns such as sharp turns, sudden acceleration, hard braking, drifting and speeding [2]. This can be used to profile the driver as safe or aggressive, to rate and compare different drivers and share such data with insurance companies for customized premiums. Pay As You Drive (PAYD) and Pay How You Drive (PHYD) are the upcoming use based insurances packages [12] provided by auto insurance companies that reward safe drivers and penalize rash ones with different premiums**.**

2.4On-Board Diagnostics for Predictive maintenance

The On-Board Diagnostics (OBD/OBD-II) port is commonly used in automobile service and maintenance for self-diagnosis and reporting of any issues that may occur, or have occurred within the system [12]. Using this, information such as emissions, mileage, faults, vehicle and engine speed, engine temperature, fluid levels, gear shifts, battery status, etc. can be monitored-II is connected to the Check Engine light or MIL-Malfunction Indicator Light, which illuminates when the system detects a problem. Till now it was largely used for post-facto analysis; i.e. only when some problem arises. However, by pairing smartphones with vehicles, this information can be readily made available to the vehicle owners and service stations [2], giving them a better picture of the car performance. Monitoring these parameters actively and with some level of on-device analytics, drivers can get proactive service alerts on their smartphones and potential faults can be identified for early diagnosis and care.

2.5Safety: Real Time Driver Monitor

To encourage efficient and safe driving, drivers are screened and evaluated on driving habits. Advanced sensor based technologies to detect and monitor behaviour and fatigue levels of driver [43] are emerging which makes the cars more intelligent for avoiding accidents on roads. Systems are being developed for real time monitoring of vehicles [30] which controls the speed of the vehicle and fatigue level of the driver to prevent accidents [4]. The primary components of such a system, as shown in Fig.2, will be microcontrollers along with some sensors [44] like eye blink, gas, impact sensors, alcohol detecting sensor and fuel sensors. GPS and Google Maps API's is used to track the location of the vehicle which can sent to a predefined number in the system.

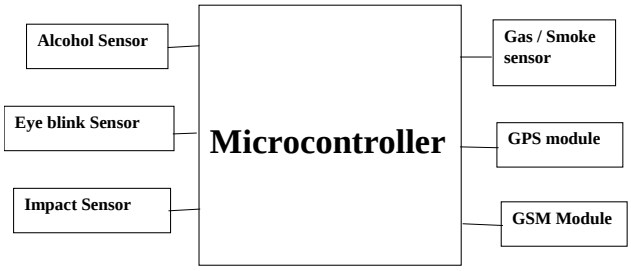


Figure 2 Real time driver monitoring

2.6Geofencing and Speed Monitoring

The geofencing and speed monitoring applications [34] can be used to inform the car owner if the vehicle has gone out of the predefined geographical area or is being driven faster than a preset threshold speed [6]. Speed of the vehicle can be measured speed sensors [45] and geofencing can be achieved with the help of GPS. This can be used for parental control or for remotely monitoring the use of company cars.

2.7Law: Stolen Vehicle Tracking

GSM and GPS based Vehicle Tracking System as shown in Fig.3 is used with a tracking device [46] which is hidden in the vehicle to monitor and track the location of vehicles [24]. Satellite signals will be received by a remotely located application server and then position co-ordinates with latitude and longitude are determined. Exact position of the vehicle can be determined from these coordinates and using the GSM system [35], owners can be notified.

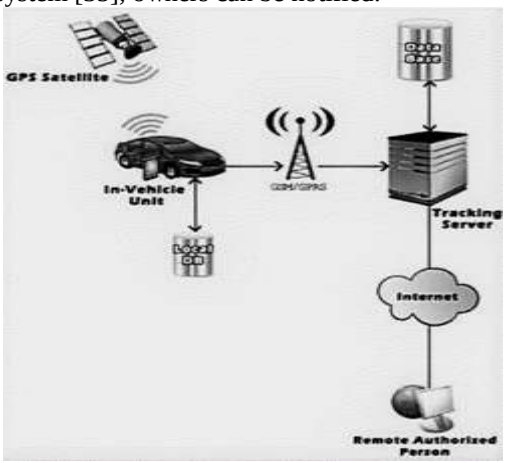


Figure 3 Vehicle Tracking System

2.8Biometrics Information for Driver identification

Biometrics refers to the physical, biological or behavioral characteristics of a person. It can be used to identify and authenticate a driver. Biometric identifiers include face recognition [6], fingerprints or voice recognition. Voice samples [12] of a driver can also be used to provide a hands free experience for navigating through the apps in a connected car environment. Biometric data can be used as a powerful anti-theft protection tool for increased safety. Cameras and sensors within the car can be useful for such biometric based driver authentication and also for comfort features inside the car by quickly changing car settings like seat position, mirror settings etc. to accommodate different driving patterns of the people authorized to use the car. Real time health parameters of a driver like pulse rate and breathing patterns can be monitored with the help of sensors attached on the steering wheel and seatbelt which in turn can be used to monitor their stress levels, other health conditions and prevent accidents.

III. Vehicle Communications

As more and more connected cars emerge and in-vehicle embedded connectivity becomes common, a whole new paradigm of vehicle communications is set to unfold.

3.1Vehicle to Vehicle (V2V*)*

V2V communication comprises of a wireless network where the vehicles send speed and location data to the vehicles near-by to prevent accidents and offer the opportunity to improve the safety of commuters significantly [2]. Each vehicle continuously broadcasts a message with the speed and position data to the nearby vehicles over an ad hoc mesh network as shown in Fig. 4.. Dedicated Short Range Communications (DSRC) [47] technology designed specifically for automotive use allows vehicles to communicate with other vehicles [12]. V2V relies on Vehicular Adhoc Network (VANET) [48] which is a wireless adhoc network of the vehicles for exchanging data.

Figure 4 V2V and V2X

3.2Vehicle to Infrastructure(V2X)

V2X communication is the wireless transmission of information between the vehicles and roadside infrastructure [32]to avoid or mitigate accidents and also to provide a wide range of other safety, mobility, and environmental benefits. The vehicles can communicate with the roads, digital signage, traffic lights, safety and control systems [2] to avoid crashes and traffic congestion [47] through intelligent safety applications. Drivers can also be made aware of various other conditions such as roadwork, diversion and adverse weather conditions. This will not only help in reducing the number of accidents and casualties but also in tracking, tracing and monitoring vehicles on the move. Even in the event of emergency, vehicles would be able to quickly intimate details to roadside assistance, emergency services like ambulance, insurance providers as well as family members.

3.3Vehicle-to-Retail (V2R)

The retail industry has been exploring the innovative use cases and presenting drivers with location-based advertising or even discount coupons while driving in the vicinity of a shopping mall. Similarly, applications to book restaurants and to place their saved 'Easy Order' from their vehicles through a voice interface are quite popular. OEMs are exploring other vehicle-to-retail (V2R) applications [7] such as Volvo has set up its Roam Delivery trial, which allows delivery companies to locate and unlock a connected vehicle to deposit an item purchased online.

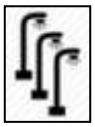
IV. Iot In Intelligent Transportation

4.1Electronic Smart Toll Collection

Electronic Smart Toll Collection system on Toll plazas is used to collect the road toll charges in a convenient manner without any traffic jams and delay. This system relies on roadside sensors such as RFID readers or Automatic number plate Recognition cameras. Another telematics based solution uses GPS [9] and cellular network to provide Electronic toll collection services. Also, smart card/tags can be used to identify vehicle details and for payment [36].

4.2Smart Parking

Traffic jams caused by vehicles is an alarming problem and is increasing day by day with the increase in number of vehicles. Lack of sufficient parking space is the main reason in this problem along with the increase in size of luxury cars. Finding a free parking space is often a tedious and frustrating task. Smart parking will optimize the use of parking space, resulting in efficient parking and smoother traffic flow. Smart parking system can be deployed with the help of microcontrollers [37], sensors, real time data about available parking space [8] and automated payment of parking charges. Such system will allow people to reserve a parking space before they actually reach that location thereby saving a lot of time and energy. This also controls the air pollution and reduces the traffic jam problems.




4.3Energy Conservation: Smart Street & Traffic Lighting

Smart or Intelligent street lighting, also referred to as adaptive street lighting, dims or switched off when no activity is detected, but brightens when movement of pedestrians, cyclists and vehicles is detected. A new, innovative and optimized traffic light system as well as street light management system will achieve significant energy saving. It will use many sensors and cameras to control and improve the efficiency of the system, presence of vehicle or person can be detected by using the presence detector (IR sensor), street light glows with full intensity for some time and then becomes dim. Also, energy-efficient LED-based streetlights [38] which consumes lower energy can be coupled with providing IP connectivity and IoT based Smart Street lighting systems. Another use of this system can be to control the traffic jams. The RFID tags [10] are used for detection of emergency vehicle like ambulance. Priority can be assigned to each lane depending upon number and type of vehicles. Green traffic light will be given for the lane having highest priority and more time than another lane. This system saves more power and provide safety on the road.

4.4Post Event Diagnostics: Car Black Box

An event data recorder (EDR) is a device for recording [6] vehicle data related to events such as an accident or a crash. Such "Black Box" technology [11] can be used as an accident investigations tool. It records vehicle data like speed, fast acceleration, heavy braking, use of

seatbelt and airbag deployment [12] several seconds before, during and/or a fraction of a second after the accident. To detect and collect the information from the vehicle, many types of sensors like proximity sensor, ultrasonic sensor, pressure sensor and temperature sensor are used. To download the data recorded using an EDR some scanning tool can be connected to the vehicle and this data can be presented in an easy to read graphical form.

4.5Intelligent traffic control with priority for emergency vehicles

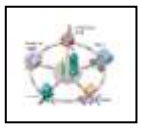
Intelligent traffic control systems in city traffic strive to give priority to selected type of users, such as public transport, VIP users, and emergency services [13]. Traffic light control system uses RFID tags attached to the vehicles. Priorities can be assigned to different types of vehicles. RF readers are installed on the road intersections considering the traffic density on the roads. On the two intersecting roads, two linked lights [14] are installed, RF reader will store the details of all the vehicles that pass from that road. For usual traffic, the traffic light controller follows the round robin sequence of the traffic lights. As an emergency vehicle such as an ambulance is detected, the controller generates the green signal for the lane with emergency vehicle, leaving the round robin sequence.

4.6Warrant of Fitness: Feedback to Road Transport Authorities

Warrant of Fitness (WoF) is a mandatory certification mark required on all LMV's (Light Motor Vehicle). It certifies that the vehicle has passed all the necessary inspections of safety. A WoF test checks the following parameters of the vehicle – [15] tyre and brake condition, lights, windscreen wipers, seat belts, doors, airbags, suspension, speedometer, exhaust, fuel system etc. To pass WoF test, a vehicle must some minimum criteria in each category. WoF is in the form of a sticker displayed on the windscreen indicating the date on which the vehicle passed its last WoF test and when it is due for the next inspection. Local car repair garages can perform this WoF test and issue WoF certificate. Traffic police can check this WoF anytime and if the WoF sticker is not found or it is expired, the driver has to pay the fine. This WoF checking can be automated using RFID based WoF stickers which can be read by RFID readers installed on roadside.

4.7Environmental Control: Emissions and Air Quality Monitoring

The problem of emission of gases from vehicles is increasing the pollution levels. Incomplete combustion of fuel is one of the main reasons of this high level of emissions. Vehicle emissions can be monitored and controlled [39] by using an IoT based system consisting of smoke and temperature sensors, along with GSM and GPS based modules [5]. Whenever the vehicle crosses the predefined threshold limit of pollution level, the system generates an alert message using the GSM module and the engine of the vehicles gets switched off automatically. To locate the position of the vehicle, GPS module can be used. Such a system can save the environment by controlling the air pollution caused by vehicles.



V. iot Based Supply Chain Management In Automotive Industry

IoT has a huge impact on Automotive Supply Chain Management. It is the interconnected network [17] which binds all the tiers of suppliers, manufacturers (OEM's), service providers, dealers, distributors and customers located at different geographical regions. Smarter Supply Chain [40] will address almost all the challenges faced by supply chain managers such as cost, changing customer demands, risk and globalization.

5.1Raw Material Procurement: Order Optimization

To gain more visibility in raw material procurement, Sensors and RFID tags can be used. Movement of material from suppliers to shop floor and throughout the assembly line can be tracked with the help of these 'smart' devices [16]. Specific automobile components can be monitored and tracked with the help of these smart tags for better customization and order optimization.

5.2Manufacturing: Process Optimization

IoT has immense potential to improve visibility in manufacturing to the extent where each unit of production can be "monitored" at each step in the production process. With IoT interconnectivity, shop floor and top floor can be connected which reduces the human intervention to monitor deviations and changes. Operating parameters [17] such as alignment, temperature, pressure etc. are periodically measured by the sensors. Any deviations beyond the preset values are controlled automatically by making adjustments in the process. Such real time visibility in the manufacturing process results in increased productivity, efficiency and reduced cost.

5.3Quality Assurance

Quality assurance refers to a systematic process of auditing and inspecting the process and product for meeting the specified requirements [18]. Quality control in all the stages of automotive supply chain is very critical to maintain the competitive edge in the market. With the increasing demand for connected cars, automotive industry is currently facing a transition in car production [19]. Connected cars are more software centric. Expertise in Software Quality Assurance will make a big difference and ensure that great software-driven connected cars are manufactured and delivered.

5.4Sales Order Management

IoT and connected products are transforming traditional sales and marketing models in automotive industries.

Products such as 'Cars' are now connected and OEM's can stay in touch with the customer through out the lifecycle of the product. This creates tremendous potential for cross-selling and up-selling. The Internet of Things is the right platform to provide such connected environment. Companies can gain detailed insights into the customer relationship by collecting and analyzing product usage information to understand how the product is performing [20], how much is it being used, which features are being used, and which features are not and accordingly providing post sale services.

5.5Delivery Management: Dispatch and Logistics

Applying IoT to dispatch and logistics operations promises a huge impact. Data Analytics plays an important role in optimizing the distribution networks. By analyzing the parameters like production time, order quantities, production cost, customer locations and delivery cost, supply chain managers can decide on the correct number of distribution centers along with their ideal locations [16]. Such use cases ensure that high service standards are maintained and thereby reducing the transportation and warehousing costs.

VI. New Generation Cars

6.1Autonomous/ Self driving/Driverless Car

An autonomous car/ self-driving car/ driverless car [41]is a vehicle that is designed to sense its environment and navigate without any human input. With the continuous developments in self-driving cars, network connectivity between the car and its environment will enhance thereby giving a whole new driving experience. The IoT powered self-driving car is in its own control once the destination is predetermined, and communicates with its environment and the on-going traffic [21]. Drivers of a self-driving cars can enjoy the freedom to make use of their phones, laptops and other devices without any fear in mind.

6.2Electric cars

An electric car is a car that is powered by an electric motor [42], using electrical energy stored in array of rechargeable batteries [9]. Electric cars are growing in popularity as an alternative to vehicles powered by petrol/diesel as they are more sustainable, cheaper, easier to maintain and more efficient [22]. Electric cars are becoming more mainstream due to the increasing availability of plug-in technology, which has allowed owners to charge their cars easily at home, and more powerful lithium-ion batteries that allow them to travel over longer distances. Recently, many countries have started offering incentives for public charging stations making long distance travel a much more economical option for electric car owners. Also, there are companies beginning to develop wireless charging for electric cars, making the charging process much easier.

Electric Cars- IoT Applications are

- Home charging solutions
- Scheduling a charging slot.
- Nearest charging station with tariff rates.
- Battery charge status with estimated driving time.

VII. Scope

Internet of Things is reshaping almost all industry sectors. Applications like Smart Home, Smart Manufacturing, Smart Healthcare, Smart City, Smart Farming, Connected Cars and Wearables amongst many others are transforming the Businesses and enhancing the Customer experience. This paper identifies the innovative applications of IoT in Automotive industry in the areas of Connected Car services/applications, Vehicle Communications, IoT in Intelligent Transportation; IoT based Supply Chain Management in Automotive Industry and New Generation Cars.

VIII. Key Findings

Table 1 summarizes the developments discussed in this paper on IoT in Automotive sector.

Table 1 - Developments on IoT in Automotive sector

Connected Car services / applications	Vehicle Communication	IoT in Intelligent Transportation	IoT based SCM in Automotive Industry	New Generation Cars
Infotainment	Vehicle-to-Vehicle (V2V)	Electronic Smart Toll Collection	Raw Material Procurement: Order Optimization	Autonomous / Self driving/Driverless Car
Vehicles and Smartphones Integration	Vehicle-to-Infrastructure (V2X)	Smart Parking	Manufacturing: Process Optimization	Electric cars
Driving Insights - Analytics	Vehicle-to-Retail (V2R)	Energy Conservation: Smart Street & Traffic Lighting	Quality Assurance:	
On-Board Diagnostics for Predictive maintenance		Post Event Diagnostics: Car Black Box	Sales Order Management	
Safety: Real Time Driver Monitor		Intelligent traffic control with priority for emergency vehicles	Delivery Management: Dispatch and Logistics	
Geo-fencing and Speed Monitoring		Warrant of Fitness: Feedback to Road Transport Authorities		
Law: Stolen Vehicle Tracking		Environmental Control: Emissions and Air Quality Monitoring		
Biometrics Information for Driver identification				

IX. Conclusion

This paper outlines developments on IoT in Automotive sector such as Connected Car services/applications, Vehicle communications, IoT in Intelligent Transportation, IoT based Automotive Supply Chain Management and New Generation Cars. As cars get smarter and connected with the other cars, smartphones and things, suitable analytical processing can be applied to the operational parameters, allowing OEM's, automobile drivers as well as road safety authorities to get better visibility about the automobile's performance as well as the overall traffic situation, allowing for timely actions.

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