**IoT in Avs**

In recent years, digital transformation has emerged as a key growth driver in several business sectors. Companies are exploring new ways of working with customers and building new frameworks of digital and autonomous systems. Such a shift towards digital transformation is even more important in urban mobility, especially to overcome the challenges due to the COVID-19 pandemic. It is estimated that by the year 2050, nearly half of the revenue from the mobility sector (> $9,000 Billion in total) will be from digital services including smart, digital finance, and shared services. The automotive industry is also adapting with this trend, North American automakers have begun to transition from their conventional role as a vehicle manufacturer to a digital system and service platform integrator, reshaping new products and services to end-users. In the past two decades, significant advancements in the area of sensing, control, high-speed computing and AI have led to development of autonomous vehicles that drive themselves without human intervention to bring benefits such as reduction of traffic accidents. However, autonomous vehicles that rely solely on on-board sensors have restrictions on sensing range and operating conditions. By integrating vehicle autonomy with connectivity significant improvement of performance can be achieved for self-driving connected car.

**What is automotive IoT?**

Automotive IoT is the integration of gadgets, sensors, cloud computing, applications, and other such components into vehicles to function as a complex system for the connection of cars, predictive maintenance, [fleet management](https://onomondo.com/resource-hub/iot-the-future-of-fleet-management/), OEMs, insurance, and more.

The integration of the Internet of Things in the automotive industry allows manufacturers to implement sought-after innovations that can ultimately transform cars into near-artificial intelligence.

As embedded automotive IoT solutions develop, more complex innovations will enter the picture. And the continual rapid advancements in the speed of mobile communications and the technology inside connected cars enable automotive manufacturers to continue to offer more new and exciting services.

According to Car and Driver, [driverless cars have multiple levels](https://www.iotforall.com/5-autonomous-driving-levels-explained/). Level 0 is a vehicle with complete human control. Level 1 refers to “driver assistance.” Some of these features are common in most cars today including cruise control.

Level 2 is partial automation. In certain circumstances, the car can accelerate, brake, and steer on its own. The driver still is completely responsible and should keep their hands near the wheel. Examples of level 2 technology are Mercedes-Benz Driver Assistance Systems, Audi Traffic Jam Assist, Cadillac Super Cruise.

Level 3 is conditional automation. When the circumstances are right, the technology in level 3 cars can do most things for the driver. This also includes examining the environment around the vehicle. But the driver should still be ready to obtain control if needed. An example of this is Audi’s Traffic Jam Pilot.

Level 4 is high automation. On the right roads and conditions, the car can operate fully without any human input.

Level 5 is Full Automation. This is self-driving to its complete potential. A fully automated car can handle any road and any condition that a human driver can. One just enters a destination, and the car will take you there. This technology isn’t currently available yet.

Demonstrated in Fig. 1, a fully autonomous driving system relies either solely on AI or the combination of it with traditional algorithms to make decisions like a human driver on tasks such as perception, path planning, and control. Nevertheless, realizing such a fully autonomous driving system is a challenging task at this moment. Current autonomous vehicles could only allow partial autonomy under certain predefined operating conditions. While connectivity could provide additional useful information for both near-real-time and extend the vehicle’s information horizon beyond the on-board sensor range. Thus, the integration of Internet of Things (IoT) ensures the vehicle could safely drive themselves under any road conditions, types of weather, and is not bound to operate in a certain area. Moreover, the emergence of future smart cities would be benefited from IoT-enabled CAVs, where driverless cars, trucks, and buses can be intrinsically connected into a CAV ecosystem, reduce traffic congestion and makes driving on roads safer.

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**The benefits of automotive IoT**

The Internet of Things has brought numerous benefits to the automotive industry for manufacturers and users alike.

For **manufacturers**, four benefits of automotive IoT include:

* Better data collection and analysis,
* A faster and improved manufacturing process,
* Reduced risks and higher industrial safety standards,
* Equipment theft monitoring, and more.

A wide range of opportunities has also become available to **car users**, including the following three benefits:

* Predictive analytics about vehicle conditions which help to reduce operating costs and improve vehicle safety,
* The ability to easily access information about and activate features of a car via a mobile app, e.g. checking fuel levels and parking location, starting the engine, and connecting to your calendar,
* Upgraded in-car infotainment experiences, and more.

**How IoT is transforming the automotive industry**

The Internet of Things in the automotive industry allows connected cars to stay in real-time continual communication with the surrounding connected ecosystem. This is making advanced innovations possible and steadily transforming the automotive industry in many different ways. The integration of IoT technologies in the automotive industry is already bringing us connected cars and smart cars, paving the way for the future of the **automotive industry**: **autonomous vehicles**.

As automation technology and artificial intelligence advance, autonomous vehicles gain traction in the automotive industry. So much so that last year [Statista](https://www.statista.com/topics/3573/autonomous-vehicle-technology/#dossierContents__outerWrapper) predicted that by 2023, the autonomous vehicle market will grow by almost 60%.

Autonomous vehicles benefit both commuters and commercial drivers. They can assist with tasks such as:

* Driving,
* Braking,
* Parking,
* Lane-changing, and more.

This not only brings a new level of user comfort but can also increase road safety by reducing human error, which leads to safer road conditions for everyone.

It also enables advances such as Robotaxi – an innovation announced by Tesla which, via a smartphone app, will enable every Tesla owner to share their car with other people during particular hours of the day. This can also have a positive impact on the environment, as it reduces the number of cars on the road and thereby also vehicle-related air pollution.

**Predictive maintenance**

Cars manufactured with IoT capabilities have embedded sensors that collect performance data on specific parts of the vehicle. They then transfer the collected information to the cloud where predictive analytics:

* Process the data,
* Evaluate the condition of individual components,
* Assess the risk of malfunction, and
* Predict when parts need to be upgraded, serviced, or replaced.

Predictive maintenance is a feature that benefits consumers industrial and commercial alike. From monitoring fleet performance to notifying the driver of any issues and advising them on potential service or repairs, [predictive maintenance improves the user experience for all](https://onomondo.com/resource-hub/connected-cars-webinar/).

**Driver monitoring system**

Through low-power in-vehicle cameras and advanced vision technologies, a driver monitoring system monitors driver behavior and actions and sends notifications to avert accidents and disasters.

An AI-based driver monitoring system includes benefits such as:

**Driver behavior analysis:** Detects driver drowsiness, rash driving, distracted driving – and even driver emotions. If the driver is e.g. drowsy or texting while driving, the system notifies the driver through SMS, visuals, sounds, or vibrations, enabling them to stay alert on the road.

**Driver position monitoring:** Assesses whether the driver is wearing a seatbelt or not, and can also be customized to detect whether the driver is seated in the optimal position for hazardless airbag deployment.

**In-cabin occupancy:** Detects cabin occupancy and notifies the driver if any passengers are missing from the cabin.

**Road condition analysis and navigation assistance**

One of the most exciting applications in automotive IoT is road condition analysis and navigation assistance. This innovation enables AI-powered smartphone applications to detect road conditions in real-time and continually update the driver with data on:

* Speed limits,
* Construction work,
* Road closures,
* Accidents, and more.

Empowered with this information, the driver can choose an alternate route to their destination. Navigation assistance facilitates this: Based on real-time road and traffic conditions, this integrated feature provides the most optimal path and helps guide the driver to their destination. This is particularly invaluable to drivers traveling via unfamiliar routes.

 The [self-driving technology details](https://www.ucsusa.org/clean-vehicles/how-self-driving-cars-work#.WwWth9MvzOQ) differ from maker to maker, but most use a series of radar lasers and high-powered cameras that map out the car’s surroundings.

Various sensors play crucial role in the self-driving car:

**1. Acoustic Sensors**

Acoustic sensors are used to collect sound, pressure and vibration data. We can call it the ears of cars. Virtually all acoustic wave devices and sensors use a piezoelectric material to generate the acoustic wave.

**2. Ultra Sonic Sensor**

The Ultra Sonic sensors are most suitable for shorter range. For E.g. for features like[auto parking](https://en.wikipedia.org/wiki/Automatic_parking). Ultra Sonic sensors uses sound waves to precisely detect objects. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. It basically detects the distance using ultrasonic waves.

**3. RADAR Sensor**

Radar technology uses electromagnetic waves in the radio spectrum frequency. It uses transmitter and receiver to transmit and receive the frequency signal. Basically it is use to measure the distance of objects over wide distances. Radar depending upon their range are classified into SRR, MRR, and LRR.

**4. LiDAR**

[LiDAR](https://iot4beginners.com/lidar-light-detection-and-ranging/) stands for Light detection and ranging. It is a method for measuring distances (ranging) by illuminating the target with laser light and measuring the reflection with a sensor. LiDAR uses lasers to create a 3D high-resolution models of the objects. Basically it uses the previous data to predict the 3-D models of the surroundings. It gives 360 degree view.

**5. CAMERA**

Camera can detect traffic signs, Traffic lights, pedestrian movement, lane markers, and temperature in case of thermal camera’s. LiDAR uses laser light to detect objects but in bad weather conditions such as fog light will not be a good solution. Camera provide a high resolution real images of pedestrians and other object which a classifier can mark as objects. These cameras are located in the side mirrors, front bumper, and below the nameplates of both sides.

Disadvantage with cameras are the light condition. In low light condition the camera doesn’t perform well.

**6. GPS**

[GPS sensors](https://iot4beginners.com/future-of-gps-with-iot/) are receivers with antennas that use a satellite-based navigation system with a network of 24 satellites in orbit around the earth to provide position, velocity, and timing information. Generally, GPS are useful in location tracking.

Diagram

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The sensors are collecting the surrounding data continuously and sending it on the cloud or to the central unit, where it processes the feedback, plots a path, and sends instructions to the car’s controls (steering, acceleration, and braking). All of this happens in just fraction of seconds. Each car is also equipped with obstacle avoidance and predictive modeling that conduct the vehicle to obey traffic rules and steer around certain obstacles.

Diagram

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It’s important to distinguish between a connected vehicle and an autonomous vehicle. A connected vehicle is one that can receive information from an outside source and/or connect with a consumer’s cellphone. Connected vehicles are already common today. For example, a car’s navigation system is connected to the GPS network. In the event of traffic or other disruptions on the road, the navigation system can plan a new route to avoid these obstacles.  
  
The next phase of connected vehicle will be advances in [V2X](https://en.wikipedia.org/wiki/Vehicle-to-everything), where X may be a pedestrian or a traffic management system in an intersection. Also known as vehicle-to-everything, V2X is the ultimate connected vehicle advance that will support automated braking of vehicles to prevent traffic accidents.   
  
[OnStar](https://www.onstar.com/us/en/support/coverage/) is another good example of a connected vehicle. In the event of an emergency, the driver can connect to a help center which can send out a tow truck or dispatch emergency services. In terms of cellphone connection, many car manufacturers already allow drivers to sync their cellphone to the car in order to use apps, play music or enable voice recognition.  
  
While OnStar and GPS are helpful services, they rely on technologies that are decades old. Even connecting a smart phone to a car’s dashboard isn’t that exciting in the grand scheme of things. The next generation of connected vehicles are going to do so much more. 5G cars will connect to 5G networks, which will not only enable ultra-fast, low-latency communications, it will also allow them to communicate with each other. For example, two 5G connected cars coming to a stop sign can agree in advance who will go through first, solving the problem that under current technology, self-driving cars tend to perform poorly at [stop signs](https://www.bloomberg.com/opinion/articles/2018-02-02/what-if-self-driving-cars-can-t-see-stop-signs).  
  
As we can see, a connected vehicle is not necessarily an autonomous vehicle. Connected vehicle technology refers to V2X advances. An autonomous vehicle is the next step, where the car does the driving, and it will ultimately rely on the integration of 5G technology in automotive systems. Some of the very first self-driving cars were not connected vehicles. They relied on radar and planned routes to navigate the roads. However, going forward most self-driving cars will be connected as there is a myriad of benefits for a relatively small cost.

**Automotive IoT eases the problems of urbanization**

The above are but a few examples of trends in **automotive IoT**. Although autonomous vehicles tend to steal the headlines, the increased use of sensors and the ADAS systems in vehicles today – e.g. automatic parking and re-routing to avoid congestion – are just as important on the journey towards a connected transport ecosystem.

Such systems are building blocks for future solutions for:

* Vehicle-to-vehicle (V2V) communication,
* Vehicle-to-infrastructure (V2I) communication, and
* Vehicle-to-everything (V2X) communication.

These are important solutions for problems of urbanization such as increasingly congested roads, busier bus systems, and packed subway carriages during rush hour.

This means that in the future, smart cities can work better as a result of the information connected cars provide, including locating available parking spaces and locating potholes to improve road surfaces and warn drivers of hazards on the road.

The promise of fully autonomous vehicles requires a high-speed 5G connection for thousands of cars, simultaneously, in a city center. While 4G is an enormous enhancement over 3G and is well-suited to most IoT applications today, true autonomous vehicles requires higher bandwidth and lower latency. To that end, many cities in America, especially larger cities like Los Angeles and New York, are [expanding their 5G coverage](https://www.lifewire.com/5g-availability-us-4155914). While these networks are not always installed to benefit autonomous vehicles in particular, 5G cars will be able to link into the new networks and take advantage of this infrastructure.  
  
[Intelligent Speed Assist (ISA)](http://www.howsafeisyourcar.com.au/Safety-Features/Safety-Features-List/Intelligent-Speed-Assist-ISA/) is an interesting technology that’s likely to play a part in the development of the autonomous vehicle. With ISA, a GPS system determines the vehicle’s speed and then cross-references that to a map with known speed limits. In the event that the car is exceeding the speed limit, the ISA system can warn the driver or possibly (depending on how ISA is set up), even slow the vehicle down. In terms of autonomous vehicles, a map with speed limits incorporated into it will be essential. While machine learning and AI will enable self-driving cars to read speed limit signs, the signs may not be prevalent enough to keep the vehicle informed. Some small towns have very few signs, and in other places signs may be disfigured or missing.  
  
Another interesting technology that’s already being used in today’s cars, [like BMW](https://www.bmw.com/en/innovation/the-main-driver-assistance-systems.html), is lane assist. A car can use GPS data, cameras and/or radar to determine the vehicle’s location on the road and keep it in the appropriate lane. This technology will continue to be refined and will one day lead to an autonomous car that can stay in its lane at any speed and in any driving condition. Fully developed lane assist driving will make cruise control look like a well-trained horse that always trots at the same speed.  
  
In the meantime, as the pieces fall into place for integration of 5G in automotive applications, connected vehicle technology is being deployed today. Digi is working with departments of transportation and Intelligent Transportation Systems (ITS) groups to install the mission critical communications infrastructure for connected vehicles today, so that smart cities are prepared for tomorrow.

In future smart cities with numerous IoT-enable CAVs an effective IoT platform is essential for best functioning of connected vehicle ecosystem. Fig. 2 shows a schematic diagram of such an ecosystem. As shown in Fig. 2, vehicle components such as sensors, in-vehicle infotainment (IVI) module, and individual electronic control units (ECUs) like those of suspension and powertrain are all connected with a centralized ECU, which collects and processes the data as well as shares the data with IoT platform utilizing gateway and communication modules. From the IoT platform, data is exchanged between the smart city data center and 3rd party partners to increase the customer’s experience.

Timeline

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**How 5G Will Enable Autonomous Driving**

As we've discussed, one of the key features of 5G is that it will allow cars to communicate with each other. This will open up the possibility of data sharing, from current speed and destination to previous road conditions. A car heading in one direction will automatically share data with a car heading in the opposite direction.  
  
Cars will coordinate at stoplights and stop signs. Drivers running red lights will become a thing of the past. In the long term, several decades down the line, we could find that stoplights and stop signs are eliminated altogether as driverless cars can coordinate their actions without a sign or signal. Traffic jams will be reduced or eliminated as self-driving cars can drive in closer proximity to each other. Also, autonomous cars don’t slow down to rubberneck.  
  
5G cars will also pick up on the signals being sent by 5G phones in pedestrians’ pockets. This will be one way that autonomous cars can avoid hitting people at crosswalks or intersections. Even in the event where a car’s radar and cameras can’t detect a person, they’ll detect the signal coming from their phone. 5G-enabled autonomous cars will also be able to connect to a city’s smart grid network in order to locate available parking, access services and other benefits we may not have imagined yet. For example, maybe school buses, construction vehicles and ambulances will broadcast their locations so that self-driving cars can redirect their course.

*Hands On Exercises to follow:*

<https://www.youtube.com/watch?v=76cptRVjsiA&list=WL&index=5&ab_channel=XiLiRTechnologies>

<https://www.youtube.com/watch?v=3KJSQeCoBGI&list=WL&index=6&ab_channel=svsembedded>

<https://www.youtube.com/watch?v=DIVAkjSbEoQ&list=WL&index=4&ab_channel=NevonProjects>