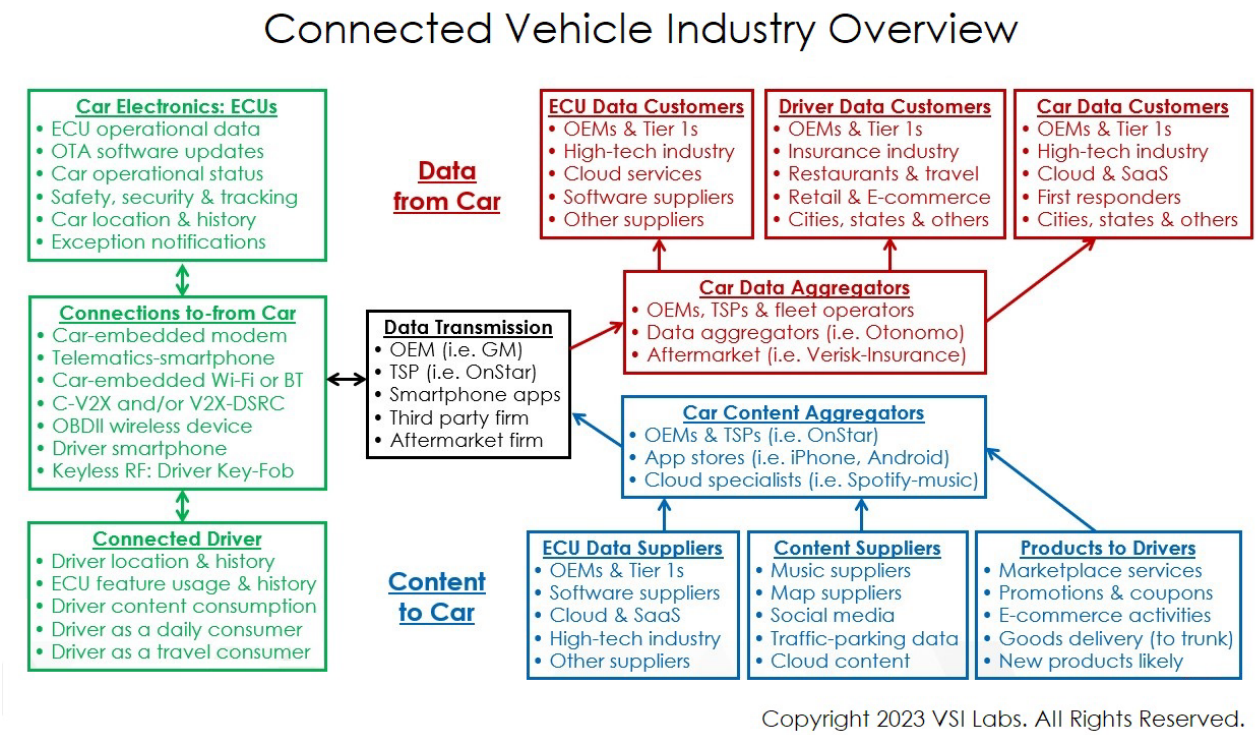
Connected Car Roadmap: Technologies & Applications

Introduction

The connected car roadmap started over 25 years ago with OnStar's first deployment in1996. Today, nearly all vehicles sold in the U.S. are connected. The early telematics vehicles were primitive compared to current technology, and there is much more technology and functionality on the way in the next decade. This whitepaper will explore what is emerging and what other future innovations may happen.

An Overview of the Industry

Today's connected vehicles have come a long way from their telematics roots and are quite complicated in terms of technology, infrastructure, suppliers, data, and content. The next figure is a simplified version of how the connected vehicle industry is organized..



The three green blocks on the left show the two segments that need connections—the driver and the car electronics or the ECUs plus the connection technologies to and from the cars.

The middle black box shows who manages the data transmission to and from the car. The red blocks show the customer segments for the data from the car. The blue box indicates the supplier segments for contents to the car. This is a simplified picture.

The data from the car has three segments. Organizations that use and/or buy ECU data are probably the biggest category. Organizations that want driver data are growing with insurance companies at the top of the list.

Content providers also have three segments. ECU data providers is again the most important one due to the growing need for OTA and cybersecurity updates. Content suppliers are also growing as infotainment consumption will increase.

Wireless Technologies

Communication technologies have had the biggest impact on connected vehicles. This started with broadcast information, which has gone from AM to FM and digital radio, with satellite radio thrown in the mix.

Satellite signals for determining the location of vehicles have also grown in importance and variety. There are now four separate systems—GPS, Glonass (Russia), Galileo (Europe) and BeiDou (China).

Short-range wireless technologies have gone through multiple generations. Wi-Fi is becoming the most important of these, and will see increasing use for OTA software updates, while Bluetooth is important for connection to smartphones and other mobile devices. Keyless RF or Key FOB is another short-range wireless technology commonly used to open doors. V2X-DSRC technology also falls into this category but will be discussed more later.

Cellular systems started with 1G, or Analog, and later 2G. Next came 3G, which has now been phased out like its predecessors. 4G remains dominant in automotive today, while 5G leads in smartphones but is just emerging in automotive.

Another technology that could impact automotive communication is low-earth orbit (LEO) satellites, which provide broadband services. SpaceX's Starlink service launched in 2019, and Amazon is developing a system called Kuiper. Future use in autos is likely but will need smaller antennas and lower prices.

5G Technology

5G cellular technology is now well established in the smartphone industry. The first 5G smartphones appeared in 2019 and are now standard for new purchases. Deployment

of new generation of cellular technology in the auto industry has traditionally lagged phone industry by three to four years, and this is the case for 5G as well.

5G networks use cellular technology with base stations at each cellular node. The 5G standards are published by 3GPP or 3rd Generation Partnership Project. The first standard was published in 2018, and three more releases are planned before 2024.

FR1 vs. FR2

5G operates in two distinct frequency segments called FR1 and FR2. The FR1 frequency band is most important to the automotive industry. Cellular systems using FR1 transmit data between 410 MHz and 7,125 MHz (7.125 GHz). On the other hand, FR2 operates at much higher frequencies between 24.25 GHz and 71 GHz. These high frequencies allow for high 5G speed, but with a low transmission range. This means FR2 will primarily be used inside buildings and high-density areas.

A portion of FR1 is called Sub-6, which uses frequency bands below 6 GHz. This is currently where most 5G is operating. The higher frequency portion of FR1 has 5G speed up to 1,000 Mbps or 1 Gbps. The FR1 Sub-6 maximum speed is currently 100 Mbps, but may increase in future 5G standards releases.

5G has other advantages for the auto industry. Low air latency of 8-12 milliseconds is important for real-time applications, and C-V2X can leverage this feature. 5G will also have a very low bit error rate due to the use of adaptive modulation and coding scheme (MCS). If the error rate crosses a low threshold, the transmitter will switch to a MCS that is less error prone. This means speed is sacrificed to gain a lower error rate.

Automotive Deployment

China is currently the leader in deploying 5G in the automotive industry. They have strong government support and lead in deployment of 5G base stations and related infrastructures. Both the U.S. and Europe have been slow in deploying vehicles with 5G technology, which has been further delayed due to the pandemic. The first 5G vehicles were introduced in the U.S. in 2022 by BMW and other OEMs. More introductions are expected in 2023, and volume deployment is expected by 2025.

Where is V2X Going?

In the last 5+ years, V2X has become a battle between two competing approaches: DSRC vs C-V2X. DSRC history dates back to the1990s when the FCC allocated 75 MHz of bandwidth for ITS safety applications using frequencies from 5,895 to 5,970 MHz. In 2014, it looked like the U.S. would pass a mandate for all vehicles to be fitted with DSRC, but this effort failed. In 2020, the FCC lowered the available frequency to 5,895-5,925 MHz.

On the other hand, advances in cellular technologies allowed V2X capabilities to be added to the 4G LTE standard in 2014, which was tested a few years later. C-V2X capabilities were added to 5G standards in 2018.

Use-cases are similar for both technologies. DSRC was built for ITS functionality and has better capabilities in this domain. C-V2X can leverage the smartphone ubiquity for better capabilities for vulnerable road users like pedestrians and bikers. But in spite of their similarities, the technology foundations are completely different for these two V2X approaches. DSRC was built for ITS and vehicle safety applications. Its name—dedicated and short-range—provides rapid response and real-time functionality.

The cellular technology that came about in the late 1990s was a mixture of analog and 2G. Since then, it has come a long way and V2X capabilities were added in 4G standards in 2014 for future use, but with limitations compared to DSRC. The C-V2X capabilities in the 5G standard are improved with PC5 as an important element.

PC5 improves C-V2X as it allows direct communication between C-V2X devices without going through a base station. This provides much lower latency, which is needed for real-time communications like C-V2X.

Overall, the outlook for V2X favors C-V2X as its momentum on a global basis is far ahead of DSRC V2X. Currently, most OEMs and suppliers support C-V2X.

Growing Importance of C-V2X

5G and C-V2X are on a path to be an important future automotive technology. Testing of C-V2X was done with 4G technology, but volume deployment is coming with 5G. A key organization driving much of the C-V2X is 5GAA, the 5G Automotive Association.

Many other companies are in support of C-V2X, including tech giants like Apple, Baidu, Cisco, HERE, LG, Microsoft, Softbank, Sony and Tencent. The chip companies are also onboard, including Autotalks, Infineon, Intel and Qualcomm. As expected, most major cellular network companies are participating as it will be another revenue opportunity.

C-V2X Use-Cases

5GAA lists seven categories of use-cases: safety, automated driving, operation, convenience, platooning, traffic, and society. The automated driving category has by far the largest number of use-cases. 5GAA is clearly planning for the future of AVs. The takeaway from the C-V2X use-cases is that it can and will improve the safety of ADAS and AVs over the next decade.

LEO Satellite Potential

LEO (Low Earth Orbiting) satellites have the potential to become a communication link for connected vehicles in the next decade. As mentioned, the two leaders are Starlink, which is deployed in many countries, and Amazon Kuiper, which is still in development. There are other players, but these two companies have the most resources.

SpaceX launched its first Starlink satellites in 2019 and currently has over one million customers in over 50 countries. They operate nearly 4,000 satellites that orbit about 340 miles above earth, which gives a short signal latency of around 25 milliseconds.

Its second-generation satellites will be launched later this year. SpaceX recently announce an upcoming partnership with T-Mobile to deliver text messages to T-Mobile customers in areas with no cellular services in the U.S.

There is limited information on Amazon's Kuiper as customer services will not launch until the end of 2024. The use-cases are similar to those of Starlink—global broadband access with initial focus on remote locations with limited internet access.

Amazon got its FCC license in 2020 and must have over 50% of its satellites in orbit by July 2026. Protype satellites will be launched in 2Q 2023. They will orbit between 590 and 630 Km above earth. Amazon will work with multiple companies to launch its satellites including United Launch Alliance, Arianespace and Blue Origin.

Summary

Connected vehicle technology has advanced tremendously in the last decade and will continue to improve. The big disruptions that are changing the industry, software-defined vehicles, autonomous vehicles, and battery EVs, all need more connectivity and data than previous generations. As AVs get in volume productions in a decade or so, the content consumption will blast off as drivers become passengers.

About VSI Labs

Since 2014, VSI Labs has been tracking the ecosystem for ADAS and automated driving. Our industry insight is based on our own hands-on vehicle research. VSI Labs has tested and evaluated many of the leading HW and SW components including sensors, algorithms, connectivity solutions, and accelerating computing.

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