REPORT EXCERPT

The following is an excerpt from an independently published 451 Research report, "Internet of Driving Things" released in September 2020.

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The Internet of Driving Things

How Connectivity Is Transforming the Automotive Market

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Widespread vehicle connectivity has the possibility to fundamentally transform the automotive industry by shifting it from a one-time sales model to an ongoing platform for future revenue, bringing with it new safety and convenience features for consumers.

About the Authors

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As Research Director of the Internet of Things practice for 451 Research, a part of S&P Global Market Intelligence, Christian Renaud covers the ongoing virtualization and digitization of the physical world around us.

For 25 years prior to joining 451 Research, Christian built nationwide networks at large and small enterprises, worked with Fortune 50 companies in the systems integrator channel, built products at Cisco Systems and ran the company's New Markets and Technologies team. He has been the CEO of multiple startups, worked in venture and angel capital, and has served as an advisor to G20 and European Commission projects.

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Executive Summary

Introduction

Consumer automobiles are rapidly becoming connected computing devices. This is fundamentally changing the automobile purchase process, how often and where vehicles are serviced and the traditional paradigm that a consumer will buy one version of an automobile that will persist throughout the ownership period, versus an ever-changing platform for new features and upgrades. Connectivity between the vehicle and the cloud, local infrastructure such as traffic signals and other vehicles will bring new levels of convenience, efficiency and safety to consumer automobiles.

Automotive connectivity is one part of a broader fundamental set of changes impacting the automotive industry. These changes are encapsulated in the auto industry term 'CASE,' which stands for connectivity, autonomy, sharing and electrification, and have far reaching implications ranging from how consumers use transportation to how automakers configure manufacturing and supply chains. We discussed a number of these changes in our previous reports *Navigating the Autonomous Vehicle Market* and *The Changing Automotive Industry: Smarter, More Connected and Increasingly Autonomous*, and the rate of change has only accelerated in the industry in the intervening time.

The changing nature of personal mobility, with alternate options such as ride sharing, spot rentals, subscription programs and increasing urbanization (and the resulting access to mass transit), is challenging the traditional individual automobile ownership paradigm. The industry is also being altered by the evolution of advanced driver assistance systems (ADAS) – from passive alerting to actively taking control of the driving function as in the case of automatic emergency braking (AEB) – dictating partial automation, sometimes by way of government safety regulations. These ADAS features are increasingly dependent on external inputs such as navigation or traffic data that require connectivity. The final change impacting the industry is electrification, in the form of hybrid electric and battery electric vehicles. These vehicles, more so than their internal combustion engine (ICE) counterparts, have computationally complex architectures with built-in connectivity components.

Connectivity itself is changing from early GM OnStar concierge applications to far more elaborate cloud-assisted driving functions. In this report, we discuss the continuum from infotainment to V2X (a catch-all acronym that encompasses vehicle to infrastructure [V2I], vehicle to cloud [V2C], vehicle to vehicle [V2V] and vehicle to pedestrian[V2P]), regulations surrounding vehicle connectivity, benefits of connectivity to consumers, dealers and auto manufacturers (OEMs), security challenges and the opportunities for secondary use of the data generated by the large fleet of 'rolling sensors.'

Methodology

This report is the result of multiple years of consumer surveys looking at the evolving relationship between consumers and their automobiles, as well as dozens of meetings with automobile manufacturers, tier one and tier two suppliers, and technology firms that provide components of current and future connected cars. In addition, 451 Research has performed custom research projects which include quantitative surveys of companies within the automotive industry (OEMs, tier one suppliers, etc.), some of the insights from which are included within this report.

Reports such as this one represent a holistic perspective on key emerging markets in the enterprise IT space. These markets evolve quickly, though, so 451 Research offers additional services that provide critical marketplace updates. These updated reports and perspectives are presented on a daily basis via the company's core intelligence service, 451 Research Market Insight. Forward-looking M&A analysis and perspectives on strategic acquisitions and the liquidity environment for technology companies are also updated regularly via Market Insight, which is backed by the industry-leading 451 Research M&A KnowledgeBase.

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2. The Evolution of Vehicle Connectivity

While there have been telematics gateways in commercial vehicles since the 1980s, consumer vehicle connectivity was commercialized primarily with the mid-1990s launch of OnStar, a cooperative venture between General Motors (GM) and Motorola Automotive (which was sold to Continental AG in 2006). GM OnStar presciently anticipated that the most important features for vehicle connectivity would focus on safety and security and would be able to alert a call center in the event of an accident. Connectivity in vehicles evolved with the technology, from 2G to 3G/edge applications such as remote diagnostics to 4G/LTE applications such as constantly updating navigation and bidirectional exchange of data and models for ADAS.

All major automakers now have multiple tiers of vehicle connectivity service subscription offerings, ranging from safety and security to entertainment and convenience, with the high-end offerings typically including a human concierge to assist with reservations and recommendations, similar to second-generation OnStar services. A subset of OEMs also have (4G/LTE) Wi-Fi hotspot offerings within the vehicles, although the consumer adoption rate on these services remains low as it requires an additional cellular subscription on top of a consumer's existing cell phone plan (which may offer its own hotspot capability at no additional charge).

This is not to conflate consumer adoption of connectivity services with connectivity embedded in the vehicle itself. OEMs embed vehicle gateways in most of their manufactured vehicles for their own purposes, to determine location and vehicle status for reasons articulated further in Section 4, as do OEM-sanctioned dealers, third-party sellers, insurance companies, rental agencies and companies that provide corporate cars. This connectivity may leverage the same vehicle gateway (referred to as a telematic control unit [TCU]) and network connection/contract as the consumer-facing services, or may operate independently such as an onboard diagnostic port (OBD-II) plug-in device to profile driving behavior for usage-based insurance (UBI).

The sophistication of both current TCUs and onboard computing in vehicles – which evolved in parallel with connectivity from compute-constrained electronic/engine control units (ECUs) to robust platforms such as NVIDIA DRIVE and Intel Mobileye EyeQ – foreshadows the future of the connected car in the 5G and autonomy era. Previous automotive architectures consisted of a distributed array of ECUs throughout the vehicle, typically performing a single function or serving a specific subsystem. More recently, these ECUs are consolidating into fewer, more computationally complex systems, working in orchestration with centralized domain controllers, CPUs and GPUs. This has, in turn, driven the deployment of greater connectivity within the vehicle, including in-vehicle Ethernet.

With more available bandwidth and compute on board the vehicle, OEMs have discovered that they can more economically maintain the code on the vehicle (avoiding costly dealer service charges) *and* upsell additional services to current vehicle owners to create an ongoing revenue stream. Given the low single-digit margins standard within the automobile industry, the appeal to OEMs for an ongoing revenue stream from sold vehicles is strong. One example of this capability in use today is from Tesla, which allows in-app purchases of additional features of the car, such as Autopilot and Full Self Driving.

Over-the-Air Profits

This ongoing revenue stream is enabled by over-the-air (OTA) updates to vehicle software. OTA is also not a recent invention, but the sophistication and security of current OTA systems from vendors such as Airbiquity is a foundational component to the ongoing upgrading of connected cars. OTA, as the name implies, enables automakers to send new code to a vehicle via a cellular or Wi-Fi connection. This benefits the automaker through the ability to address safety or performance issues it may have overlooked in the initial code, while avoiding the typical remediation step of a costly trip to a dealer for a technician to manually update the code.

One example of this capability in action was in 2018, when Consumer Reports published a critical assessment of the braking distance of the Tesla Model 3. One week later, Tesla pushed an OTA update to its Model 3s that improved the antilock braking system software, resulting in a revised recommendation from the publication.

In addition to addressing performance issues such as the Model 3 braking system example, OTA will prove to be an essential tool to protect the newly expanded attack surface that fleets of connected vehicles represent to potential hacking attempts. As attacks evolve with new devices and capabilities, OEMs will need to be vigilant in constantly updating increasingly complex software to protect vehicle owners. Volkswagen stated in its 2017 annual report that a modern VW had 10 times more software than a smartphone, and that “in just a few years, this will increase to a factor of 20 to 30.” Hackers that are able to exploit flaws in vehicle software could strand thousands of vehicle owners until paid a bounty by the automakers.

Vehicle to Everything

Beyond OTA software updates, infotainment, and real-time traffic and navigation, the next frontier in vehicle connectivity is V2X – a technology that helps cars communicate with other vehicles, roadway infrastructure and pedestrians. The technology has several subclasses including V2V, vehicle-to-motorcycle (V2M), V2I and V2P.

Where sensors such as LiDAR and cameras are critical for helping cars perceive their *visible* surroundings, V2X provides full 360-degree awareness, enabling cars to see what LiDAR and cameras cannot, such as a pedestrian around the corner of a building who is about to cross the street. It is for this reason that V2X is often regarded as a key enabling technology for self-driving vehicles.

The primary purpose of V2X technology is to increase safety; however, there are several motivations for deploying V2X. For instance, the technology can facilitate automatic toll and parking payments. It can be used to increase road efficiency and capacity through 'platooning,' a driving method in which a large number of vehicles drive close together. And it can be used by infrastructure providers and municipalities to reduce congestion and increase environmental friendliness.

There are two competing V2X technology standards: dedicated short-range communication (DSRC) and cellular (C-V2X). DSRC is based on the IEEE 802.11p standard and has been the industry standard for over a decade. Toyota was one of the first OEMs to deploy V2X technology, equipping certain Toyota and Lexus models in Japan with DSRC technology in 2015. In recent years though, the company has shifted away from DSRC technology, a move reflective of the changing tide in the industry.

As cellular technology has improved, many have come to view C-V2X as the superior standard. Toyota had initially planned to install DSRC technology in its US vehicles by 2021, but abandoned those plans in April 2019. The company cited a range of factors, the main one being not enough commitment to DSRC from peers in the automotive industry or the FCC. Toyota's decision to reverse course on V2X aligns with Ford's perspective; in January 2019, at CES in Las Vegas, Ford announced plans to deploy C-V2X in *all* US models by 2022.

There is one key regulatory development worth noting. Ever since DSRC was rolled out in the late 1990s, the FCC has allocated 75 MHz of the 5.9 GHz band to DSRC. In December 2019, the FCC decided to alter the allocation and break up the 75 MHz: the lower end of the spectrum will be dedicated to DSRC; the upper part to C-V2X; and the FCC is currently deciding what to do about the remaining 10 MHz in the middle of the spectrum. The FCC cites low DSRC adoption as the chief reason for breaking up the band. Previously, no spectrum supported C-V2X deployments.

The 5G Automotive Association (5GAA), a global automotive industry consortium backed by companies such as BMW, Audi, Daimler, Qualcomm and Nokia has supported this regulatory change since early 2019, while the Wi-Fi Alliance, an organization that promotes Wi-Fi technology and certifies Wi-Fi products, has resisted. In the end, the 5GAA got their way. The upshot of the FCC's decision is that Qualcomm, Nokia, Ford and other companies that have long touted the advantages of cellular can finally begin to deploy C-V2X technology in the real world.

Competition is strong in the V2X space with many companies involved, large and small. Qualcomm, Continental, DENSO, Aptiv, Nokia, Ericsson, and Samsung are the leading companies pushing for C-V2X deployments, while on the DSRC side, NXP Semiconductors is the leader. Autotalks has raised the most capital among startups building V2X technology and real-world hardware deployments, but there are several other notable startups including Cohda Wireless, which recently announced a partnership with u-blox; Commsignia, which debuted roadside units in January that can support both C-V2X and DSRC; HAAS Alert; Savari; Connected Signals; Veniam; Valerann; and Iteris.

3. Consumer Demand for Connectivity

Figure 4: Top-Two Box Importance of Connected Car Features

Source: 451 Research's Voice of the Connected User Landscape: Endpoints & IoT, Population Representative Survey, Q3 2020
Q. How important were each of the following capabilities in your decision to purchase/lease your vehicle?
Base: Respondents who have [capability] available with their connected car service

FEATURE	TOP TWO BOX IMPORTANCE
Roadside assistance (n=58)	97%
Speed alerts (notification if vehicle exceeds predefined speed) (n=36)	97%
Traffic and road condition alerts (n=46)	96%
Navigation (GPS) (n=56)	93%
Service/maintenance alerts and scheduling (n=50)	92%
Geofence (notification if vehicle leaves predefined area) (n=26)	92%
Stolen vehicle locator (n=54)	91%
Remote start (n=53)	91%
Recall notifications (n=34)	91%
Automatic crash response (n=52)	90%
Low fuel warning (n=53)	89%
'Find my car' parking location reminder (n=55)	89%
Concierge services (e.g., recommendations, dinner reservations) (n=27)	89%
Medical emergency response (n=48)	88%
Remote lock/unlock (n=54)	85%
Mileage tracker (trip odometer) (n=49)	82%

4. Benefits of Connectivity

There are multiple constituencies that benefit from vehicle connectivity beyond the customer-centric features highlighted in Figure 4. This section reviews the advantages of connectivity for automakers, dealers, insurers and rental car agencies.

OEMs

Manufacturers of automobiles have more to benefit from vehicle connectivity than any other constituency, possibly even exceeding the benefit for consumers themselves. This begins with knowing the disposition and location of the vehicle fleet, which sounds rather simple but yields considerable value. Additional benefits of connectivity include:

- Identifying precise locations for recall notifications or critical service requirements.
- Monitoring vehicle performance based on usage in various conditions (in heat versus cold, or at high elevations versus sea level) and duty cycles to incorporate these learnings into vehicle improvements (continuous process engineering).
- Targeting dealer-mechanic training programs for new models where new models are in operation versus rolling out regional, national or global training programs at considerable cost in areas where the new models have not yet penetrated, in addition to implementing 'just in time' training.
- Deploying constant security updates to vehicle software/firmware. Connected vehicles represent an attractive attack surface to hackers, and OEMs will need to remain vigilant to constantly patch security vulnerabilities to avoid high-visibility security incidents that could impact brand reputation and potential safety issues for drivers.

Perhaps the most promising benefit from the combination of new vehicle architectures (ECU consolidation, domain controllers, embedded CPU/GPU capability, pervasive sensors, electrification) is enabling an ongoing revenue stream to the OEM in the form of new features being enabled into deployed vehicles. Leveraging connectivity, OEMs can update software/firmware on the vehicle with new features based on customer subscriptions or one-time payments. Examples of features that could be sold post-sale could include:

- Range extension to battery electric vehicles, either temporarily (family vacations) or permanently.
- Unlocking higher degrees of autonomy, such as point-to-point navigation
- Selling temporary or permanent performance improvements to owners, including the ability to simulate torque/horsepower profiles of classic vintages of the same automobile

This would further benefit OEM lease programs that bundle routine vehicle maintenance in flipping the model from one that prescribes maintenance at specific intervals (i.e., every six months) to one based on vehicle usage patterns. Vehicles that are seldom driven would only be serviced as needed, and heavily utilized vehicles (such as ride share vehicles) would require more frequent servicing. This would result in reduced cost of maintenance by dealers to the OEM and therefore higher margin in the lease bundle.

The opportunities for cost savings and incremental revenue post-vehicle-sale opportunities are compelling enough for OEMs to embed TCUs into vehicles and enable wholesale cellular contracts even without the subsidy of paid consumer connected services contracts.

Dealers

Dealers are similarly low-margin businesses and depend on margins from financing and additional add-ons. Leveraging connectivity opens opportunities to stock parts only for models in operation within a specific radius of that dealer, lowering inventory costs and increasing utilization. Paired with repair data correlated with models, more precision is possible for dealers and OEMs to stock parts in anticipation of repairs to nearby vehicles based on actual usage (e.g., when model XYZ reaches 50,000 miles, have a replacement air filter assembly in stock as this is when they typically require exchange).

In addition, usage data is a valuable input into marketing campaigns. Vehicles sitting unused can be targeted for purchase and resale, and marketing campaigns can be customized for owners of high-usage vehicles to swap out for new models. For buy-here/pay-here aftermarket dealers, sale contracts frequently include prohibitions against vehicles leaving a geographic range in the event that a purchaser misses excessive payments and the vehicle needs to be repossessed. Embedded connectivity built into the vehicle can be leveraged by aftermarket dealers more extensively than easily removed OBD-II tracking dongles such as Bouncie and presents another potential revenue opportunity to OEMs that license access to the data to these dealers.

Insurers

UBI is already revolutionizing the automobile insurance market by empowering insurers to break free from static tables of risk and instead leverage data from the location, speed and frequency of the use of vehicles, enabling them to provide insurance rates commensurate with the actual utilization of the vehicle. Driving styles can be inferred from rapid acceleration, speeding, braking and destinations and opens visibility into which drivers in each household are using which vehicles most frequently.

Precise location and usage information also allows insurers to correlate accident and crime data to geographies, contextually rich information that could represent a secondary data licensing opportunity to rental agencies, for example. Additionally, insurers are now leveraging connectivity paired with accelerometers to determine severity and direction of impact in traffic incidents, and to also determine based on the data if the insurer needs to dispatch a claims adjustor, or even ‘total’ (mark down entirely) the vehicle based on the severity of impact and other telemetry such as airbag deployment.

Rental Agencies

Rental car agencies have numerous business challenges that connectivity will help ameliorate. As with all businesses, inventory levels (number of cars vs. demand) is a key metric and constitutes the vast majority of the debt held by these firms. Having a leaner inventory risks a ‘stock out’ situation where customers cannot rent due to lack of inventory and potential loss of business to a competitor, so visibility into when vehicles are being returned, and expediting the cleaning and fueling (turning) of these vehicles, can allow rental agencies to keep leaner inventories by avoiding unnecessary downtime.

In addition, many international agencies have implemented contract conditions where rental cars may not be driven in specific areas (such as high crime areas, or areas known for a greater quantity of traffic incidents) without the renter incurring an additional fine. By geofencing the car, the rental agencies can insure compliance with these conditions on the part of the renter, identify when cars leave the geofenced area, and also provide a ‘breadcrumb trail’ of where the car has been driven in the event the agency receives a traffic citation and needs to correlate it to a renter.

5. Conclusions

OEMs have many compelling reasons to include basic connectivity in vehicles for the benefits afforded to them enumerated above, and also are heavily incentivized to have customer-desired features to attract owners to paid connectivity plans to subsidize the ongoing cost of the connectivity. While customer benefit is certainly important, the value of persistent connectivity benefits the entire value chain from OEMs and dealers to rental agencies and insurers and creates a number of attractive data licensing opportunities for OEMs.

The small number of connectivity-enabled ADAS will grow to include features that are integrated into the driving process, improving overall safety and mitigating traffic with V2X communication with road infrastructure, traffic signals, pedestrians and other vehicles. It will also enable a far more dynamic and secure automotive market where new features and capabilities are deployed OTA as part of the warranty or as sold upgrades by the OEM after the original vehicle sale. This ongoing revenue opportunity will catalyze a wave of innovation for features between automakers as they seek to differentiate themselves and ultimately benefit both customers (new convenience and safety features) and OEMs (ongoing revenue stream) alike.

There is ample road between today and this future however, with 5G and V2X infrastructure rollouts required to interface with to-be-designed connected cars. This market trajectory could be impaired by misguided attempts by tier one suppliers and OEMs to develop proprietary implementations that only work within their own vehicle fleet, or over-rotating on too many features and data too soon, potentially falling afoul of data privacy regulations and incurring a disproportionate regulatory response. Interoperability, level-headed regulation and the marketing of the benefits of these capabilities to consumers will take time to develop but will ultimately reshape the automotive industry.

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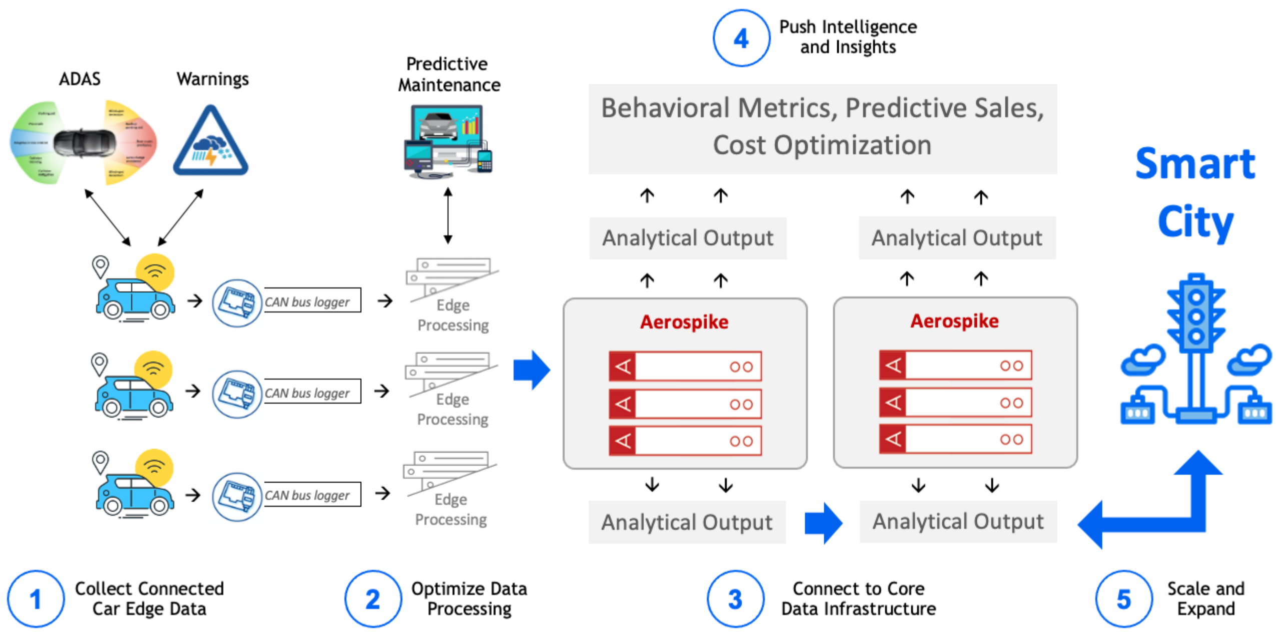
Great IoT Starts with a Great Database

Data collection and management is at the heart of the growing connected vehicle opportunity. Aerospike's next-generation NoSQL data platform optimizes data across every facet of the connected vehicle ecosystem, managing data in the ingest system, assimilating data quickly in edge devices, and scaling to support millions of connected vehicles.

Aerospike's flexible data architecture can be adapted to any edge network, helping drive large scale IoT adoption and generating business benefits more quickly. The platform scales without losing performance, making it easy to expand ADAS and other edge and analysis systems to connected vehicle infrastructure as the market evolves. Aerospike pushes the intelligence derived from connected vehicle data to wherever it's needed, moving data seamlessly and at extremely low latency across the connected vehicle ecosystem, including smart city infrastructure to help manage traffic patterns and safety challenges.

AEROSPIKE IS THE BACKBONE OF THE CONNECTED VEHICLE ECOSYSTEM



Key Capabilities and Benefits

- Boost confidence in mission-critical advanced driver assistance systems (ADAS)
- Improve diagnostics, predictive maintenance and scheduling for test systems
- Deliver immediate external road safety and environmental conditions
- Connect vehicle-to-infrastructure and vehicle-to-vehicle communication
- Capitalize on a marketing and monetization opportunity based on onboard user data

For more information, please visit www.aerospike.com/smart-car/.