WHITE PAPER

Enabling the Connected Vehicle Market to Thrive

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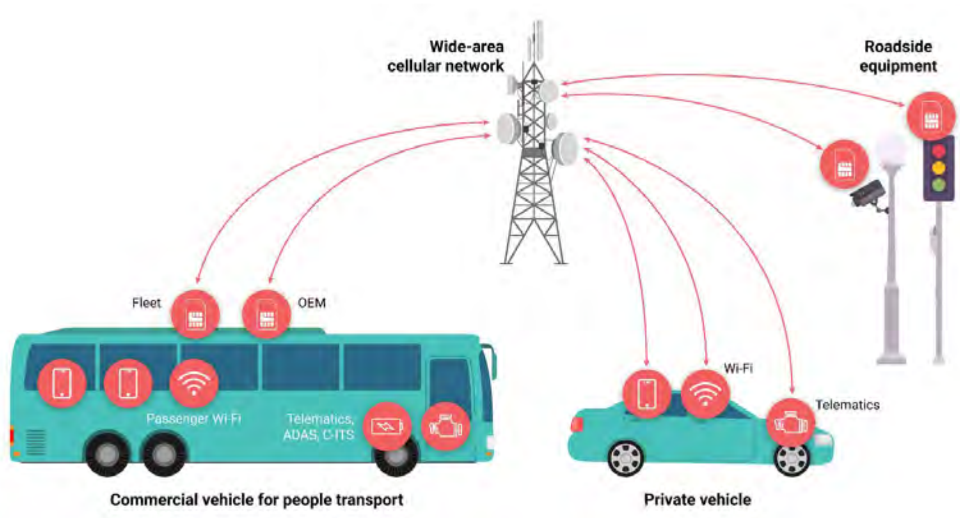
Executive Summary

By 2025, every new vehicle will be connected. Estimates predict that vehicles will send 1 to 10 exabytes of data traffic per month to the cloud, at least 1000 times larger than the present volume. This data is valuable for many automotive digital services, such as those that will drive new insights into global fleet operations, uncover new vehicle revenue streams, and improve vehicle, driver, and operational efficiencies. Automotive digital services, such as High Definition Mapping (HD-Mapping), Intelligent Driving Support, Vehicle Quality Control, and other Location-Based Services (LBS), will fuel the connected vehicle market, which is forecast to exceed USD 150 billion by 2025. However, today's ecosystems are not optimized to handle the increasing volumes of connected vehicle data and reliably and economically support emerging automotive digital services globally on a mass-market scale. These ecosystems are complex and must address their many stakeholders' strategic, technical and commercial objectives, with optimized computing and connectivity resources for mobile vehicles, see Exhibit 1.

Given the complexity of automotive digital services, collaboration forums, thought leadership documents, proof-of-concept (POC) system designs, reference architectures, and blueprints are crucial. For example, HD Mapping-based digital services have diverse data payload and service latency demands that must be well understood in the context of distributed edge computing workload orchestration, end-to-end security and privacy, data, and network management. Also, cross-industry collaboration is needed to address stakeholders' respective interests with globally compatible solutions.

The AECC is supported by members across the entire connected vehicle ecosystem. It provides a critically important platform for its members to collaborate, share thought leadership, and develop PoC system designs, reference architectures, and blueprints for high-value digital services for connected vehicles.

Exhibit 1: Computing and connectivity resources must be optimized for mobile vehicles.



Source: AECC and AECC member Ericsson, 2021

Introduction

The automotive market is massive. Almost 1.5 billion vehicles are in operation worldwide, and 60 to 70 million vehicles are sold each year globally. According to Cisco's Annual Internet Report (2018-2023), connected vehicle services represent the fastest growing industry segment for machine-to-machine connectivity. By 2025, all new vehicles will be connected, with sophisticated on-board capabilities that will generate up to 10 Exabytes of data traffic per month and drive a global market for digital services, which is forecast to exceed USD 150 billion by then.

Over the last decade, the automotive industry has benefited from tremendous digital innovation, with sophisticated autonomous and assisted driving, proactive vehicle monitoring and maintenance, fleet and traffic management, and safety and infotainment capabilities. With these innovations, vehicle designs are becoming increasingly software-centric and dependent on connectivity and cloud and edge computing capabilities.

As vehicle designs continue to advance and new vehicles are sold, the addressable market for digital services will grow tremendously. For this growth, networking, cloud, and edge computing infrastructure must reliably, securely and cost-effectively address the digital service performance requirements with sufficient scale. These requirements can vary significantly for different services. Some services require near real-time performance, some have heightened security and privacy demands, some are voluminous, and others have intensive computing requirements. A one-size-fits-all design approach is inadequate. Instead, network and computing resources must be carefully orchestrated to reliably and securely address diverse service demands and the interests of the many ecosystem stakeholders involved.

The Opportunity

It is no surprise that radios have been in cars since 1929, and mobile phones started out as an in-vehicle technology. From their earliest days, cars have provided captive market opportunities for new innovations to thrive. Today the automotive industry is heralding tremendous digital service opportunities as connected vehicles proliferate. The range of digital services is vast, and depends on critical enabling technologies such as High Definition Mapping (HD Mapping), Vehicle-to-Cloud Cruise Assist (V2Cloud Cruise Assist), Mobility-as-a-Service, and Usage-Based monitoring for insurance and financial services.

HD Mapping

HD Mapping consolidates static and dynamic information, such as vehicle positioning and pedestrian and obstacle identification. HD Mapping is mandated for autonomous driving and is significantly more dynamic than traditional route guidance solutions. Lidar, radar, imaging, and other data sources are geotagged, collected from vehicles and stored in the cloud and edge computing platforms to provide local HD Maps. The data volumes collected from specific locations will vary greatly depending on vehicle traffic patterns (particularly when traffic jams and accidents occur). Sophisticated edge and cloud server orchestration and data management capabilities are needed to minimize redundant data collection (e.g. when conditions are relatively static and multiple vehicles are recording the same information), and for workload optimization amongst edge and cloud platforms.

V2Cloud Cruise Assist

V2Cloud Cruise Assist offers sophisticated routing capabilities for edge and cloud connectivity. Here the network mediates vehicle-to-vehicle communications by integrating information obtained from neighboring cars. This mechanism is called the vehicle-to-cloud-to-vehicle service or simply V2C2V. This service scenario is especially effective for broadcasting information needed for other vehicles by using neighboring vehicles, roadside units, and other networking nodes to route the information. Since vehicles are mobile and might be traveling at highway speeds, V2C2V routing requires dynamic orchestration capabilities to rapidly add and remove vehicles from the application's 'zones of interest' while ensuring the underlying digital service performance requirements are maintained. As a vehicle's journey continues, the application must mediate for vehicles moving from one access point (such as a cell-tower) or entering and joining an adjacent localized network and its associated edge server.

The Opportunity

Mobility-Data-as-a-Service

Real-time mobility data collected from vehicles can be used to support real-time navigation services, can be tremendously valuable for other third-party service providers (e.g., traffic control by road authorities, digital map providers and positioning-based value-add service providers). Real-time data will enable Mobility-Data-as-a-Service (MDaaS) opportunities to thrive, particularly as digital service capabilities mature. Notable examples include multimodal navigation, ride-sharing, car-sharing, and even parking lot sharing, in urban environments where trips tend to be shorter, and car parks are scarce. Mobility sharing services that share different types of information in a timely manner between asset owners, service providers and end-users should be built on top of intelligent driving, high-definition maps and cruise assist.

Usage Monitoring

Connected vehicles are well suited for usage-based service models. For example, auto insurers are adopting usage-based-insurance models that monitor various indicators, including driving behavior and driving times, to better assess customers' risk levels and set premiums accordingly. Auto insurers are also investigating dynamic insurance premiums that capitalize on real-time data harvested from emerging digital service enablers such as HD Mapping. Services, such as dynamic insurance premiums, must be reliable and secure. High-performance edge computing capabilities are likely to be essential to achieve the reliability, security and real-time performance needed.

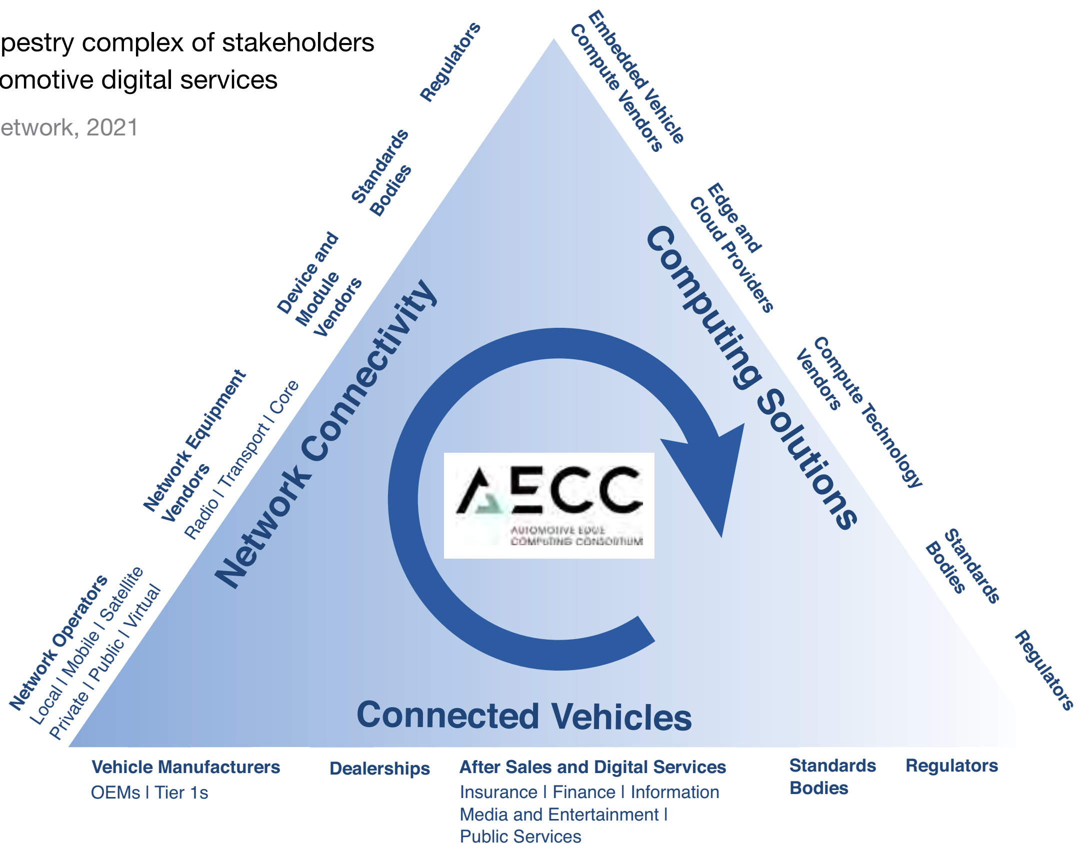
The digital service opportunities for connected cars are exciting and seemingly endless. However, the services depend on adequate stakeholder engagement and sufficient alignment for the underlying technologies used.

The Stakeholders

No one player can enable the automotive digital services market to flourish. Instead, this lucrative market depends on coordinated engagement amongst the stakeholders for connected vehicles, networking and connectivity, and computing solutions (see Exhibit 2). To succeed, the digital services requirements must align with the overarching technical and commercial objectives for each stakeholder involved.

Exhibit 2: A tapestry complex of stakeholders are driving automotive digital services

Source: Topio Network, 2021



Connected Vehicles

Connected vehicle ecosystems are supported by an extensive web of original equipment manufacturers (OEM) and Tier 1 providers. In addition, numerous Tier 2 companies provide specialized parts and components to the Tier 1s and OEMs.

As automotive digital services proliferate and connected vehicles become increasingly software-centric, Tier 1s and OEMs can extend beyond the manufacturing process and potentially engage throughout entire vehicle lifecycles. Dealerships will also have opportunities that extend beyond their traditional sales roles with even more after-sales solutions. In addition, automotive digital services extend to other players well beyond the traditional automotive industry. For example, insurance and finance companies are already trialing targeted and personalized digital solutions. Media and entertainment companies are already offering in-vehicle solutions that will be significantly enhanced with emergent digital service capabilities. Information and public service providers can capitalize on digital services to substantially improve driver experiences and safety, and address key challenges such as fleet management and traffic congestion.

The Stakeholders

Network and Connectivity

Network and connectivity ecosystems are supported by network operators, network equipment vendors, device and module vendors, standardization bodies, and regulators.

Network operators include local, mobile, and satellite network providers. In most cases, automotive network connectivity will use public 4G and 5G mobile networks. In some cases, local network operators might provide services in targeted areas, typically using unlicensed radio spectrum technology such as Wi-Fi or cellular connectivity, unlicensed or licensed. Satellite network providers enable connectivity over massive geographical footprints to provide wide-area coverage overlays for automotive services.

Network equipment vendors provide radio, transport, edge computing, and core network technologies. Networking equipment is complex, and since networks typically integrate equipment from multiple vendors, standardization is essential. Traditionally, proprietary hardware-centric network platforms have been needed to address performance demands. However, with advancements in commodity hardware platforms, network equipment has become increasingly software-centric, which enables increased network agility with virtualized and cloudified architectures.

Device and module vendors provide a variety of vehicle communication modules and other connectivity solutions. These vendors leverage technology standards like 4G, 5G, and Wi-Fi and key technologies like eSIM to enable compatibility and roaming between network operators.

Standardization Bodies, including the 3GPP, IETF, ETSI, and the IEEE are responsible for establishing networking standards such as 4G, 5G, and Wi-Fi. Also, the 5GAA supports the advancement of 5G to meet the specific needs for automotive. The AECC

> **Most Governments across the globe have Regulators responsible for establishing key regulations.**

is collaborating with the 3GPP and establishing relationships with other standardization bodies to emphasize the networking and edge computing requirements for automotive digital services.

Most Governments across the globe have **Regulators** responsible for establishing key regulations, including radio spectrum band plans, licensing and emission controls, competitive industry structure, and other related resource allocations that are important for automotive digital services.

Since network technologies are regularly upgraded, the range of available technology generations varies between regions and countries. Today 4G-LTE is widely available, and 5G is coming. According to the Global mobile Suppliers Association (GSA), as of December 2020, 4G-LTE was available in 237 countries and territories with 806 network operators. 5G is still nascent but is rapidly becoming available in many markets. In December 2020, the GSA reported 140 network operators were deploying 5G, albeit with relatively limited coverage, in 59 countries. Of the 140 5G operators, 61 have commenced investments in 5G-standalone, which is required for many of the proposed advanced automotive digital services.

Satellite networks enable wide-area broadcast services and two-way connectivity, particularly in areas where mobile service is lacking. In recent years, High Throughput Satellite (HTS) technology has improved satellite systems’ capacity, and medium and low earth orbit (MEO and LEO) constellations have enabled improved latency performance.

The Stakeholders

Computing Solutions

Computing resources are distributed throughout entire digital automotive ecosystems. These computing resources must be efficiently orchestrated for digital services to flourish and address the market expectations of the stakeholders involved.

Embedded vehicle computing platforms, such as engine control units (ECU) are provided by Tier 1 suppliers and OEMs. Today, embedded vehicle computing tends to be siloed and align with the Tier 1s' modular platforms. However, there are increasing efforts to equip vehicles with standardized and multi-functional compute platforms to capitalize on advancements in commodity computing hardware and enable increased software centricity and design agility.

Cloud Service Providers have mature service offers and established partnerships with major OEMs for a range of digital services. Since cloud services operate in highly centralized hyper-scale data centers, they cannot address the latency, data localization, and performance demands needed for many future digital services. These demands have fueled investments in edge computing solutions, bringing computing resources closer to vehicles. These edge resources complement embedded vehicle and cloud computing capabilities so that tapestries of computing resources can be optimized to meet specific digital service demands economically.

Edge Service Providers, including network operators, cloud service, and outsource facilities providers, have been deploying distributed edge computing infrastructure. Edge computing is still nascent, and in many cases, the edge service offerings are essentially enhancements to existing cloud offers. However, as edge computing matures and becomes more readily available, "edge native" automotive digital services will become feasible. These edge native services will only function when reliable edge resources are readily available.

Compute Technology Solution Providers have advanced solutions designed and optimized for different implementation scenarios, including embedded vehicle, edge, and cloud computing environments. Each environment has unique performance requirements to address. In-vehicle computing tends to have a high degree of customization for the services they support. Edge computing platforms must contend with computing resource scarcity, which contrasts hyper-scale cloud environments. This scarcity creates unique conditions for edge compute platform designs and management and orchestration solutions.

The Stakeholders

A Complex Tapestry of Technologies

Automotive digital services depend on complex technology ecosystems, which can vary dramatically amongst different regions, depending on technology availability and stakeholder engagement. In addition, digital service performance will likely change as vehicles move through areas. The performance will depend on various factors, including network and computing resource availability, service orchestration, connected vehicle densities, and the type of services demanded.

Computing Solutions

In contrast to traditional centralized cloud-based services, emerging automotive digital services require distributed computing architectures with diverse resources that must be orchestrated and optimized for different service requirements. Distributed computing resource availability will vary significantly amongst geographies and depend on infrastructure availability and stakeholder investment priorities. High vehicle densities and high-performance digital service requirements will create additional computing demands, which will likely be offset by leveraging on-board vehicle computing resources, even though the vehicles are moving. Dynamic and sophisticated orchestration solutions are needed to leverage the available computing resources and to ensure they are secure and optimally managed based on the demands of the specific digital services that are supported.

Network Connectivity

Even when technologies like 4G and 5G are available, digital service performance and reliability cannot be guaranteed. Networks might become congested and radio signals obstructed. Also, 5G network densities will be sparse for many years as network operators continue to rely on their established 4G networks and strategically target 5G to areas where it is most beneficial. Furthermore, even when a particular technology is deployed, it does not guarantee that the network is configured with the features required for specific automotive digital services.

Networking for automotive digital services is unique and must include specific connected vehicle requirements that need to place for digital services to be successful. Future automotive digital services will leverage vehicle-to-vehicle communications (with moving vehicles) to enhance capacity and coverage performance and overlaid satellite communications for global coverage and service ubiquity. Automotive digital service implementation strategies and performance expectations must incorporate these network complexities.

Security

Robust security and data privacy solutions are crucial for automotive digital services to gain market traction. The solutions must anticipate increased attack surfaces created by diverse vehicle data and intelligence and heterogeneous connectivity and computing environments. Sufficient end-to-end security and data privacy capabilities must be enabled, with robust governance regimes and taxonomies that account for all operating scenarios. The security solutions must also incorporate best practices for protection and detection, and rapid response and recovery capabilities in case breaches occur.

The Stakeholders

AECC Brings It All Together

The Automotive Edge Computing Consortium (AECC) addresses the challenges in enabling automotive digital services to thrive. The AECC is not a standards organization. Instead, it collaborates with key stakeholders to enable optimal topology-aware distributed edge computing cloud architectures for automotive digital services. The services that AECC is currently focused on include:

- Intelligent Driving to improve vehicle safety and driver assistance capabilities by leveraging collaborative vehicle intelligence and edge computing.
- HD-Mapping to provide connected vehicles with mapped environments that have high-level centimeter precision, especially for information beyond the line of sight, such as the topology of the upcoming road
- V2Cloud Cruise Assist, which encompasses V2C2V connectivity capabilities to enable enhanced collaborative vehicle operations.
- Mobility-as-a-Service concepts, and;
- Extended services for the finance and insurance industries.

The AECC publishes thought leadership, enables its members to collaborate and is launching a growing number of proof-of-concept (PoC) projects and operating test-beds in collaboration with its members. These PoCs and test-beds capitalize on stakeholders' diverse expertise to identify the salient characteristics of key digital services in practical operating environments with real-world networking and in-vehicle, edge and cloud computing architectures. This provides stakeholders with an environment for pre-competitive collaboration to accelerate the development of high-value digital services. The PoCs provide the basis for design blueprints and frameworks to identify the implementation priorities and constraints associated with specific automotive digital services. These blueprints and frameworks provide crucial design and implementation guidelines. They also account for the complex network and computing orchestration requirements that will remain a hallmark for the automotive industry for the foreseeable future.

Exhibit 3: AECC Accelerates and Reinforces the Automotive Digital Service Ecosystem

Source: Topio Network, 2021

Conclusions

The automotive industry has always been a hive of innovation. This innovation will accelerate in the coming years as connected vehicles proliferate and enable lucrative digital services. These services will create profitable opportunities for many stakeholders in the automotive, communications, and edge and cloud computing industries. The digital services also create opportunities for information, media and entertainment companies, and other players, including finance and insurance companies.

By 2025 all new vehicles are expected to be network-connected, and the globally connected vehicle market is expected to exceed USD 150 billion. There is a lot at stake, and it is prime time for a connected vehicle ecosystem of stakeholders to establish their digital service strategies.

To succeed, emerging digital services requires coordination amongst key stakeholders, such as network equipment vendors, network cloud and edge computing service providers, and computing infrastructure providers. Effective stakeholder coordination is needed to achieve the technical and commercial requirements for emerging digital services. These services have diverse reliability, bandwidth, security and latency performance requirements, which must be orchestrated amongst complex network and computing environments to deliver optimum performance at scale.

The AECC unlocks lucrative automotive digital services by bringing together key stakeholders to establish thought leadership, best-practices, blueprints, and design frameworks with research publications and PoC studies in real and practical operating environments. This enables AECC members to engage in pre-competitive collaboration with other industry stakeholders and accelerate automotive digital service opportunities.

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To accelerate markets and businesses, Topio Networks offers detailed data insights and natural language analysis about the shape, structure and sizing of the thousands of use cases, verticals and technologies that are the building blocks of the fourth industrial revolution. Our data is constantly fed by the daily insights generated by our taxonomy driven, human curated AI Platform. The Topio Networks Market Intelligence Center provides free access to our industry research with detailed data about market sizing, innovations, funding and marketing activities for each specific use cases, industries and emerging technologies.

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