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Connected Cars – Architecture, Challenges and Way Forward

Whitepaper

Abstract

This paper by, Sasken Technologies Limited, discusses the need for relevant and economic solutions, emerging trends and accompanying challenges that arise with growing complexity and evaluates the best-possible mechanism to overcome these challenges.

Keywords—Kernel Tracers, trace-cmd, Blu-ray, de-interlace, blending

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Introduction

The global automotive industry has been witnessing a transformation over the last decade with digital communication technologies making rapid inroads in vehicles. The world is moving towards the concept of connected transportation that focuses on providing enhanced connectivity like vehicles communicating with each other to know their presence, real-time communication facility to the occupants of the vehicle. This functionality is enabled by variety of technologies like vehicle to vehicle communication, vehicle to infrastructure, vehicle telematics, and vehicle informatics that provide various services such as real-time street updates, smart routing and tracking, roadside assistance in case of accidents, automatic toll transactions, automatic parking/parking management, on-board entertainment, and much more. This paper discusses the need for relevant and economic solutions, emerging trends and accompanying challenges that arise with growing complexity and evaluates the best-possible mechanism to overcome these challenges. It also delves into the various components that get into the connected car gateway/wireless gateway beginning with analysis of the software components, complexities of a modern connected car gateway system and optimization possibilities. It concludes with a view on the existing supply chain precision and the way forward.

Global Connected Car Market

The global connected car market is estimated to grow from $46.9 billion in 2015 to $140.9 billion in 2021. Safety and autonomous driving are the largest categories, accounting for about 61% of the total market. In the premium automobile segment, spend on digital technology is expected to rise to 10% of total vehicle sales by 2021; more than double the current level of 4%.

OEMs and Tier-1 are making the related R&D investments. The volume segment of cars made for middle-income purchasers is also witnessing the addition of basic connectivity functions. Here, digital content is on course to reach 2.6% of total selling prices by 2021, up from just 0.5% in 2015.
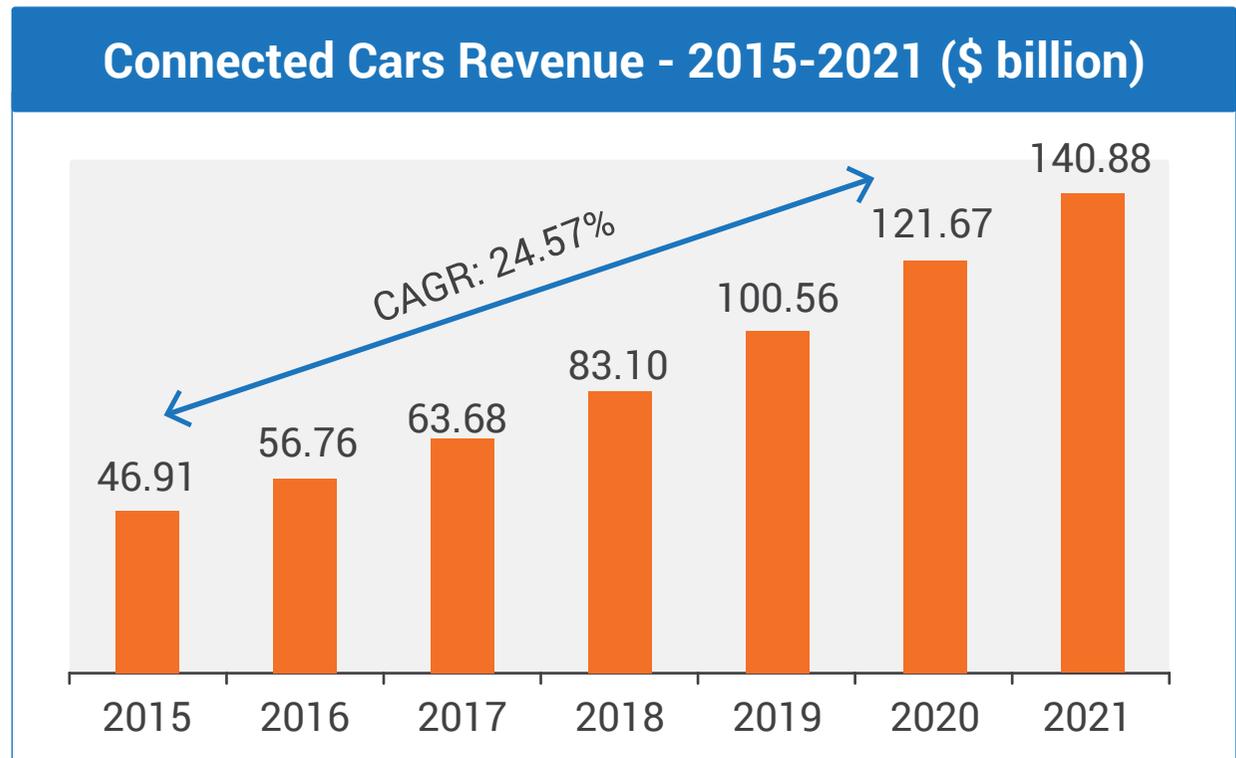
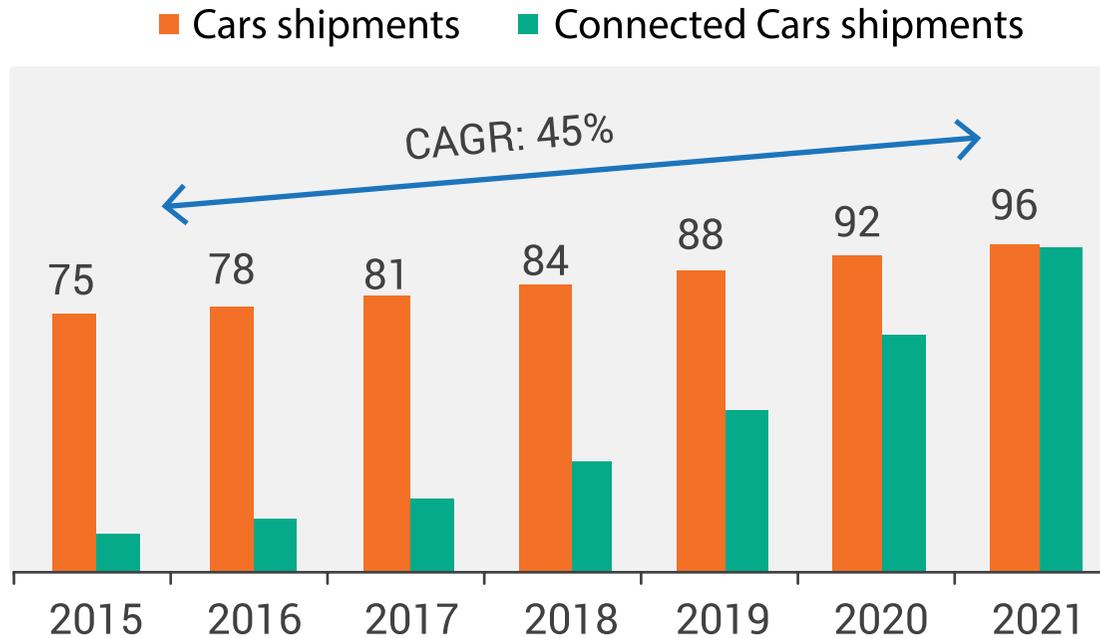## Connected Cars Revenue - 2015-2021 ($ billion)

CAGR: 24.57%

Year	Revenue
2015	46.91
2016	56.76
2017	63.68
2018	83.10
2019	100.56
2020	121.67
2021	140.88

Figure 1. Global Connected Cars Market

Connected Cars Shipments Forecast (Units in Mn)

■ Cars shipments   ■ Connected Cars shipments

CAGR: 45%

Year	Cars shipments
2015	75
2016	78
2017	81
2018	84
2019	88
2020	92
2021	96

Globally, electronic components are expected to be 50% of the value of a car by 2030, from the current 30%. Considering that the volume growth in emerging markets will be in low-mid to mid-high segments, the key to driving adaption in these segments is by arriving at electronics architecture that optimize on the costs while providing value to the customer.

Automotive Electronics Architecture

Traditionally, automotive architecture comprised of Infotainment, Telematics, and Diagnostics which acted as silos with minimal to no communication between them. The advent of advanced communication technologies like LTE, V2X has resulted in these silos being broken resulting in more seamless exchange of information across them. This has resulted in interesting use cases like connected infotainment, real-time diagnostics, and real-time tracking. Modern connected cars bring together various silos in a car like infotainment, telematics, and diagnostics through real-time communication systems enabling use cases that greatly enhance the user experience.
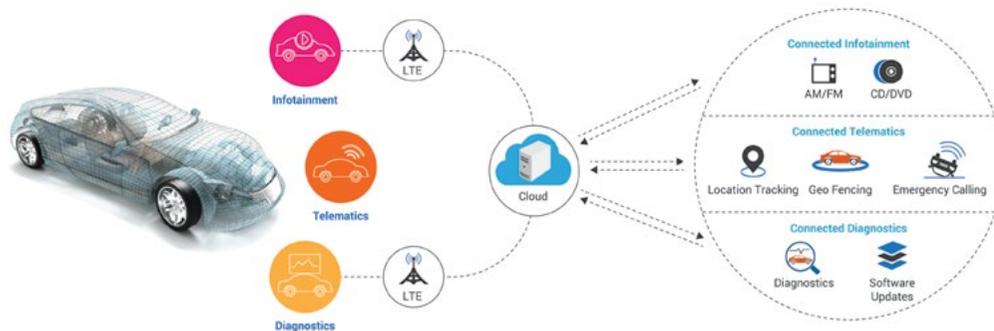
Silos getting merged and resulting in real-time, on demand services like Spotify and Connected Diagnostics among others

The software architecture of modern connected cars comprises of three main components:

• Connected Car Gateway (CCG) which forms the entry point for a car to communicate to the external world

• Cloud based servers that perform real time analytics on the data that is generated from the car generating real-time insights

• Applications on smartphone that provide an intuitive user interface that allow a user to interact with the car over wireless networks to perform variety of operations starting from getting vehicle status to controlling some of the aspects of the car like switching on the HVAC or locating a car in the parking lot

Key Functional Blocks of Connected Car Gateway

1. OPERATING SYSTEM LAYER
Operating systems provide key functionality like scheduling, memory management, threading, application security, drivers to access the peripheral devices that can be used by applications. While there are many operating systems available in the market like Linux, QNX, Android, VxWorks, the auto industry has been traditionally dominated by OS like QNX due to its reliability.

In recent times, there has been a movement towards Linux due to costs and availability of talent to perform upgrade or maintain the system. Consortiums like GENIVI and AGL which includes representatives from automotive OEMs, automotive Tier1s, and Silicon vendors are actively working towards

creating distribution that contain automotive specific features which can be used by the industry. These distributions standardize the non-differentiating middleware allowing automotive OEMs to innovate and add differentiating features on top of the middleware thus reducing the costs and enabling lower time-to-market.

2. VIRTUALIZATION LAYER
In order to optimize the hardware costs, the automotive market is witnessing a phenomenon of ECU consolidation where multiple functions like IVI, Connected Car Gateway, and Digital instrument cluster are integrated into a single ECU.
Virtualization provides an option to share the hardware resources across multiple

applications running across multiple OS. Virtualization can be achieved by use of hypervisor on top of hardware. There are various types of virtualization that is possible in the automotive systems. Each has its own benefits and choice of type of hypervisor is mainly dictated by the type of applications that are can to run on these systems.

Full Virtualization
Full virtualized system provides complete hardware abstraction to the OS above creating a view to the OS that each one has its own hardware. Thus, multiple guest OS can run on the hypervisor without any modification. Issues in one Guest OS do not affect the other.

Para Virtualized System

Para virtualized systems are those that try to remove the overhead associated with binary translation involved in Type1 hypervisor. This in turn provides better performance than type1 hypervisors since the OS and hardware are knit more tightly. This is crucial for operations that are IO intensive, compute intensive like graphics, multimedia, gaming engines etc.

In terms of the available choices, the various hypervisors available in the market are:

- Green Hills Integrity
- Sysgo's PikeOS
- QNX's Hypervisor
- Open source options include Zen hypervisor

3. CONNECTIVITY

Connectivity block is a very important block of a CCG. It comprises of various blocks like long range connectivity modems like LTE and short range connectivity modems like Wi-Fi and BT along with positional tracking systems like GPS.

- **Modem connectivity**

Modem connectivity is required for transmission and reception of data in real-time to and from internet. At the lower end we have 2G/2.5G modems which provide data rates less than 100kbps going to LTE which provide data rates at a few Mbps. Key services enabled by modem include high speed data connection, eCALL services that provide emergency alerts to the Public Safety Access Points in case of emergencies so that help can be provided to the victims at shortest span of time

4. V2X

V2X technologies help in real-time communication between vehicle to vehicle and vehicle to infrastructure so that a vehicle is aware of its environment thereby avoiding collisions with other vehicles. Traditionally V2X is based on 802.11p technology. This technology is based on 802.11a (5.8GHz band) with increased range at cost of lower bit rate and 802.11e for QoS. QoS helps in priorities the messages and further reducing the delay.

A new technology based on the LTE standard called LTE-V is also competing for usage in V2X communications. This technology is trying to standardize long range as well as short range communication system.

5. FOTA

With software content in Connected Car Gateway unit increasing by the day and considering that the average unit has a life span of over 7 years, it is natural that the unit needs software updates periodically. Software updates are also needed to fix the issues that appear during the field run including security vulnerabilities that are un-covered from time

to time. FOTA (Firmware Update over the Air) module helps keep the software in the unit up to date.

6. SECURITY

The security module implements various mechanisms to secure the connected car gateway from malicious code. This involves mechanisms like secure boot, secure storage for storing the keys, secure communication with external world like SSL, TLS, application signing, access restriction/privilege control to for various types of applications to access system peripherals, vehicle bus like CAN.

7. APPLICATION FRAMEWORK

Connected Car Gateway Application framework implements a SDK that allows third parties to develop applications that can be downloaded into the device. This will enable development of an ecosystem to provide variety of services using the data that is available from Connected Car Gateway box like usage based insurance, preventive diagnostics, and location based services. The framework abstracts all hardware specific intricacies from app developer. The framework exposes APIs in Java/HTLM5/JS allowing ease of programming.

Challenges in Development of Connected Car Gateway

1. COST OPTIMIZATION

Mass penetration of Connected Car units is required to ensure that the participants benefit from the network effect. E.g. a V2X solution integrated in majority of the vehicles ensures that these vehicles exchange information about their location, speed and there by prevent accidents. This requires that the connected car gateway be available at attractive price points for mass market adoption. This puts pressure in terms of optimizing the hardware cost, software costs and associated maintenance.

The following approaches are considered for optimizing the costs of Connected Car Gateway:

- Consolidating multiple functions into a single system-on-chip (SoC)/hardware block using Virtualization

- Choice of OS - Operating system forms the layer that sits above the hypervisor and is a key component of any Connected Car Gateway. While the basic requirements for choice of OS depends on need of near-real time scheduling capabilities, reliability, foot print, availability of base port in popular SoC some of the other key considerations are:

- Cost (Licensing fee, Royalties etc.)

- Maintainability/upgradability/scalability – Access to source code, availability of talent to work on updates, adding support to new peripherals

- Consolidate connectivity blocks - Connectivity module forms an important cost component of the system and the approach for choosing a connectivity block differs based on the volume of the product and proportion of fixed costs to variable costs. In case of high volume products, the fixed cost is spread over large number of units. Hence, it makes sense to take an integrated SoC comprising of application processor and all connectivity blocks and

add specialized components like GPS in case the component provided by SoC does not meet the required specifications. However, the economics work differently when the volumes are low and it makes sense to take a pre-certified connectivity module and integrate into the system. On the technological front, some of the challenges include:

- Additional interference due to car body metal and lower RF penetrations.

- Asymmetric gains from roof top antenna due to gain in downlink but 3GPP power restrictions in uplink causing device failure

- Handover and Fall back

  - Seamless handover from one radio to another radio (4G to 3G/2G) and across multiple operators has to be implemented and tested to ensure that there is continuity of services

- IoP and compliance

- eCALL integration

  - provision to try out all possible means to communicate the information about the incident so that help is made available

2. FOTA
The key challenges in FOTA integration are:

2.1 ENSURING SOFTWARE INTEGRITY
It is necessary to ensure integrity and genuineness of the source of the image that is being updated. Asymmetric and symmetric cryptographic functions along with hash of images can be used to ensure that the image is secure while ensuring that the time spent on decrypting the image during boot is kept minimal.

2.2 FAIL SAFE & RECOVERY
Challenge here is to ensure a backup image in place in case there is a failure of update due to reasons ranging from link loss to loss of power.

2.3 OPTIMIZATION OF BANDWIDTH FOR UPDATES
While a Connected Car Gateway image can run into hundreds of MBs, it is necessary to ensure that the FOTA updates are optimized to conserve the bandwidth by segmenting the image into various logical groupings and ensuring that only the required part is updated instead of the whole image (delta updates).

2.4 VEHICLE NETWORK SECURITY
With more and more vehicles getting connected to internet allowing access to vehicle information and control of vehicle from remote location, the security threat to vehicles from external hackers has increased exponentially.

With multiple layers of security, isolation of vehicle interface networks from external world, etc., some of the solutions include:

- Isolation of systems in the CCG (IVI vs Vehicle Interface Network)

- Intrusion detection prevention systems which monitors suspicious activity on vehicle network and provide alerts

- Secure communication with external world using protocols like SSL/TLS

Where is the Telematics Industry headed to?

- Evolution of Domain controllers like Cockpit Domain Controller that integrates multiple functions like ADAS, Connected Car Gateway, and Heads-Up Display resulting in cost optimization and reduced weights. On the connectivity front, the car would form a connectivity hub integrating wide range of connectivity technologies like Wi-Fi, LTE, NFC, and BT

- Some of the traditional ADAS functionality that are implemented using vision/radar based technologies could be realized using new age connectivity technologies like LTE direct that provides low latency P2P communication using priority messages/alarm messages, complementing the 802.11p

- Key to connected car success is evolution of application ecosystem where third party application developers can innovate. We envisage an Open Connected Car platform where tier-1s provide a platform and expose an SDK where third parties can develop a variety of apps and provide services

- The connected car generates enormous amount of data that can be used for multiple applications. We envisage that innovative business models for data monetization will emerge. There will be an emergence of data aggregators who aggregate data and make this available to users

- Security will be a moving target but levels of security will increase resulting in higher adoption

The coming years would see standardization and possibly growth of these functions leading to a vibrant ecosystem of connected car application/services developers and successful business cases. Soon the car will not just be a ride to go from one place to another but would rather be a whole new travelling experience.

About The Author

Dorairaj Vembu has over 20 years of experience in product management, product development, and program management in Consumer Electronics, automotive Electronics, and the Internet of Things. He has authored and co-authored articles on Smart TVs, automotive Electronics, and Urban governance by leveraging the smart city concept.

About Sasken

Sasken is a specialist in Product Engineering and Digital Transformation providing concept-to-market, chip-to-cognition R&D services to global leaders in Semiconductor, Automotive, Industrials, Smart Devices & Wearables, Enterprise Grade Devices, Satcom, and Retail industries. With over 27 years in Product Engineering and Digital Transformation and 70 patents, Sasken has transformed the businesses of over a 100 Fortune 500 companies, powering over a billion devices through its services and IP.

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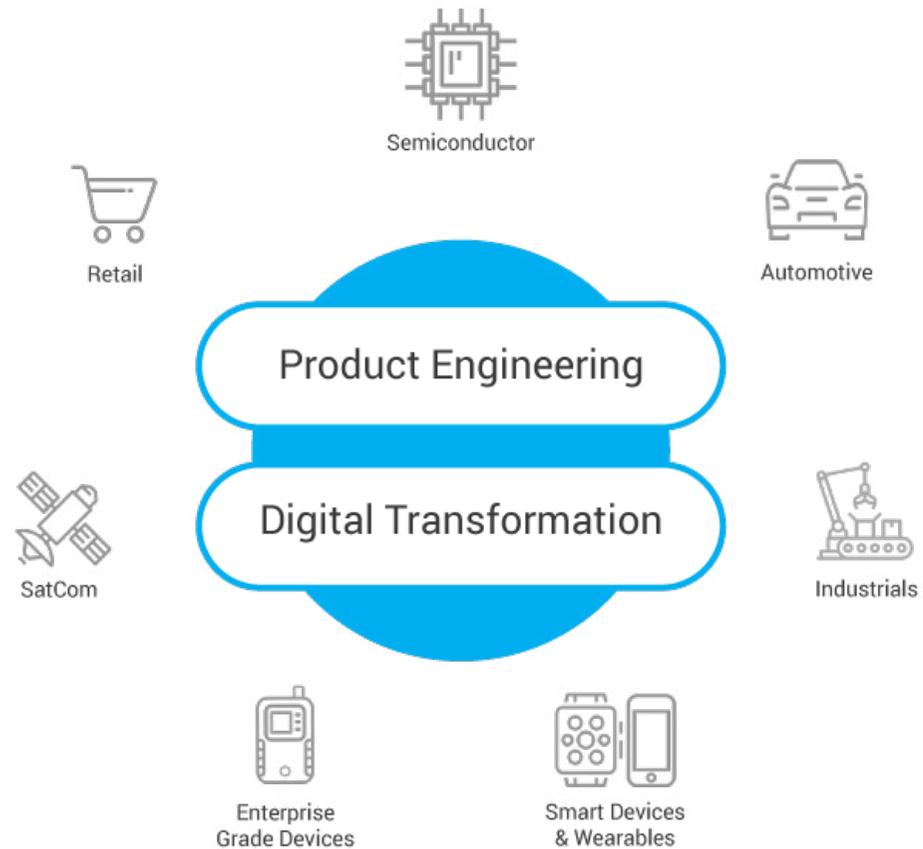
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