Capgemini engineering

VIDEO FOR PASSENGER ENTERTAINMENT IN THE CONNECTED CAR

The opportunities and challenges ahead for automakers

Table of contents

Executive Summary: rapid growth ahead for in-vehicle infotainment

FM radio and MP3 audio are the most popular forms of in-car entertainment today. However, as we enter a new decade, basic radio and bring-your-own-device (BYOD) experiences are unlikely to satisfy drivers and passengers for much longer. In the next few years, one of the most significant opportunities foreseen in the automotive industry will be the digitally connected car, including internet enabled e-cockpit platforms and rear-seat entertainment displays for passengers. As a result, the growth rate of mobile entertainment is expected to follow a trajectory similar to the meteoric growth of the smartphone in the early 2000s. With an enormous number of cars being connected to the internet, wireless connectivity makes it possible for passengers to consume a substantial amount of in-car streaming data via the internet.

In-vehicle infotainment (IVI) in the connected car market is an exciting opportunity that spans streaming video and audio, video conferencing, and gaming – see Figure 1. In the coming decade, connected cars and enhanced wireless connectivity such as Wi-Fi, 4G, and 5G will be the primary factors driving the amount of time passengers spend consuming media content. This white paper details the market trends, implementation challenges, and emerging hardware platforms for designing tomorrow's IVI solutions.

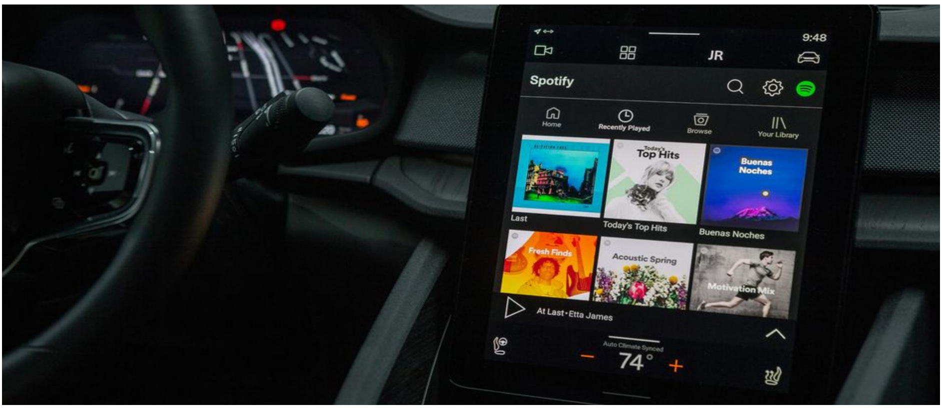


Figure 1: Media entertainment in the connected car (e-cockpit)
Source: Public domain

Overview: video is pivotal for the evolution of the connected car

Video plays a significant role in the connected car market, both for passenger entertainment and the safety of the driver, passengers, other vehicles, cyclists, and pedestrians. Until recently, video has played a limited role in the connected car as the market focus has been on streaming video to the e-cockpit platform only in park mode.

However, a shift is underway to extend video connectivity to passenger rear-seat entertainment devices (RSEDs) – see Figure 2.

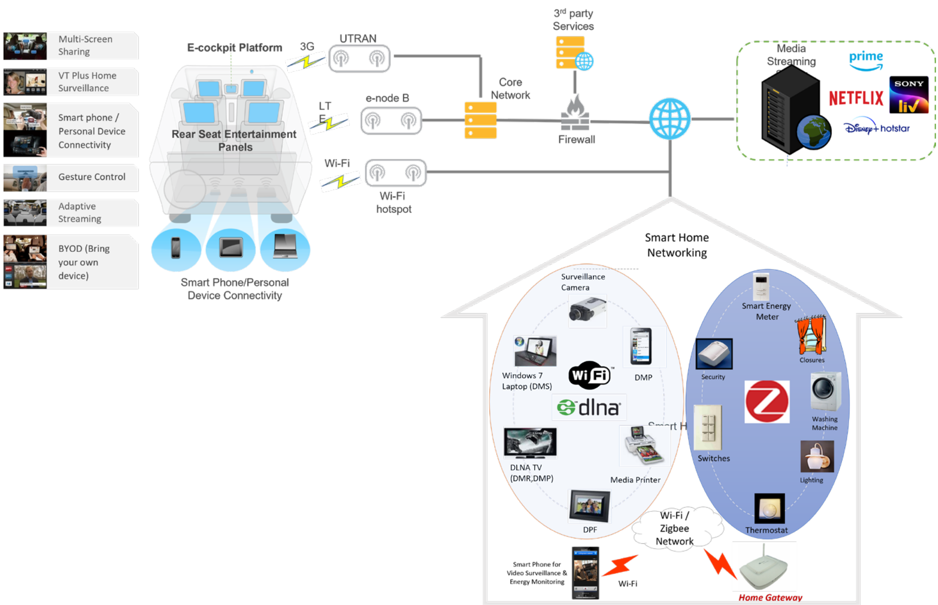


Figure 2: Rear-seat entertainment devices for media streaming and gaming

Source: Capgemini Engineering

According to Intel, the new "passenger market" could be worth $800 billion by 2035 and a staggering $7 trillion by 2050. This includes $200 billion specifically for video entertainment as pilotless vehicles transform the cabin into an immersive entertainment platform.[1]

According to McKinsey & Company, by the end of 2025, 75% of cars will be connected to the internet.[2] By 2030, the global market for connected cars is expected to reach $400 billion, creating significant revenue growth for OEMs and Tier-1 vendors.[3] According to General Motors, subscription services alone could generate $20 billion in annual revenue by 2030 for autonomous driving features and subscriptions for infotainment, internet connectivity, and diagnostics.[4] And close to 461 million vehicles will be shipped over the next ten years with high-resolution displays and flexible hardware solutions.[5]

While BYODs provide a standard streaming experience, RSEDs offer a richer overall user interface and experience (UI/UX), including a 10- to 12-inch display, high-definition (HD)/4K resolution, and digital 7.1 sound for each passenger. The passenger video entertainment services in the connected car will be provided by over-the-top (OTT) players such as Amazon Prime, Disney+ Hotstar, Netflix, and others. These players deliver a variety of video entertainment services, which can generate enormous amounts of data and cellular network traffic.

When it comes to video telephony and home surveillance, the in-car RSED connected to the car network is superior to the mobile phone. (See Figure 3.) It has a rich UI/UX that is only available today on airlines, in first-class in-flight entertainment systems. The connected car provides a similar experience with high-speed network connectivity via 4G or a Wi-Fi hotspot. Also, today's connected cars support video conferencing that turns cars into a rolling office, where passengers can be more productive during business travel.

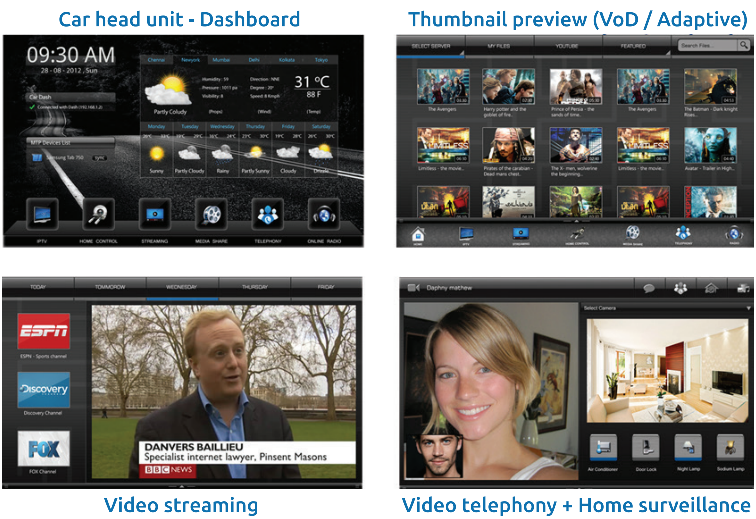


Figure 3: UI or UX design for the driver's dashboard and RSED passenger entertainment
Source: Capgemini Engineering

The evolving automotive infotainment landscape

As streaming entertainment services in the connected car increase, they become more sophisticated. The options include a complete portfolio of media content – such as music, full-length HD movies, TV programs, and sports – on the main dashboard of the e-cockpit and the passengers' RSEDs, where unique content can be streamed on each passenger screen. Today, many car models are being transformed into entertainment hubs. Each passenger can customize the service to meet their interests for the journey's duration from a selection of content options from various OTT players – see Figure 4.

As media streaming becomes a must-have service in the connected car, passengers will expect fast start-up time, near-instant responsiveness, and uninterrupted streaming, even when network conditions are suboptimal. In addition, they will expect HD streaming content playback on their RSED and seamless access to media regardless of whether they are in the car or not.

For example, a family member watching a program at home in the morning on their smartphone gets in the car to go to the office and expects the show to be available on the RSED at the point the program left off. In addition, family members expect the seamless switching of streaming video between smartphones and RSEDs in the car without interruption. In this case, the car's e-cockpit platform has to provide the switching by synchronizing the family member's smartphone with the in-car RSED device so that data from the smartphone can be mirrored on the RSED – see Figure 5.

1. Adrian Pennington, "Driving Content into Vehicles," Jan 20, 2020, IBC 365
https://www.ibc.org/trends/driving-content-into-vehicles/5363.article

2. Trevor Neumann, "Seven Automotive Connectivity Trends Fueling the Future," Jabil
https://www.jabil.com/blog/automotive-connectivity-trends-fueling-the-future.html

3. Michele Bertoncello, Christopher Martens, Timo Möller, and Tobias Schneiderbauer, "Unlocking the full life-cycle value from connected-car data," Feb 11, 2021, McKinsey & Company
https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/unlocking-the-full-life-cycle-value-from-connected-car-data

4. Aarian Marshall, "Why Subscription Automakers Mimic Netflix's Playbook," Oct 12, 2021, Wired
https://www.wired.com/story/subscriptions-automakers-mimic-netflix/

5. "Digital Cockpit To Be Mainstream by 2030 Due to Major Restructure of The Connected Automotive Infotainment Architecture," Sep 9, 2020, ABI Research
https://www.abiresearch.com/press/digital-cockpit-be-mainstream-2030-due-major-restructure-connected-automotive-infotainment-architecture/

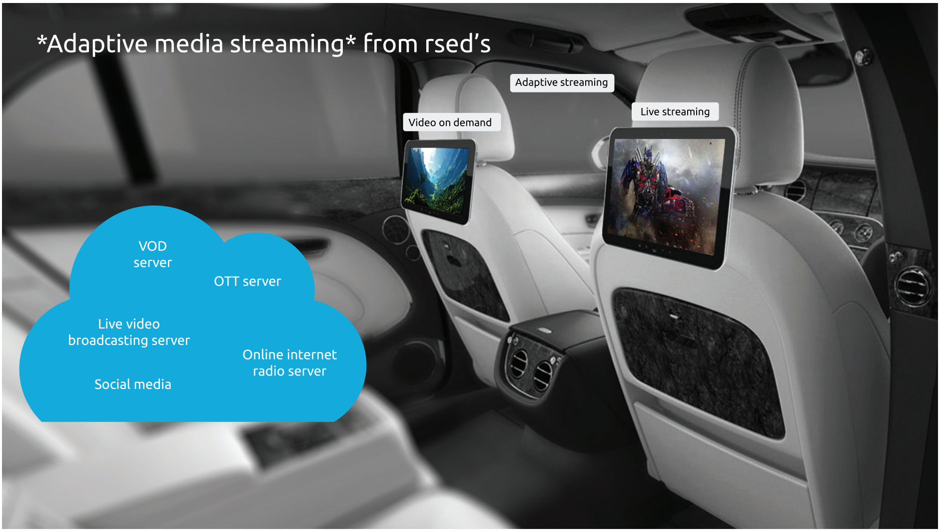


Figure 4: Adaptive media streaming for rear-seat entertainment devices (RSEDs)
Source: Capgemini Engineering

Figure 5: Live video broadcast from the connected car
Source: Capgemini Engineering

Each family member will also have their favorite unique video content. So, when they go on a long trip together in the car, commonly shared streaming of video content – for example, sports or movies – won't satisfy them all – see Figure 6. Instead, the e-cockpit will deliver customized entertainment services, including video, audio, live TV, and games, to each passengers RSED via IEEE 802.1 Ethernet Audio Video Bridging (AVB) and BYODs via the in-car Wi-Fi/Digital Living Network Alliance (DLNA) network.

The e-cockpit provides a decentralized, distributed environment for sharing content across multiple devices within the car network and enables a multi-device user experience. It is far superior to simply fetch content from a single mobile device via streaming applications, screen sharing, or mirroring from a smartphone. Emerging trends in the car such as a gesture-based control system allow the driver and passengers to interact using natural hand or head movements.

For instance, the driver can increase or decrease the volume or select the next song or FM channel with touchless interaction. Communication via voice assistant devices, such as Alexa or Google Home, can provide the most natural, intuitive control methods for a seamless user experience in the connected-car network.

Streaming technologies and connectivity protocols on the e-cockpit

The e-cockpit embedded platform manages the content transmission and reception with the support of streaming protocols like RTSP/RTP/RTCP, HLS, MPEG-DASH, and HTTP-PD – see Figure 7. The e-cockpit platform connects over a 3G, 4G, or 5G network. When in park mode, a Wi-Fi hotspot continuously streams video content and speeds up content delivery by seamlessly switching between 3G, 4G, 5G, and Wi-Fi.

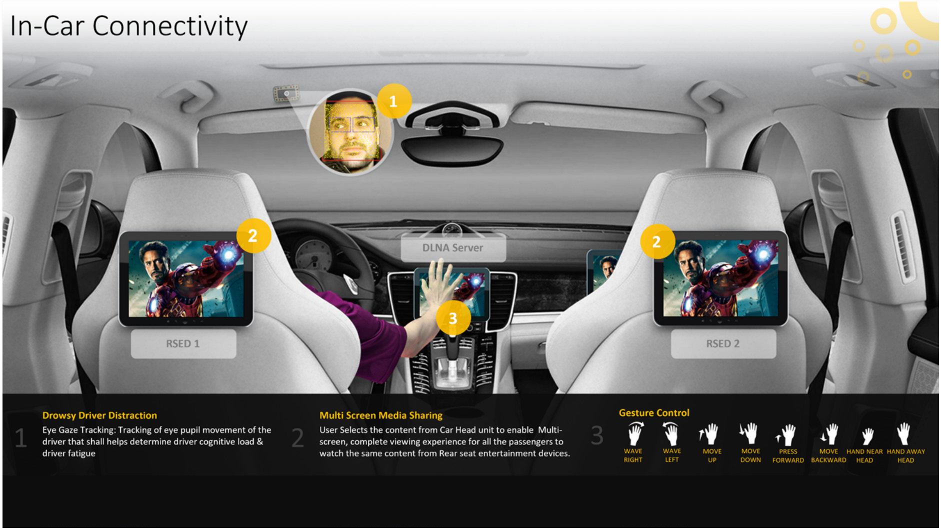


Figure 6: Multi-screen media sharing from the connected car

Source: Capgemini Engineering

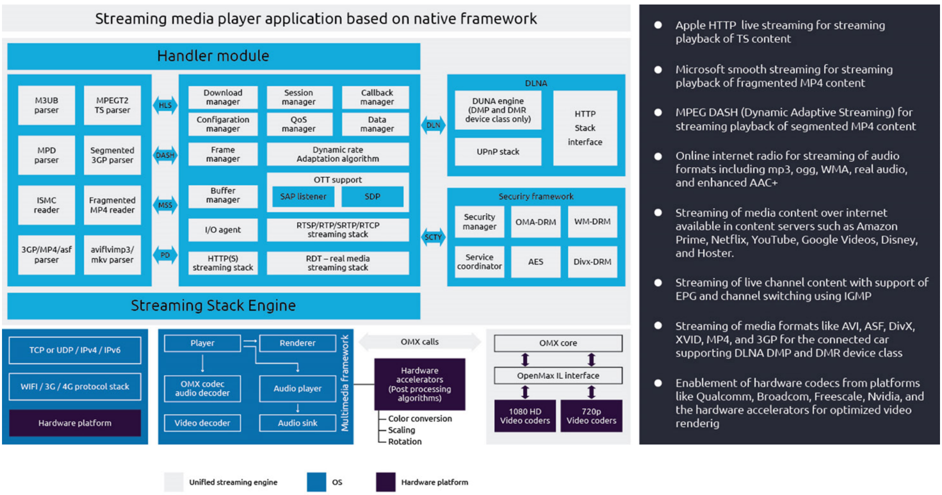


Figure 7: Unified media streaming engine on the e-cockpit embedded platform

Source: Capgemini Engineering

Video playback on RSEDs could be based on built-in Wi-Fi, where media is controlled by DLNA technology which has become more popular, especially in luxury car models – see Figure 8.

To run entertainment HD media apps on the e-cockpit requires a high-powered NVIDIA or Qualcomm Snapdragon SoC to manage the large amounts of HD data to be processed on the driver's screen and for the passengers' RSEDs. Ethernet AVB provides highly reliable transmission for low-latency media applications to handle the large amount of video entertainment data sent to these devices inside the car network.

Ethernet AVB supports time-sensitive networking requirements by forming a single network inside the car for video entertainment. Ethernet AVB standard provides reliable delivery of video data and is the most popular communications protocol for handling entertainment services in the car network. It offers seamless audio and video delivery, and supports a data rate of up to 100 Mbit/s. As a result, it is a popular choice for infotainment and safety systems in the connected car system design – see Figure 9.

Figure 8: BYOD connectivity with RSED over Wi-Fi or DLNA
Source: Capgemini Engineering

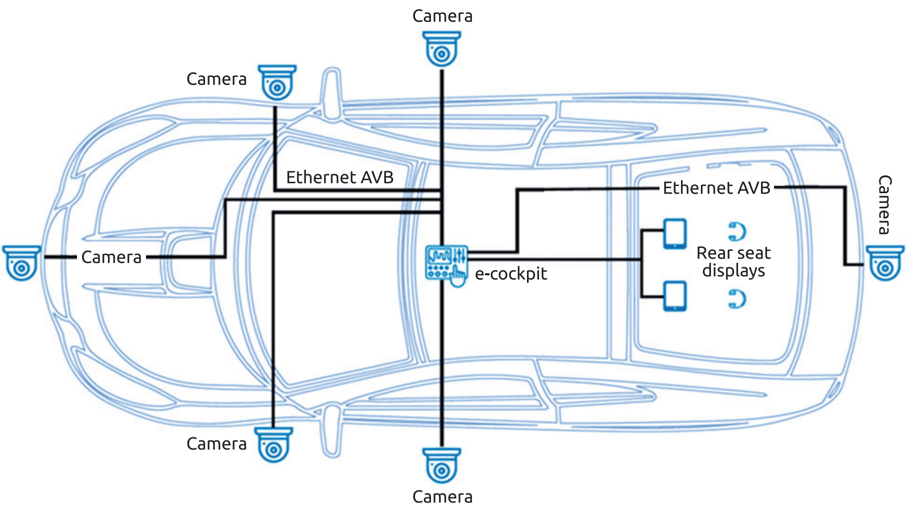


Figure 9: Ethernet AVB-based entertainment panels in the connected car
Source: Capgemini Engineering

ReactNative (RN) based application development is gaining popularity in the automotive industry today for developing connected car video entertainment applications. The RN-based application monitors driver behavior inside the car and video or media player applications on top of the RN framework. Some RN-based apps can be offloaded from the RN-enabled e-cockpit to other RN-enabled devices such as RSEDs and BYODs. 90% of RN code is reusable, which helps reduce development time and project cost.

The RN-based app for car telematics provides valuable insights to the driver with analysis of telematics data. Simplified UI library support from the RN platform allows application developers to create apps with responsive UI and seamless UX that require less time to load the app onto the car embedded platform. The ReactJS library is free and offers a rich tool collection and fast app development for the connected car.

Seamless handover – data switching on the move

Ideally, when connectivity from the car network gets exposed for transmission and reception over the cloud for entertainment applications, the biggest challenge is to have seamless network connectivity for the driver and passengers to get all the necessary entertainment services from the service providers – see Figure 10. With advancements in the connected car, wireless network connectivity from mobile network operators (MNOs) has become a requirement to provide superior end-user service.

Seamless connectivity is a critical competitive differentiator in the connected car market. A high-quality, uninterrupted connection to LTE Advanced, Wi-Fi hotspots, and 5G will be vital for keeping drivers and passengers satisfied and safe. Whichever network the car connects to, based on user preference i.e.,– cellular or a public hotspot, users expect a high-quality seamless mobility experience. Therefore, the connectivity between the car and the entertainment service provider should always be integrated seamlessly over the wireless network via secure data transmission. In addition, session persistence must be maintained based on the handover algorithm – see Figure 11.

Figure 10: Seamless handoff with different wireless networks
Source: Capgemini Engineering

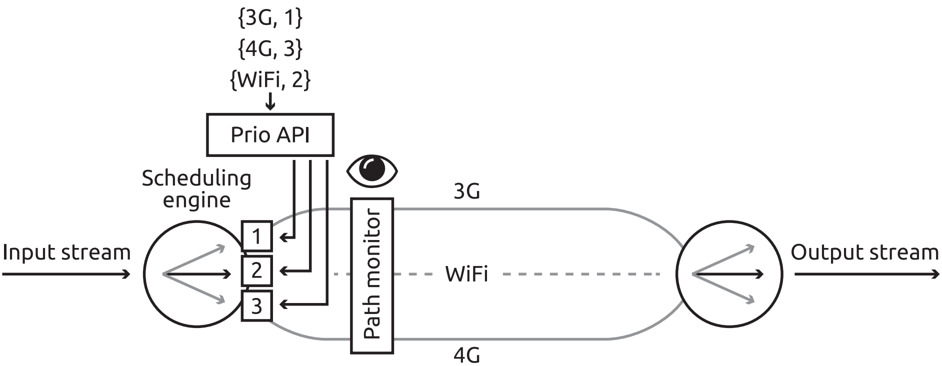


Figure 11: Seamless handover algorithm designed with session persistence
Source: Capgemini Engineering

Secured car data transmission is required during network switching, where car data is monitored and transmitted securely to avoid tampering, eavesdropping, and denial-of-service. Always-on connectivity allows the connected car to provide seamless entertainment to passengers by fetching data via the cloud. The futuristic concept of an always-on connected car requires higher bandwidth and throughput for in-vehicle data communication based on the always best connected (ABC) model. With the seamless connectivity feature supported in multiple car variants, OEMs can meet end-user expectations where the key aspects are to:

- Design, monitor, and classify handover patterns before and after switching

- Implement appropriate user policies during switching for entertainment applications

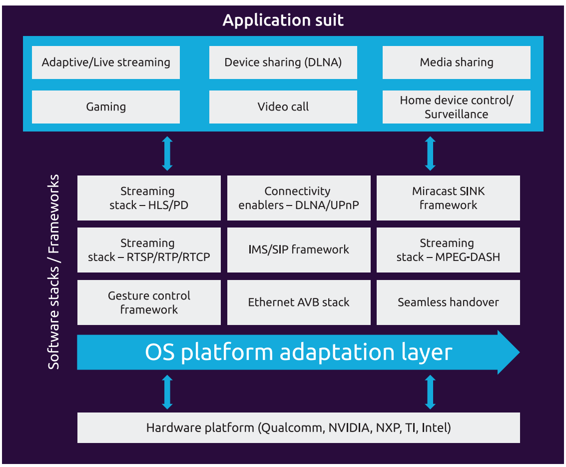
- Provide service-level monitoring and reporting to actively manage and change the wireless connection under different conditions and characteristics

- Generate substantial savings in data traffic with enhanced productivity

Hardware platforms and protocols

To realize the vision of HD video entertainment in the connected car requires a next-generation e-cockpit design with high-end SoCs – for example, a core application ARM-based processor along with DSP – and the right middleware software protocols and frameworks – see Figure 12. With these advances, the e-cockpit can process video, audio, and location using GPS and V-2-X connectivity and make decisions quickly to provide meaningful information to the driver and passengers.

E-cockpit embedded platform



Hardware benefits from E-cockpit platform for safety usecases

- Leveraging powerful media processing capabilities for achieving high media performance for video streaming and surveillance solution
- Use hardware accelerators for video decoding, scaling, and rendering
- Leveraging the powerful and low-power hardware acceleration for HD video decoding from the processor platform for high-quality video rendering
- Leveraging the flexible display support from the hardware platform for rendering multiple streams on to the same displayunit

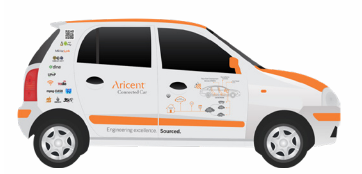


Figure 12: Software architecture of the e-cockpit platform and the Capgemini concept car

Source: Capgemini Engineering

The high-end core application processor, either Freescale, Qualcomm, NVIDIA, or TI – in the e-cockpit platform, enables HD video playback that covers streaming different types of HD content at the front-end, on the main dashboard, and RSEDs, by accessing the online content via the internet. Bringing certain types of video content to the connected car requires digital rights management (DRM) in the car ecosystem that enables premium movies and series to be securely played back in the car network. OEMs are turning to Ethernet AVB, which supports the high data rates demanded by next-generation infotainment and safety systems, simplifies the cabling and network interfaces, and reduces operational costs.

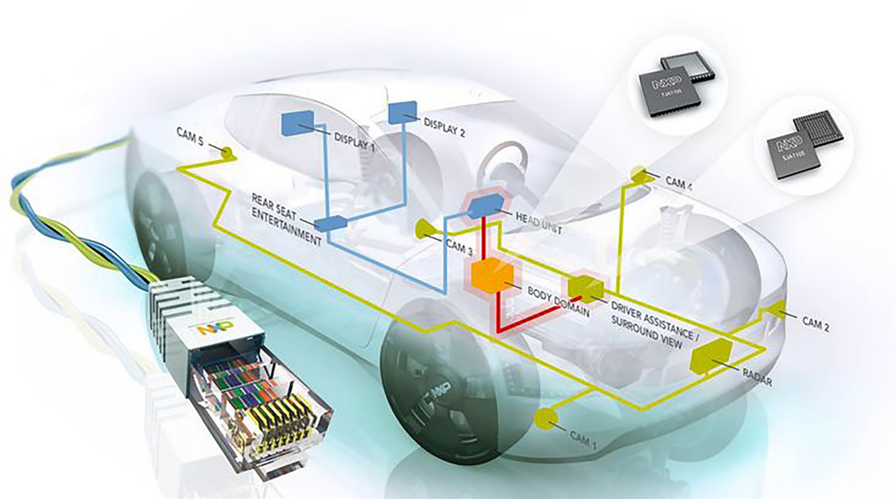


Figure 13: Video data processing based on the ethernet audio video bridge
Source: NXP

Ethernet AVB connects infotainment devices such as speakers, microphones, navigation systems, radio tuners, and smart headrests within the car network and provides high bandwidth and flexibility. Ethernet AVB stack includes protocols such as IEEE 1722a AVTP, IEEE 802.1AS, 802.1Qav, 802.1Qat – see figure 13.

IEEE 1722a can transmit more flexible, higher-density video data streams than an analog-based camera. The 100 Mbps for video transmission has become insufficient for today's connected cars. So, the industry has moved towards 1 Gbps over a single twisted pair – standards bodies are considering speeds of up to 10 Gbit/s.

Five challenges automakers face for seamless passenger infotainment

Automakers need to answer a fundamental question – how will video consumption in the car network differ from consuming video outside the car? The answer is not straightforward. Quality of service (QoS) will be critical because the car network must be able to stream video in a car traveling at 150 kilometers per hour – see Figure 14.

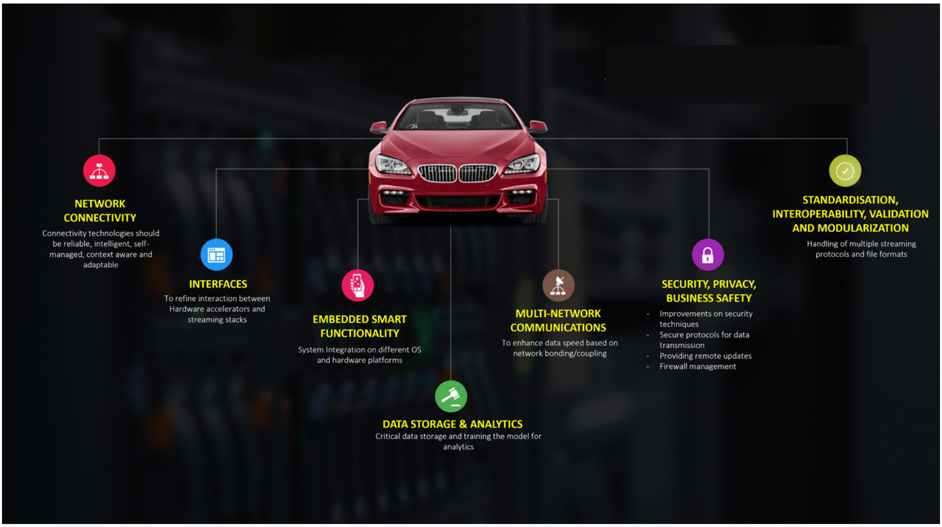


Figure 14: IVI design challenges in the connected car ecosystem
Source: Capgemini Engineering

Video is considered a necessity for media streaming applications in the connected car. However, there are many software and hardware system design challenges for receiving video feeds and transmitting live video – see Figure 15. The e-cockpit platform resides inside the car and is the primary interface between various RSEDs.

There are three challenges specific to video handling and the challenges for entertainment applications that require more focus during implementation.

Challenge 1: bandwidth issues, network latency, congestion, and failovers

The behavior of cellular network quality is difficult to predict, where the average bandwidth utilization and round-trip time (RTT) supported by the cellular network, for example 3G, 4G, and 5G, are key indicators of the quality of cellular networks. The other characteristics, such as stability and predictability, also make a big difference when it comes to video streaming in the connected car traveling at 80-100 km/hour. For example – a video session initiated by a passenger from their RSED for streaming video, music, and games requires sufficient network bandwidth to and from the car network to handle multiple sessions that are simultaneously connecting over the cloud – see Figure 15. Sometimes, the e-cockpit takes too long to receive data from the external streaming server hosted by the MNO on the cloud, or some chunks of video and audio data can get blocked due to heavy cellular network traffic congestion that leads to delay and packet loss.

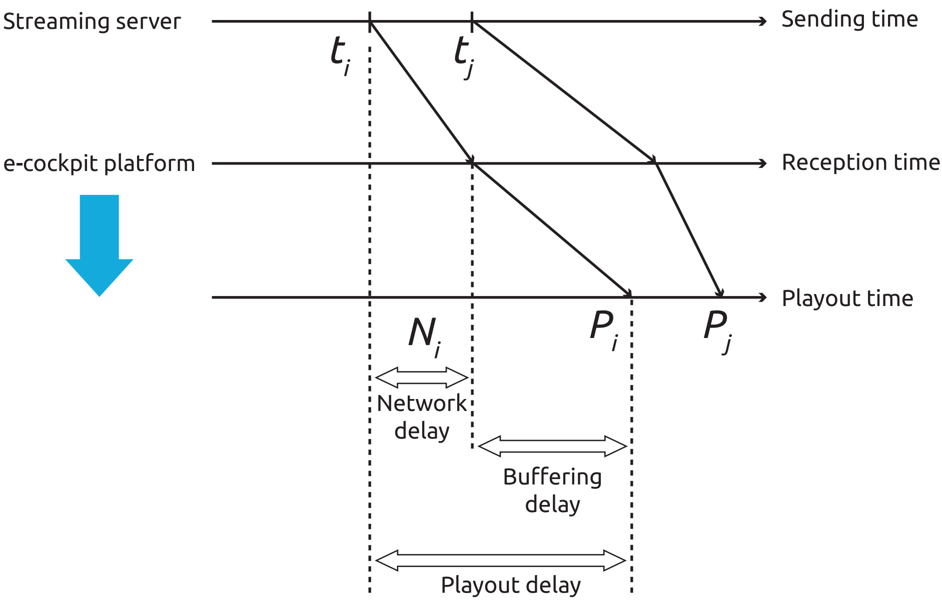


Figure 15: Challenges around latency and congestion
Source: Capgemini Engineering

Live video streams are viewed mainly by passengers on RSEDs, and the driver on the e-cockpit platform in park mode. However, unstable or inconsistent streaming quality may cause passengers to stop watching the video stream. To overcome this challenge and provide better streaming quality requires connectivity and seamless handoffs between the 3G, 4G, and 5G cellular networks and Wi-Fi hotspots. Further, the connectivity can be done by network bonding and coupling by interfacing with two different networks, for example 3G and 4G, to deliver a high-quality experience to passengers watching entertainment videos or playing games – see Figure 16.

The other possible scenario is to capture moments from family members traveling in the car and transmit the live video to friends and relatives over a cellular network. The data rate needed will be high and will require network bonding to transmit HD video quality – see Figure 17.

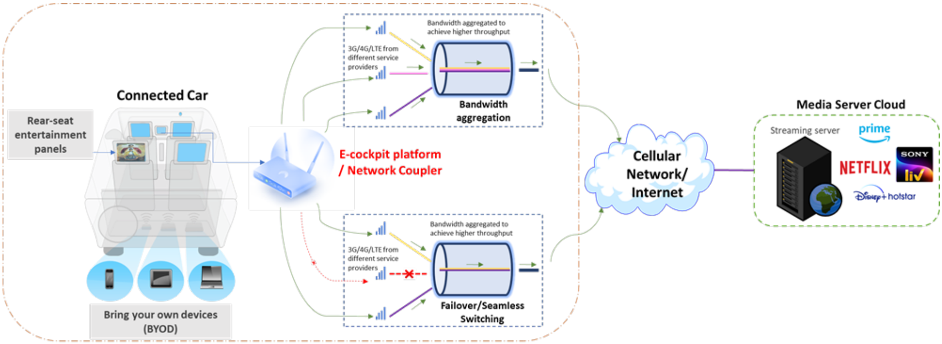


Figure 16: Network bonding and connectivity for receiving the media data from the cloud to the car
Source: Capgemini Engineering

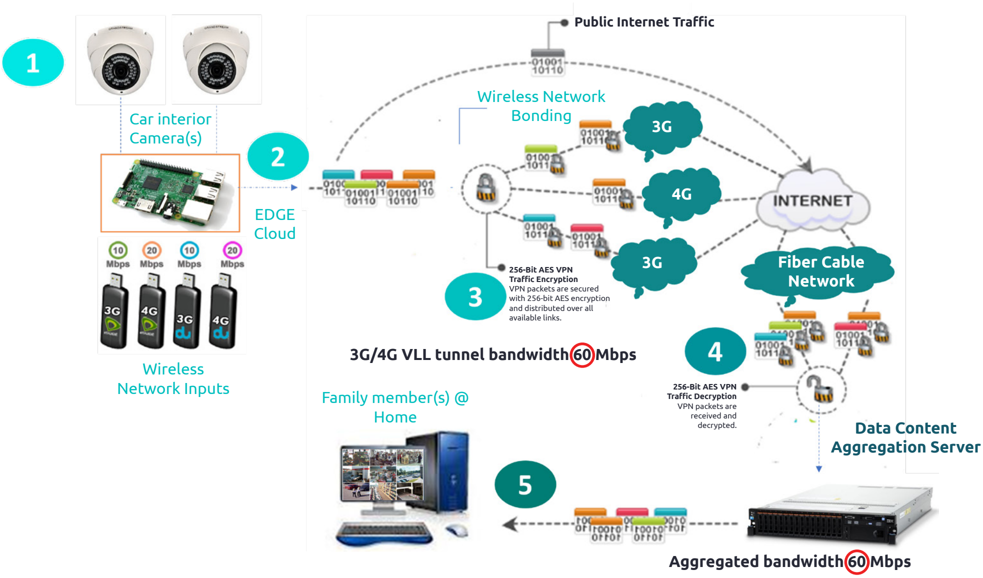


Figure 17: Network bonding or connectivity for transmitting video from car to home network
Source: Capgemini Engineering

Challenge 2: data storage, either local or in the cloud

Storing critical video data locally for analysis requires a large video storage capacity in the connected car depending on user requirements – see Figure 18. Since video transmission to the cloud requires a lot of bandwidth, the cost of storing and accessing video in the cloud at a later stage can be expensive.

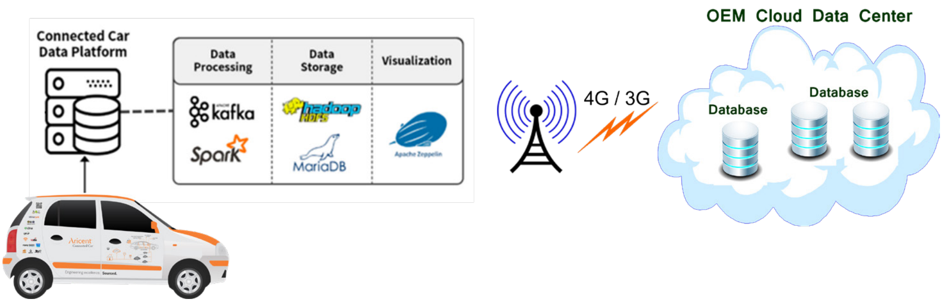


Figure 18: Local data storage
Source: Capgemini Engineering

Challenge 3: using machine learning to improve video quality

Enabling machine learning for video quality measurement can simplify and accelerate the performance of the overall IVI system for the connected car, where a supervised learning technique can be used to learn the performance of the key parameters of HD video codecs for different media format, for example H.265, MPEG. Further, the reinforcement learning technique can be used to continuously improve the video codec and its compression parameters with minimal effort. This makes it possible to automate codec creation for building the data pipeline in the e-cockpit platform for both encoding and decoding – see Figure 19.

As the connected car evolves, video will play an increasingly important role in the network to entertain passengers. With the emergence of autonomous vehicles, enhanced wireless network connectivity and improved network coverage offered by MNOs will deliver more screen time in the car and a better-than-home experience for passengers. As network coverage expands, the e-cockpit, RSEDs, and BYODs such as tablets and smartphones will be able to play many types of media content such as HD video, MP3 audio, and FM radio. In addition, video services on the connected car can be enabled on the fly to provide media content and related personalized information that matches a passenger's interests.

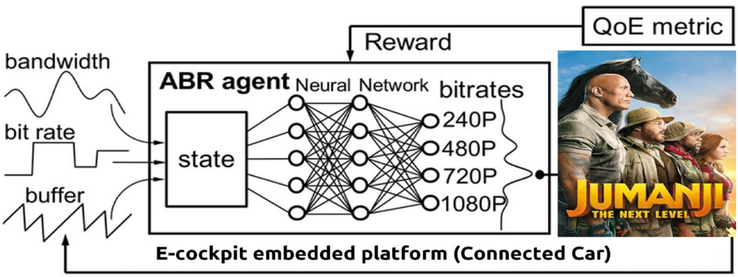


Figure 19: Machine learning to improve video quality playback
Source: Capgemini Engineering

Different parameters need to be predicted using modeling and learning, where the data can be quite noisy and can fluctuate in various aspects. For example:

- Can we predict what throughput will look like for the connected car at a speed of 80Km/hour in the next 15 minutes, given the last 15 minutes of entertainment data?
- How much historical information can be stored in the e-cockpit embedded platform for the video playback experience on RSEDs?
- What kind of metadata can be provided from the media server hosted in the cloud that would allow the e-cockpit and RSEDs to adapt the media bitrates optimally?
- Even if we cannot predict precisely when cellular connectivity – 3G or 4G will drop – one of the factors could be a long tunnel while streaming – is it possible to characterize the distribution of the video-data throughput that can be expected given the historical data?

Since the cellular network coverage and data rates fluctuate, technologies such as adaptive bitrate streaming, i.e., – MPEG-DASH, local content caching, and pre-downloaded content can deliver a reliable user experience for passengers on their RSEDs – see Figure 20. The quality of the entertainment experience can be measured in several ways:

- The initial amount of time spent waiting for the video to play on the RSED
- The overall video quality experienced by the passenger
- The number of times playback pauses to load more video onto the buffer
- The amount of perceptible fluctuation in video quality during playback

When there is poor network connectivity in spite of network bonding enablement, the caching technique on the e-cockpit embedded platform can be automated to ensure that all the important frames are cached to provide a better end user experience.

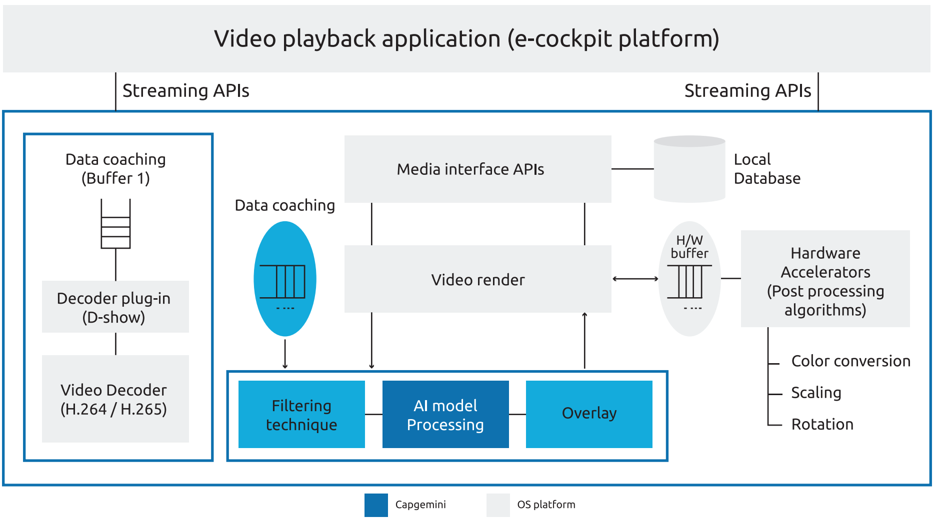


Figure 20: Embedded design to improve video quality playback

Source: Capgemini Engineering

Video streaming in some regions and countries with no audio or video reception is a big challenge. Fortunately, there are workarounds for streaming solutions to address this challenge. With the support of location-based applications based on the car's current location in the coverage area and the journey's destination, the streaming stack that runs on the e-cockpit platform can prefetch the data, so passengers can continue using their RSEDs even with an unstable network connection. As more cars are connected to the internet, the expansion and advancement of wireless network connectivity with LTE-Advanced Pro and 5G make it possible to consume a sizable amount of video data streaming and video data transmission to and from the car ecosystem.

Since there are many observations made, there is a clear opportunity to bring more complex models that can combine temporal pattern recognition with various contextual indicators to make accurate predictions of video quality from the cellular network.

The Capgemini Engineering POV spans both entertainment and safety

Our perspective on video-based solution design for the connected car spans both entertainment and safety. Capgemini Engineering provides many features for both drivers and passengers – see Figure 21. Most importantly, the performance of streaming cannot be compromised. This is especially true for high-speed highway driving, where the car must stay connected and recover quickly as it connects with different wireless connectivity endpoints.

Figure 21: Video specific scenarios and applications in the connected car ecosystem

Source: Capgemini Engineering

As video evolves to provide more advanced safety and entertainment features in the connected car, video analytics enhance entertainment and safety applications by addressing new opportunities in connected and emerging autonomous vehicles. Video analytics at the edge of the connected car drives proactive, predictive, and productive results more efficiently for both the driver and passengers.

An evolution of wireless connectivity is taking place in the connected car market. Carmakers are attempting to create unique business opportunities that fulfill service requirements and user expectations for IVI. The next-generation e-cockpit platform based on emerging SoCs from Tier-1 chipmakers will be a central access point for OEMs to offer differentiated entertainment services for drivers and passengers to enjoy a seamless experience. It will act as the connected car's connectivity hub allowing various interfaces required for handling the entertainment, such as 4G, 5G, Wi-Fi, and ethernet AVB – as well as middleware protocols and frameworks, such as RTSP/RTP/RTCP, MPEG DASH, HLS, HTTP-PD, DLNA, IMS/SIP, Miracast and other related applications, to be merged into the e-cockpit platform.

Conclusion

The growth of the connected car market is being fueled by end-user demand and expectations of advanced entertainment and enhanced safety features. The connected car will become the standard in the not-too-distant future. The in-car entertainment system will play a significant role, and so will large HD entertainment passenger RSEDs, quality of HD content, and integration with the car's e-cockpit.

Today, 4G is the standard connectivity service for the connected car, providing decent bandwidth for streaming video content. However, the cellular connectivity that will be fitted into all new vehicles will be based on the evolving 3GPP R16/R17 standard and will likely be 5G ready. In addition, it will support short-wavelength radio signals, and have more integrated radio antennas that deliver a superior experience compared to smartphones. As a result, the car will become a reliable 5G access point, with broad network bandwidth, low latency, higher throughput, increased reliability, and an all-in-one infotainment experience for drivers and passengers – see Figure 22.

The combination of advanced software capabilities and new SoC platform designs with the emerging 5G network design will transform the car into an OEM-branded communications hub offering entertainment, advanced passenger and driver safety, and many other value-added services. In addition, 5G technology will enable autonomous driving and connected ecosystems. Combining AI with 5G will deliver more sophisticated services in the future for the driver and passengers.

Figure 22: Coming soon: the 5G connected car
Source: Continental

Author

Vijay Anand,

Senior Director, Technology,
and Chief IoT Architect,
Capgemini Engineering

Vijay plays a strategic leadership role in building connected IoT solutions in many market segments, including consumer and industrial IoT. He has over 25 years of experience and has published 19 research papers, including IEEE award-winning articles. He is currently pursuing a Ph.D. at the Crescent Institute of Science and Technology, India.

About Capgemini Engineering

Capgemini Engineering combines, under one brand, a unique set of strengths from across the Capgemini Group: the world leading engineering and R&D services of Altran – acquired by Capgemini in 2020 – and Capgemini's digital manufacturing expertise. With broad industry knowledge and cutting-edge technologies in digital and software, Capgemini Engineering supports the convergence of the physical and digital worlds. Combined with the capabilities of the rest of the Group, it helps clients to accelerate their journey towards Intelligent Industry. Capgemini Engineering has more than 52,000 engineer and scientist team members in over 30 countries across sectors including aeronautics, automotive, railways, communications, energy, life sciences, semiconductors, software & internet, space & defence, and consumer products.

For more information please visit:
www.capgemini-engineering.com

Contact us at:
engineering@capgemini.com