A New Architectural-Approach for Next Generation Automotive Applications

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Abstract

The automotive FM-tuner has evolved to a headunit which provides various functionalities to the passengers, e.g. navigation, audio/video-player and car-control functions. The customer demands are further increased by current smartphone and personal computer capabilities. Hence the development of appropriate architectures for the next generation of automotive applications, which facilitate such enhanced functionality, is a current research topic. As new applications in general require more hardware capabilities the traditional approach of integrating more and more functionalities into a powerful 'thick' headunit causes difficulties. With respect to the longer operating lifetime of vehicles, compared to most consumer electronic products, the hardware capabilities are becoming a bottleneck for the integration of future functionalities. This paper proposes an alternative approach to cope with that issue by use of an application delivery platform, accessed via wireless networks. In addition, requirements for wireless access networks are identified and first estimations on performance are made.

Keywords

Vehicle Communication, C2X, Automotive, Infotainment, Web of Services

1. Introduction

During the last decade the software embedded in cars has increased exponentially. Today's premium cars have more than 10 million lines of code distributed over up to 70 Electronic Control Units (ECUs) (Broy, 2006). The FM-tuner has evolved to a general-purpose headunit which integrates more and more functionalities such as navigation, phone, audio/video-player and also car-control functions (e.g. air-conditioning, driving-mode). The customers have demands for the same variety and flexibility of functionalities on next generation of automotive applications as they are used to having on their personal computers and smartphones. The architectures of the next in-car infotainment systems have to facilitate those. Additional functionalities in general require more computational power and memory. This poses a problem for the traditional approach of integrating new applications into the headunit ('thick headunit' approach) - especially in respect to the long lifetime of cars.

In this paper a new architectural approach of a thin headunit as a solution for the next generation automotive applications is proposed. This approach utilizes the fact that many new functionalities come along with mobile internet connection of the vehicle.

This paper is structured as follows: At first two basic architectural alternatives will be discussed. Beginning with the traditional thick headunit approach this paper motivates a new thin headunit approach. Afterwards first assumptions on the impacts of requirements regarding the wireless access network are made.

2. Architectural alternatives

As depicted, there is a high demand for new innovative or improved automotive applications. Thus future architectures for headunits have to facilitate innovative functionalities. Similar to personal computers and smartphones the fast and easy adding of applications during lifetime is requested. Also continuous update mechanisms for maintenance purposes are necessary. Two basic alternative architectural approaches will be discussed in the following: thick and thin headunit. This paper focuses on the technical problems which have to be solved and does not discuss cost issues. It is well understood that the wireless access and the storage of data in the network need very strong security protection, but security will not be discussed in detail within this paper.

2.1. Thick headunit

A thick headunit constitutes the continuation of the traditional development approach. It integrates more and more functionality, by installing new software applications. For that purpose AppStores, already known from actual smartphones, are currently discussed (Grunert, 2009) as mechanisms to provide new functionalities to the customers. Because of the historically highly specialised software of headunits (Pretschner et al., 2007), new operating systems, respectively software frameworks, are under development to facilitate open and individual automotive headunits. Examples are the Android based AutoLinQ or MeeGo.

Nevertheless, the integration of new functionalities into the headunit during its lifetime generally increases the requirements against the hardware. At least more memory is needed, but most of the enhanced applications also require more computational power. The studies showed that current headunits in many use-cases already working at their full CPU load with their factory range of functions. Therefore the hardware capabilities of headunits are an issue that has to be considered while discussing next generation of automotive software. These circumstances intensify if the average age of cars is taken into account. While consumer electronic products like smartphones and personal computers are usually replaced every 2-3 years, the vehicles in Germany have an average age of 8 years (KBA, 2010) and the OEMs have to maintain the vehicle at least 15 years.

Innovative automotive software is not only a requirement related to software architecture. By continuing the traditional approach of thick and powerful headunits, concepts for upgrading and replacing the headunits' hardware are required. Those difficulties motivate an alternative approach which will be discussed subsequently.

2.2. Thin headunit

Future innovative automotive software applications are accompanied by connecting the vehicle to the internet. Fully aware of the challenges for such network connections like high and variable vehicle velocities, tunnels etc. it can be expected that the capabilities of wireless access networks are continuously rising, which motivates the new approach of a 'thin headunit'. The basic idea is moving functionalities from the in-car domain into a centralized application delivery platform, accessed through a communication network (see figure 1).

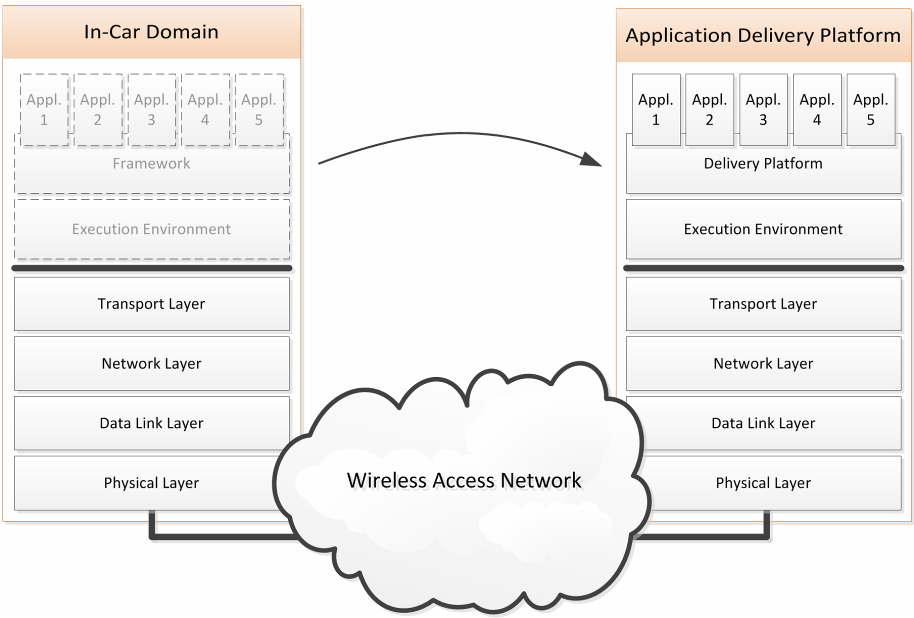

Figure 1: Abstract network-layer-centric view

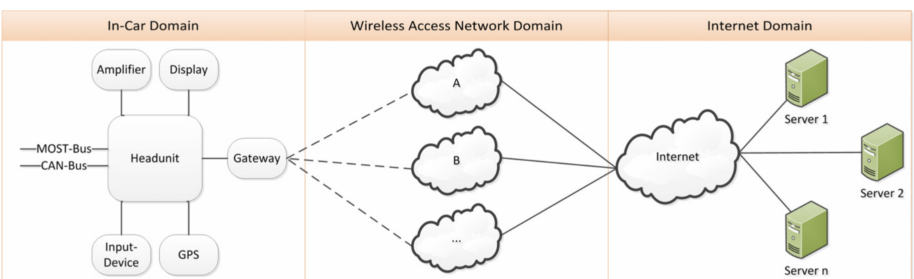

Figure 2: Overall technical architecture view

More precisely, the in-car applications are provided by one or many server(s) and have to be accessed via wireless access networks (see figure 2). The remaining headunit is a thin terminal, connecting the in-car display, speakers, input devices, and internal bus-systems to the access network.

This approach moves computational- and memory-intensive functionalities to the web, where it can be assumed that ‘infinite’ processing and storage resources are available and processing is well organized and managed. Having the most dynamic parts of the embedded infotainment system outside the in-car domain makes it easier to add new applications after market launch, meaning during the systems’ lifetime since the hardware capabilities of the headunit have less significance. For example if an enhanced 3D-navigational map requires 200 MHz more computational power – just add it to the server. If the passenger would like to have 10 GBytes more memory for his audio files – just add it to the server. In both examples the requirements for the in-car part of the system remain constant: Displaying an enhanced 3D-navigational map requires transferring the screen with a defined resolution, frame rate and colour depth. Playing an audio-file means transferring one audio-stream per time, independent of the amount of tracks contained within an audio library. Hence the need for headunit’s hardware upgrade becomes less important.

Beside use-cases for vehicles as service consumers, use-cases as service generators are currently investigated in many research projects dealing with advanced traffic safety and traffic efficiency scenarios. The generic term is c2x (car-to-x) communication which stands for the communication of vehicles among themselves and with infrastructure e.g. traffic lights. While sensitive traffic safety services may be handled by means of highly specialised communication technologies, all other services are supposed to be handled via public wireless access networks. This approach offers a new view on the discussed c2x scenarios: Realisation of safety uncritical use-cases as applications within a centralized application delivery platform turns many c2x communication scenarios into ‘simple’ server to server communication scenarios.

Further, the realisation of next generation automotive applications using a centralized application delivery platform improves maintainability, because the servers can be accessed at any time. Software updates can be performed immediately without physical access to the vehicles.

The new thin headunit approach in particular generates requirements to the wireless access network. First rough assumptions are depicted in the following.

3. Wireless Access Network Requirements

For the thin headunit approach the wireless access network is the enabling technology. It has to ensure that the services, provided by a centralized application delivery platform, can be used in the vehicle with a suitable quality. It has to be investigated, how a wireless access can be provided, which is sufficiently stable and provides sufficient capacity for transporting the required mixed communication traffic. A first rough approximation of uplink and downlink traffic, offered for selected use-cases, is given in the following.

3.1. Bandwidth

A central requirement for the wireless access network is to provide sufficient bandwidth and stability for the applications. The required bandwidth is being considered separately for the uplink-/downlink directions. At this stage we do not yet consider a specific wireless access technology and therefore we neglect additional load, such as protocol overhead.

3.1.1. Upload per headunit

With a thin headunit, which does not perform any pre-filtering, all information on the connected internal bus systems have to be uploaded. The CAN (Controller Area Network) is common for infotainment and car management purposes. Depending on the OEM and vehicle series it operates with speeds up to 125 Kbit/s which therefore can be assumed as necessary upload bandwidth. Since all input devices are connected to this bus, the application control data is already covered as well as the geographical position, the speed, the heading and other vehicular information related to service generation use-cases.

For some special use-cases like speech recognition for headunit control commands or navigational destinations, an additional 192 kBit/s for audio upload with MP3 or AAC codec is needed temporarily.

3.1.2. Download per headunit

For modern infotainment systems an 8 inch display with a resolution of 800x600 pixels can be assumed. All displayed data has to be received via the wireless access network. The hardest requirement is to display a video, because of the necessary high frame rate. For a DVD video with a resolution of 752x480 pixels (nearly fullscreen), making use of an actual video codec like h.264, at least 1 Mbit/s can be assumed. In case of displaying simple configuration menus mechanisms comparable to VNC (Virtual Network Computing) respectively RDP (Remote Desktop Protocol) may perform well. They show adequate results with much less than 1 Mbit/s on average (Yang et al., 2002).

Furthermore audio data such as navigational announcements or music have to be transmitted. Current MP3 or AAC codecs are providing good results with bandwidths from 128 kbit/s through to 192 kbit/s. Latest codecs already enable surround sound at those bitrates (Rose et al., 2008).

Finally some application data has to be transferred to the internal bus systems. As previously described the CAN works with speeds up to 125 kbit/s. Since many ECUs are connected to this bus, the share of the headunit is assumed to be 20 kbit/s on average.

3.1.3. Total per headunit

The given assumptions lead to a necessary bandwidth of approximately 1.5 Mbit/s downstream and 0.5 Mbit/s upstream per vehicle. This bandwidth also has to be available while the vehicle is moving, even with high speeds up to 250 kph.

3.1.4. Assumptions per wireless access network cell

Assuming that every vehicle has a thin headunit the wireless access network has to provide a multiple of the per vehicle bandwidth within a certain area. The total available bandwidth of the wireless access network within a wireless cell is divided by all of its members. The highest vehicle density occurs in city or traffic jam scenarios, where many vehicles are driving with quite low speed and hence small inter-vehicle-space. Assume a 6-lane motorway traffic jam scenario, where approximately 5 m long vehicles are driving with an average speed of 10 kph with an assumed inter-vehicle-space of 5 m. This leads to 600 vehicles per 1000 m motorway. If 25 percent of all vehicles are using a thin headunit the wireless access network has to provide up to 225 Mbit/s of download-bandwidth and up to 75 Mbit/s of upload bandwidth per 1000 m cell size.

3.2. Further requirements

Beside the bandwidth the wireless access network has to meet further requirements to enable the proposed thin headunit approach. The most important ones are briefly presented in the following. Since several decades of research, it is well known that mobile radio channels are unreliable, varying with time and location (Jakes et al., 1994; Hata 1980; Parson 1992; Rappaport 1996), are absolutely limited by the allocated radio spectrum and require special procedures for accessing the common medium (Goodman 1989; Fuhrmann 1994).

Bit error ratio: Average bit error ratio is much higher than in wired access networks. This requires strong forward and backward error correction procedures, depending on the application.

Latency, Jitter: Some applications are delay critical and require fast responses, e.g. speech recognition, voice calls, user interactions. They need low latency of the wireless access network. Especially audio applications need a low variance in delay (jitter). As different applications may run in parallel (e.g. voice call and navigation) adequate Quality of Service (QoS) profiles have to be accessible to provide an appropriate network quality.

Coverage: Vehicles are able to reach far-off areas, tunnels etc. The discussed approach demands for an adequate coverage of the accessible areas.

Seamless handovers: Handovers between different wireless access network cells or technologies have to be seamless by means of no disruption of the ongoing communication occurs.

Security, Privacy: The transmission of vehicle data e.g. the current geographic position and speed is sensitive. The networks and application server delivery platforms have to provide secure communication. Further mechanisms have to be applied to protect the users' privacy (also referred to as informational self-determination).

New wireless standards, such as Long Term Evolution / System Architecture Evolution (LTE/SAE) of 3GPP (Holma et al., 2009; Olsson et al., 2009) define a wireless access framework, which in combination with other wireless technologies potentially provide the necessary functional building blocks to realize the proposed wireless access approach.

4. Conclusions and Outlook

It has been shown that there is a demand for innovative automotive applications. Motivated by the issue of rising hardware limitations for new applications regarding to the traditional software architecture, a thin headunit approach was proposed. This approach, however, requires intensive wireless communication between cars and fixed infrastructure.

Future research activities have to detail those requirements and have to analyse how wireless access networks can meet them. These issues will be investigated using practical experiments in the in-car multimedia lab in Darmstadt and using extensive simulation. The simulations will be carried out using ns-3 (ns-3, 2010) where we have started adding required modules.

It has to be further investigated how applications for the application delivery platform have to be designed for most effective network utilisation. Depending on those results some use-cases might be identified that have to be solved inside the car because of their special requirements. Further, the realisation of in-car applications on centralized application delivery platforms potentially generates privacy and security issues. Related threats have to be identified.

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