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Making Sense of the Smartphone-Vehicle Cacophony

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Abstract

Automakers must accommodate the long lifecycles of their vehicles, which are measured in years and decades, and the short lifecycles of consumer devices, specifically smartphones, which may become dated or even obsolete in less than two years, and the even shorter lifecycles of applications that may require upgrades or renewals every few months.

Automakers, their suppliers, and smartphone vendors all seem to agree that the solution involves some sort of integration of the smartphone and the in-vehicle head unit. There, however, the agreement ends, and today we have a veritable cacophony of solutions, each with its merits and its weaknesses.

In this paper we offer brief, non-technical reviews of these solutions, and we make some suggestions we hope will help automakers and their suppliers decide how best to approach the problem and ensure that their infotainment systems will remain current for the life spans of their vehicles.

Silicon, Steel and Smartphones

The advent of connected in-vehicle infotainment systems has added a new dimension to vehicle buyers' decision matrix, and a new demand to the many challenges automakers already face. While it is unlikely that buyers will choose a particular vehicle only for its infotainment system, these systems do factor increasingly into purchase decisions. It is quite probable that buyers will now strike a vehicle off their evaluation list if it does not include an attractive and viable infotainment system, in the same way that a few generations ago they might have passed up a vehicle that did not include a radio.

Automobile development and lifecycles are measured in years, even decades, but new consumer electronics are launched, upgraded, and sometimes even rendered obsolete in months. Consumer electronics are also easier and less expensive to replace than cars. This is certainly true

of smartphones, which now work (and may sometimes compete) with in-vehicle head units to bring drivers and passengers the most compelling in-vehicle infotainment systems possible.

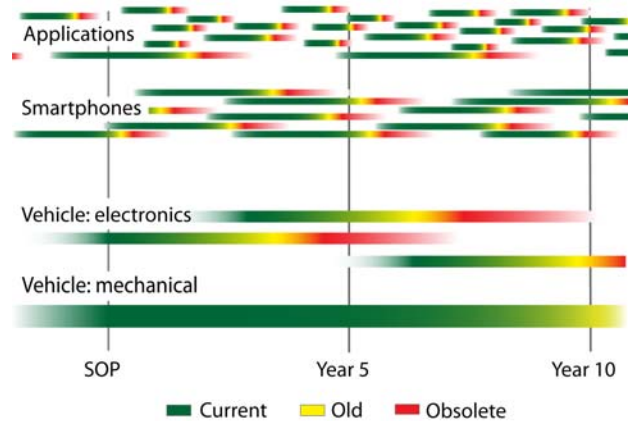


Figure 1: Comparison of vehicle and smartphone lifespans.

Manufacturers are thus faced with reconciling the development- and lifecycles of their vehicles and the lifecycles of the rapidly becoming ubiquitous smartphone. Unlike older generation cell phones, whose functionality did not go far beyond making and receiving calls, and sending and receiving text messages, smartphones are designed to do just about everything or more that an in-vehicle infotainment system can do. Conversely, in-vehicle systems are increasingly becoming connected; they can now do just about everything that a smartphone can do — except fit in a pocket or purse.

These developments appear to offer the best of both worlds: consumers can get what they want, either from their in-vehicle system or from their smartphone. Ideally, the user experience should be seamless. For example, toddlers watching a movie in the living room on Saturday morning can be pulled from the living room floor, plunked into their car seats and continue watching the movie on the way to

Gamma's. The reality is not quite so rosy, however. The difficulty and the cost of building and — just as importantly, maintaining — such seamless solutions are considerable, though the cost of ignoring the problem is quite likely far greater. No user seems to want to manage multiple devices and sources, and maintain distinct phone contacts, music and video libraries, games, and so on in the house, in the car, and on every smartphone in the household. Any automaker (and perhaps smartphone vendor) who ignores this reality does so at his peril.

Seen in the context of engaging vehicle buyers in a positive user experience, the vehicle-smartphone problem has two parts: how best to integrate in-vehicle systems and smartphones in the vehicle, and how to ensure that the integration strategy will remain viable throughout the life of the vehicle and multiple generations of smartphones — not to mention as yet unknown applications for these smartphones.

The solutions currently being discussed and implemented range from turning the head unit into little more than a conduit for whatever the smartphone passes through it to screens and speakers, to handing all control over to the head unit, which uses the smartphone as little more than a conduit to the cloud, or does not use it at all.

Embedded

With the embedded model (which is already in use in millions of vehicles) the vehicle head unit is responsible for the HMI, all applications, and connectivity.

Advantages

The embedded model has many advantages:

Connectivity — vehicle antennae are larger and more powerful than mobile phone antennae; and multiple antennae placed on vehicles exteriors provide better connectivity than cell phones, especially where cell network coverage is poor. Recognizing this, some in-vehicle systems, such as OnStar, even allow time on the vehicle phone to be billed to mobile phone accounts.

Safety and security — with no reliance on external devices (a smartphone), applications in the vehicle itself, and a more powerful antenna, embedded systems are less



Figure 2: The embedded model connects directly to the cloud and benefits from the more powerful vehicle antennae.

vulnerable to mishaps. For example, connectivity and functionality will not be lost because the driver has forgotten his smartphone.

HMI and branding — with full control of the user experience, automakers can use their infotainment systems both to differentiate their vehicles from the competition's offerings, and to reinforce their brand.

Disadvantages

Placing everything in the vehicle head unit has some disadvantages that weigh in against this model's many advantages. Chief among these are:

Cost — in exchange for control over the complete user experience, the automaker bears the costs of developing and adapting applications to offer a full range of features and capabilities.

Updates — to keep their systems current automakers must devise a strategy for reconciling the lifecycles of consumer devices and applications with their vehicles' lifecycles

Usability — while automakers can control the complete user experience offered by their infotainment systems, users may want to continue using their smartphones (with their applications) integrated with the in-vehicle system.

Billing — a separate phone in the vehicle means either that the user receives two separate phone bills, or that the vehicle manufacturer and mobile phone service provider must successfully negotiate joint billing agreements.

Tethering

As with the embedded model, with tethering applications reside in and run exclusively on the vehicle head unit. The smartphone is relegated to tethering the in-vehicle system;

that is, it provides connectivity to the cloud and not much else.

Advantages

The advantages of tethering are chiefly in the realm of vehicle independence from the smartphone:

Independence — the system depends on the smartphone only for connectivity. Users can change or upgrade seamlessly to most phones.

Control — with applications residing and running only in the vehicle head unit, the automaker has complete control over them, and can filter what gets out to the driver and passengers and how it looks.

HMI and branding — with the HMI in the vehicle, the automaker defines how it looks and behaves, and how it is branded, and can thus use the infotainment system to reinforce brand recognition and loyalty.

Simplicity — there is no need to develop and re-develop interfaces for the plethora of phones on and coming on the market.

Disadvantages

Tethering has some disadvantages that can seriously reduce its viability:

Network opposition — tethering uses the smartphone as nothing more than a data pipe for the in-vehicle system. Telecommunications service providers may resist use of their networks to tethering. They may charge extra fees or even prohibit tethering, considering that it violates the terms of use of for their networks.

Cost — automakers must develop or adapt the applications they want available in their vehicles; this requires a considerable investment of time and money.

Updates — automakers are responsible for keeping their applications current, and must, therefore, devise a strategy for reconciling the lifecycles of consumer devices and applications with their vehicles' lifecycles.

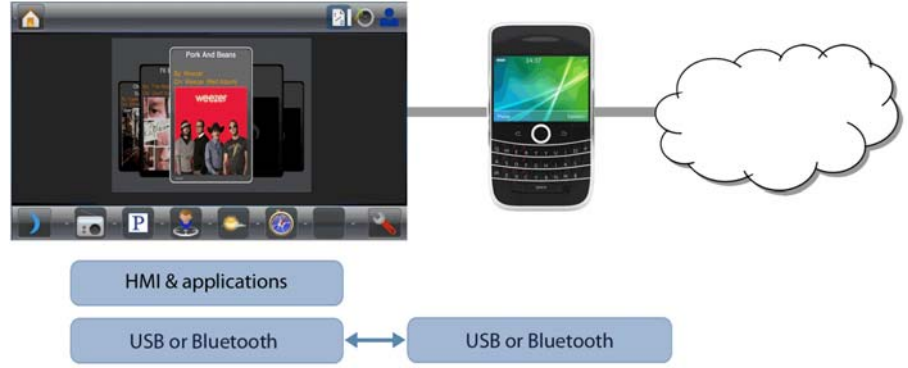


Figure 3: Tethering uses the smartphone as a data conduit and not much else.

Connectivity — connecting through the smartphone connectivity may in fact offer poorer service than connecting directly through the vehicle, which can have larger, more powerful antennae.

Cloud Services

The cloud services model is widely used by navigation applications, and is gaining acceptance with services such as Pandora Link or Stitcher. It can also be used to add value by providing improved or non-essential services. For example, a service might locate dealerships and give up-to-date information about their hours, and even wait times for specific services. Similarly, a navigation system might use a cloud service model to offer speech recognition, or to provide images, or traffic updates to maps in the vehicle database.

With the cloud services model, a small application on the vehicle head unit runs the HMI. The application itself runs in the cloud; that is, on the service provider's servers, somewhere, though an in-vehicle fallback application may also be included. The head unit connects to the service either directly, or through the smart phone.



Figure 4: The cloud services model can use the vehicle system and antennae or the smartphone to connect to applications running on remote servers.

Advantages

The cloud service model opens up new possibilities for in-vehicle infotainment systems:

New services — new features and services can be easily added to a vehicle's infotainment offerings.

User control — users can subscribe and unsubscribe to services offered through the cloud

Updates — updates and upgrades to applications are the responsibility of the service provider, though upgrades to the small in-vehicle HMI applications may occasionally be needed

Independence — connectivity can be directly from the vehicle, or through a smartphone.

Disadvantages

The cloud service model has some important limitations:

Connectivity — the cloud service model relies on a continuous, high-throughput connection to the cloud. It is of little use in areas with poor or no mobile coverage, for example, outside urban areas and transportation corridors, or in urban canyons.

Limited usefulness — the relatively high possibility of a cloud service becoming even temporarily unavailable restricts its usefulness to non-essential applications, or applications with "soft-failure" designs.

iPod Out

Apple introduced iPod Out with iOS4. This technology allows users to access their iPhone or iPod touch through their vehicle's infotainment system, and output content from the device to the vehicle speakers and screens.



Figure 5: iPhone output through a vehicle head unit.

With this model, the iPhone or iPod runs the show. It has the media libraries and applications, and it runs all applications and controls the user interface. USB or Bluetooth provide connectivity between the portable device and the vehicle. If an iPhone is used, it can be used to make and receive calls. After an initial handshake, the head unit does nothing more than serve as a conduit for audio and video from the device to the vehicle speakers and screens, and for commands from the in-vehicle infotainment controls (up, down, next, select, etc.), which are delivered to the device using the iPod accessory protocol.

Advantages

The advantages of the iPod Out model include:

Simplicity — the iPhone or iPod looks after everything. The automaker's responsibilities go no further than setting up the head unit to be able do a handshake with the Apple devices, pass them commands from the in-vehicle controls, and pass the device audio and video out to the vehicle speakers and screens.

Familiarity — the HMI is familiar to users, who, presumably, use their iPhones or iPods when they are not in the vehicle.

Future-proof — Apple can update iPods, iPhones and applications without automakers needing to change or revalidate anything to stay current

Car-centric interface — Apple developed the iPod Out interfaces in consultation with BMW to ensure that it is appropriate for in-vehicle systems. Limited options reduce possibilities for driver distraction.

While it is not, strictly, a design advantage, the popularity of iPods suggests that a vehicle infotainment system that did not implement iPod Out support will needlessly put itself at a disadvantage.

Disadvantages

Despite, or perhaps because of its simplicity, the iPod Out model has some drawbacks:

Dependency — with the head unit reduced to a conduit for commands and output, the entire system becomes dependent on what is offered by the external device — and on the future of this device.

Proprietary — iPod Out is only implemented by Apple. Unless they want to restrict their customers to only those who have Apple devices, automakers should

implement this model as a complement to other models.

Limited functionality — the iPod Out model only supports audio playback and mobile telephony. In order to ensure that the application HMIs designed for portable devices do not cause undue driver distraction, other applications are not accessible through the head unit.

UI design — users may find using both the iPod interface and the vehicle-specific interface irritating and even distracting.

Branding — with the iPhone or iPod providing and controlling the display, automakers lose the ability to maintain their vehicle brand in the infotainment system HMI. For example, a driver will not be driving, say, a Lexus with a great Lexus infotainment system, but a Lexus with an iPhone infotainment system.

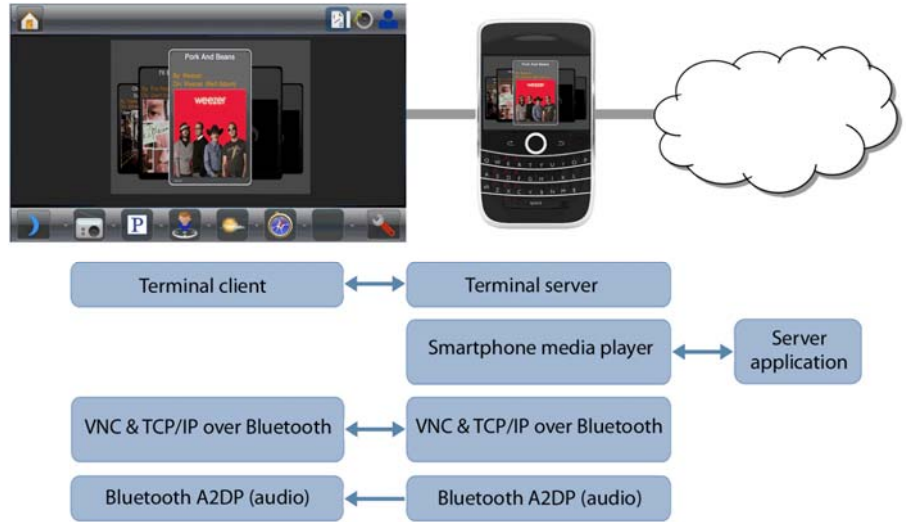


Figure 6: Terminal mode uses a VNC client on the vehicle head unit, and a server on the smartphone.

may be modified for in-vehicle use, and controls the applications on the smartphone through this replicated HMI.

Advantages

The advantages of terminal mode include, like the iPod Out model, simplicity and user familiarity with the HMI. Other advantages include:

Control — the vehicle’s infotainment HMI has control over scale and position of elements in the display, though not of content of these elements. For instance, the vehicle’s HMI can instruct the VNC client to scale the display from the smartphone to fit a portion of the in-vehicle display, say, navigation instructions into a corner of the infotainment display.

Non-proprietary — terminal mode can be implemented with any smartphone. It is not limited to a specific vendor’s products, though work is of course required to support different smartphone designs.

Applications and features — terminal mode can support whatever applications and features are available for the supported smartphones.

Disadvantages

Terminal mode carries many — but not all— of the same disadvantages as the iPod Out model, plus some additional drawbacks:

Usability — the HMI designed for a smartphone is replicated on the vehicle infotainment system’s display, and may be difficult to use.

Terminal Mode

Terminal mode provides solutions to some of the problems of the iPod Out model while keeping many of its advantages. As with the iPod Out model, with terminal mode applications reside in the smartphone, connectivity between the head unit and the smartphone is provided by USB or Bluetooth, and connectivity to the cloud is provided by the smartphone.



Figure 7: Terminal mode replicates the smartphone HMI on the head unit, which has some control over how and where it is displayed.

Unlike the iPod Out model, however, the smartphone does not simply push content out through the head unit to speakers and screens. Instead, the smartphone acts as a server to the head unit’s VNC (Virtual Network Computing) client. This client replicates the smartphone’s HMI, which

Safety — even with modifications, the HMI is not designed for in-vehicle use; it may thus distract the driver and even be dangerous.

Dependency —terminal mode is completely dependent on the smartphone to run applications and to access the cloud.

Retrofits—although the protocol supports applications’ displaying vehicle-specific HMIs, retrofitting applications is a significant undertaking. It might be easier to simply build a new HMI.

Remote Skin

The remote skin model can be summed up as terminal mode with tailored clothes. Instead of replicating the smartphone application-specific HMI, the vehicle infotainment system uses its own lightweight HMI. This HMI uses a TCP/IP connection to communicate with the smartphone over Bluetooth or USB. From the perspective of the smartphone, where the applications run, this lightweight HMI (or skin) is remote.

Advantages

The remote skin model offers some advantages over terminal mode, as well as compared to other designs that place more responsibility on the vehicle head unit. These include:

Simplicity — the remote skin doesn’t need to implement all application logic. It merely needs to provide the HMI veneer, and is thus cheaper and faster to build, test and implement than a complete application.

HMI design — by taking over HMI design, the remote skin model ensures that the user interface is appropriate for in-vehicle systems, reducing the risk of driver distraction. This model also allows manufacturers to reinforce HMI look and feel across all applications used in the vehicle.

Branding — with control of the HMI, manufacturers can brand applications being used in the vehicle, even if they are running on the smartphone.

Disadvantages

The remote skin model resolves the issues of in-vehicle HMI design and branding of the infotainment system. However, it does so at some cost, and it is not without its drawbacks:

Dependency — the remote skin model is highly dependent on the smartphone, since this is where applications reside and run.

Cost — building the remote skin is cheaper and faster than building complete applications, but it still requires design work, development and testing that that is not needed with the strict terminal mode approach, and this cost is usually born by the automaker. The cost of this development is compounded by the number and variety of smartphones which the HMI must accommodate.

Upgrades — as new smartphone models and applications come on the market, the automaker must upgrade the remote skin to accommodate them and keep the vehicle infotainment system current. Without a built-in mechanism for safe, sandboxed deployment, all new applications will require a new validation cycle.

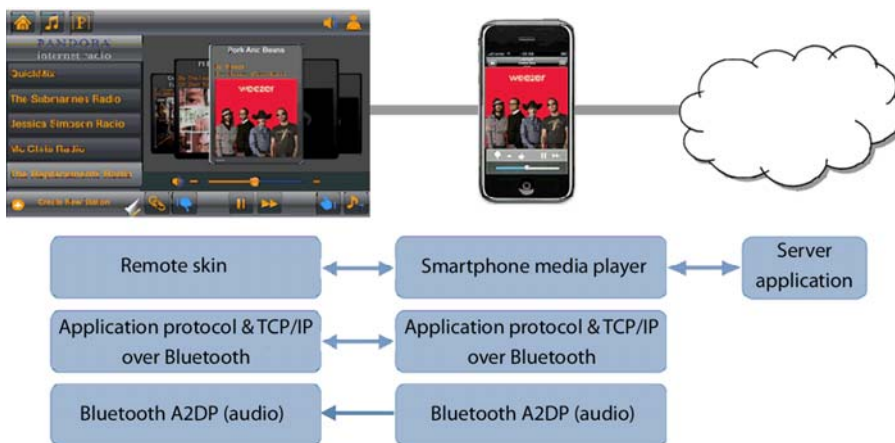


Figure 8: The remote skin model hands control of the HMI over to the in-vehicle system.

Simple UI Protocol

Simple UI protocol was developed by QNX and RIM with Harman Becker. It will soon be publicly available and open to all OEMs and Tier 1 suppliers. With this model, the vehicle head unit controls the applications, which reside and run on the smartphone. Bluetooth provides the connectivity.

Instead of replicating the smartphone HMI on the in-vehicle system, simple UI protocol transfers icons, text, and

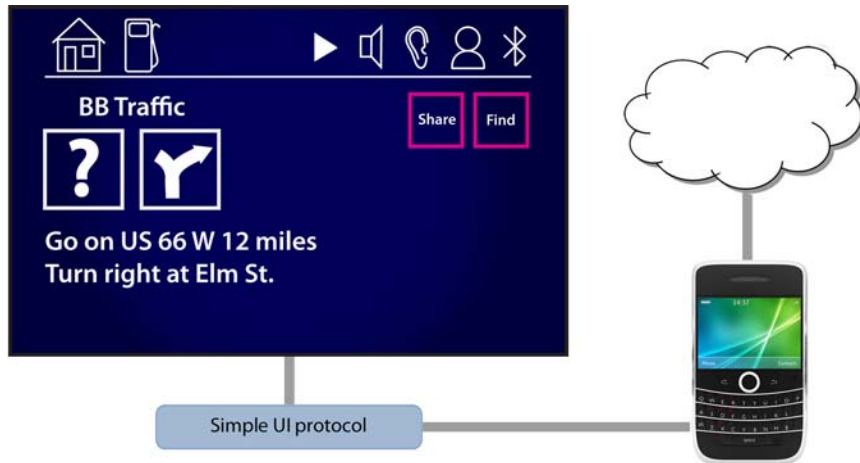


Figure 9: Simple UI protocol can be used to deliver a minimalist HMI to the vehicle head unit

labels for two application buttons to the vehicle head unit. The smartphone application can use this minimalist HMI any way it wants to provide users with a simple interface.

Advantages

Simple UI protocol offers some advantages over other models:

- Safety — simple UI protocol is designed specifically to reduce driver distraction.
- HMI — the minimalist HMI is easy to use with limited text, labels and buttons
- Adaptable — a smartphone application can use simple UI protocol on the vehicle head unit in whatever way is most appropriate for that application.
- Updates and upgrades — adding new smartphone applications that use simple UI protocol is simple, and it requires no revalidation of the in-vehicle system.
- Open protocol — simple UI protocol is an open protocol. It will be open to all OEMs, mobile phone manufacturers, and Tier 1 suppliers.

Disadvantages

- Like other models, the simple UI protocol has some disadvantages:
- Control — application and UI controls remain exclusively with the smartphone
- Connectivity — all connectivity is through the smartphone, and does not, therefore make use of the vehicle’s more powerful antennae

Summary

The number of proposed models for solving or mitigating the issues arising from the different lifecycles of vehicles and smartphones is an indication, not only of the importance of this problem for the automotive industry, but also of how difficult it is to find a viable solution to the problem.

Table 1 below presents a high-level comparison of responsibilities in the models we have examined. The majority of these models focus on leveraging the smartphone to increase the vehicle infotainment system’s capabilities, and to keep these

capabilities current. This bias is not surprising, and it is intelligent. These solutions attempt to solve the problem caused the smartphone’s short lifecycle by using this very characteristic of the smartphone.

As we have seen, no model proposed thus far is ideal. Considering the number of variables involved — the number and variety of vehicles and, especially, smartphones and their applications, and the speed at which smartphone technologies evolve, it is unlikely that there will ever be an ideal model, though one or two models may eventually come to dominate the market.

| | Application | HMI | Connectivity |
|--------------------|-------------|------------|--------------|
| Embedded | Head unit | Head Unit | Head unit |
| Tethering | Head Unit | Head unit | Smartphone |
| Cloud service | Cloud | Head unit | Either |
| iPod Out | Smartphone | Smartphone | Smartphone |
| Terminal mode | Smartphone | Smartphone | Smartphone |
| Remote skin | Smartphone | Head unit | Smartphone |
| Simple UI protocol | Smartphone | Head unit | Smartphone |

Table 1: A comparison of responsibilities in different in-vehicle infotainment-smartphone integration models.

For the foreseeable future, automakers will have to implement a blend of models based on the requirements of their specific markets. They may choose, for example, an

embedded system as the primary model, complemented by a remote skin implementation and cloud service; or they may choose to work with a smartphone vendor to design vehicle- and smartphone-compatible HMIs. They could then include these smartphones with their vehicles, place most applications on them, reserving the head unit for a minimal set of core applications.

If it is possible to draw any conclusions to this discussion, we might venture the following:

- In-vehicle infotainment systems must now integrate with smartphones.
- In-vehicle infotainment systems should be able to easily integrate new technologies, applications, and integration models.
- The in-vehicle system platform: board, OS and middleware, must be powerful, resilient, and flexible enough to accommodate multiple integration models.

Choosing an Application Platform

Staying current with the latest mobile content and services requires a new approach to upgrading infotainment systems. To leverage the pace of mobile development, automakers need an application platform that quickly supports new applications and content. At the highest level, the platform should:

- provide an HMI framework based on standards such as HTML 5, OpenGL ES, and Adobe Flash to simplify application development, enable remote skinning, and offer a visually engaging user experience
- support safe, in-field updates to take advantage of new capabilities in mobile devices
- support a variety of connectivity models, including direct internet connectivity and connectivity to consumer devices
- allow for easy, brand-differentiating customizations by automakers and their suppliers
- embrace industry standards to support a large ecosystem and a broad developer base
- use a safe sandbox to cleanly separate applications, and to keep core functions always operational

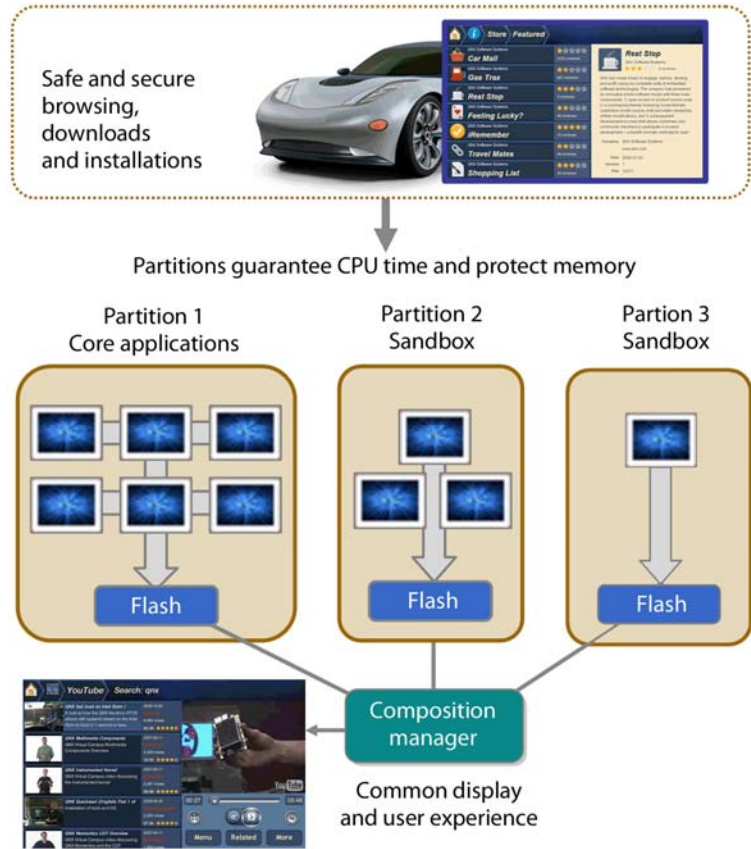


Figure 10: The cloud services model can use the vehicle system and antennae or the smartphone to connect to applications running on remote servers.

- scale across low-, mid-, and high-end systems, on a variety of hardware implementations

Figure 10 shows an in-vehicle infotainment system designed with partitions that protect core applications, while permitting download, installation and execution of any number of new applications.

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