

Analysis of Software Update in Connected Vehicles

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ABSTRACT

The substantial increase of electronic systems and processors in vehicles is increasing the already remarkable amount of software code, generating thousands of software-related recalls according to the National Highway Traffic Safety Administration (NHTSA), leading to frequent customer updates. Current software updating methods are inconvenient for customers and dealers alike, requiring a significant amount of time and expensive hardware to implement. With Wi-Fi technology and embedded modems entering vehicles, several OEMs have already taken an innovative approach with Over-The-Air (OTA) technology. OTA updating has shown to be a proven method in the telecom industry with tens of millions of phones equipped with OTA capabilities and millions of successful OTA updates performed each year, contributing to a reliable and efficient method of updating. This paper analyzes the different ways OTA is currently being used to successfully achieve in-vehicle software updates. This paper also presents the results of a questionnaire conducted to assess the familiarity and acceptance of software update technologies. This paper concludes with an analysis of the questionnaire results and the authors' preferred implementation method of OTA based on the research.

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INTRODUCTION

Dozens of microprocessors and hundreds of vehicle functionalities are based on a substantial amount of code. With the emerging trend of connected vehicle and increased functionality, software is only going to become more complex. OEMs have to ensure the software is reliable and future proof by providing updates. To ensure these updates are successfully implemented, OEMs have to provide an efficient method of updating.

Some OEMs have already taken the initiative to tackle these issues by including Over-The-Air (OTA) updating capabilities in their current and future vehicle line-ups. OTA technology gives OEMs the ability to provide a convenient method of updating. This paper analyzes the different implementation methods OEMs have used to improve the process of in-vehicle software updates.

SOFTWARE UPDATE

Software in Connected Vehicles

The increase of software code in modern vehicles gives consumers increased functionality and safety. The average vehicle today contains millions of lines of code, offering customers the ability to stay connected with the world from the seat of their vehicle using telematics and smartphone integration technologies. Recent cars have offered the ability to not only

sense collisions but also warn drivers, and in some instances act autonomously on the behalf of the driver. Moreover, several OEMs have already shown the connected capabilities of their electric vehicles, offering customers the ability to monitor the energy of their vehicle through a smartphone app, and the ability to schedule when to draw power from the electrical grid.

The addition of these technologies and functionalities in modern vehicles leads to an increase of software and complexity for OEMs. This software complexity can be difficult to master during the initial release of a vehicle, and some software bugs and defects can only be uncovered with real-time consumer usage. To keep vehicles safe and up to date, it is essential for OEMs to have the ability to update their code when desired.

The situations when an update is needed are:

- Recall
OEM will recall vehicles that have safety concerns.
- Customer issue
Customer will have a software related issue that requires updating.
- New software release
Updating the vehicle with a new software release sent by the OEM.

Updates can consist of hardware or software:

- **Hardware Updates**
Updated when recalls are issued or customer has specific problem.
- **Applications**
New or existing applications that need updating, typically weekly.
- **Stack**
Software updates to the stack of the infotainment unit, typically several times per year.
- **OS Kernel**
Update of the kernel, several times per year.

Customer Implemented Update

For customer implemented updates, the customer either receives a CD with the latest software directly from the OEM or has to manually download the software on a USB drive. This update method gives customers the luxury of updating the radio/infotainment system at their own convenience. But the update procedure is inconvenient, requiring an extensive amount of labor and an excessive amount of vehicle on-time. To successfully update the radio/infotainment system, it requires the user from 30 minutes to several hours beginning with the download procedure and ending with the update confirmation. Not only is the procedure unintuitive, but there is also a security risk of having the software in the hands of many customers, which increases the possibility of reverse engineering and uploading a hacked version of the file to the internet.

The following is a detailed description of a self-implemented USB update:

1. Open a browser and log on to OEM site
2. Locate the updates section, click "get update"
3. Click update and connect your empty USB drive
4. Click Start Download Process to your USB drive
5. Remove USB after download complete
6. Take the USB drive to your vehicle. Turn on your vehicle, and then turn on the radio.
7. Make sure your car is in a well-ventilated area. Your vehicle will need to be turned on, with the engine running between 25 to 35 minutes. Make sure that your vehicle is not in Accessory mode.
8. Plug the USB drive in to your vehicle's USB port.
9. Press AUX to select Line In. Press OK.
 - a. Press Menu. Media displays. Press OK.
10. Media Menu displays, and then Play Menu appears. Press Seek until Select Source is highlighted. Press OK.
11. USB displays. Press OK.
 - a. USB Selected displays. Press OK.
12. Press Seek until System Settings is highlighted. Press OK.
 - a. Press Seek until Advanced is highlighted. Press OK.

13. Prompts display. Press Seek until Install Applications is highlighted. Press OK.
14. Automatically detects the files on your USB drive, and then displays "Install Application?" Press OK to confirm.
15. Prompts "Installation Complete." Press MENU to exit installation mode. It is now safe to remove your USB drive.
16. Once you have installed the software updates, you will need to pair your phone again. To complete the process, take the USB drive to your computer to report the successful installation.

Dealer Implemented Update

For software related recalls, OEMs require customers to update their vehicles at the dealers. Primarily, these types of recalls affect the vehicle's ECUs. ECUs are located throughout the body of a vehicle and require special tools and procedures to communicate with and successfully achieve a reliable update. Moreover, if customers lack the ability to update their own radio/infotainment system, they have the option to voluntarily drive to the dealer for an update.

Dealer implemented updates are reliable and done in a controlled environment, giving the customer assurance that the update was implemented successfully. From the customer's point of view, driving to the dealer and the long waits associated with service centers can be a major inconvenience.

The following is the update procedure at the dealers:

1. OEM issues a recall notice (or new software release) to dealers and customers.
2. OEM sends the CD with the latest software to the dealer.
3. The customer drops off the vehicle at the dealer.
4. Technician updates the reprogramming tool with the content from the CD and connects it to the in-vehicle bus to target the ECU (or inserts CD in radio/infotainment system) and starts update process.
5. Technician ensures update successful.
6. Customer is contacted to pick up vehicle at their desired time.
7. Dealer charges OEM for labor costs.

OVER-THE-AIR UPDATES

Over-The-Air Technology

This paper will not detail Over-The-Air (OTA) technology, but rather the implementation of OTA updates in vehicles. Nonetheless, a brief description of OTA technology is provided below.

In general, the term OTA in the automotive industry implies the use of wireless mechanisms to send data or update packages for software updates to a vehicle. OTA mechanisms require the existing software and hardware of the vehicle to support the features for receiving, processing, and setting parameters.

Several software companies already provide expertise in helping OEMs and Tier 1s deploy end to end solutions for OTA updates. A typical update consist of: creating the software update package, deploying the software update package over the air, receiving the software update package in the automotive device, and finally installing the software update package.

OTA update use cases:

- **Embedded 3G/4G modem.**

OEM contracts with a mobile network operator to provide network services through its embedded modem in its vehicles.

- **Embedded Wi-Fi**

OEM adds Wi-Fi to access update via WLAN or mobile hotspot.

- **Smartphone OTA using Bluetooth® or wired tethering.**

OEM sends updates through OEM's smartphone App. Customer tethers smartphone with radio/infotainment system either by wired USB connection or wireless Bluetooth® connection to install software updates.

Described below are several important characteristics required with each use case:

- **Security:** Security is essential for ensuring a safe transaction of the data between the OEM server and the vehicle.
- **Download speed:** A high-bandwidth network is preferred to ensure a fast and reliable download.
- **User expense:** Additional monthly payments can discourage customers from enrolling in an embedded vehicle data plan.
- **Multiple devices:** OTA updates have to be convenient and intuitive for the customer, if multiple devices and steps are required then the OTA use case is less attractive.
- **Access of wireless reception:** To ensure a reliable connection to the wireless network the customer must have reliable network reception.
- **Infotainment/Radio memory:** For a reliable update, there should be sufficient memory to store the new image before installation. Without an increase of storage the new image will directly download into the flash and overwrite the old code, which can disable the system if connection is lost at any point during the download.
- **Automatic “forced update” feasibility:** Some customers might delay their updates several times until they find the convenient time to update. If an OEM has an urgent update that needs immediate implementation, a use case allowing the OEM to always have an access to the system will allow OEMs to better implement forced updates.

Use Case	Embedded Modem	Embedded Wi-Fi	Smartphone OTA using Bluetooth® or wired tethering
Security	Strong	Dependent on hotspot	Dependent on smartphone
Download Speed	(3G) Range from (0.59 Mbps – 3.84 Mbps)	Wi-Fi (1-100 Mbps) Phone Hotspot Range from (0.59 – 3.84 Mbps)	Bluetooth® USB
User Expense	Monthly subscription charge	Wi-Fi free at local hotspots, phone data connection	Phone data connection
Multiple Devices	No	Yes	Yes
Access of Wireless reception	3G/4G network area	Wi-Fi or 3G/4G network area	Smartphone
Infotainment/Radio storage increase	Yes	Yes	Yes
Automatic “forced update” feasible?	Yes	Limited range	No

Embedded Modem (3G/4G)

- Advantages:
 1. Convenient and efficient for frequent updates.
 2. 3G/4G connection common in urban areas.
 3. Secure HTTP (SSL) connection with servers, which store the firmware updates.
- Disadvantages:
 1. Not in controlled environment.
 2. User has to pay for data subscription.
 3. Slower download speeds.
 4. Carriers generally limit the number of “devices” that updates can be pushed to at a time for bandwidth limitations.
 5. Hardware upgrades

Embedded Wi-Fi

- Advantages:
 1. Faster download speeds.
 2. Secure connection.
 3. Wi-Fi connections are very common in urban areas.
 4. OEM is not concerned with network limitation bandwidth.
- Disadvantages:
 1. Vehicle has to be within Wi-Fi range.
 2. Frequent updates can be inconvenient for customer.