Gemini: Project Your Smartphone Screen to Your Car

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1. INTRODUCTION

One of the challenges in automotive technology revolution is to bridge the life-cycle difference between vehicles and consumer electronics devices: the life-cycle of a vehicle is typically 10-15 years, while a driver might upgrade her smartphone every other year. To keep up with the latest technology, upgrading a legacy vehicle with new hardware capability seems to be a natural solution; however, in reality, this approach turns out to be difficult in terms of system reliability, safety, and security.

In this paper, we propose a Gemini dual-system architecture that calls for deeper integration of smartphones into vehicles, enabling mobile apps to be used in automotive environment in a seamless, flexible and safer fashion. Using our advocated system architecture, users directly "project" their smartphone screen onto vehicular infotainment screen (*Smartphone Screen Projection to Vehicle*), while users gain the access and control of smartphones through vehicle controls (*Reverse Control from Vehicle*).

The benefits of our Gemini architecture are two-fold: richer functionalities for vehicles and safer usage of smartphones. First, using smartphone projection, users could use the same set of apps on their smartphones but with a better display/speaker and more convenient in-vehicle control functionalities, rendering a more integrated user experience. Second, users can use navigation or certain functionalities on their smartphones in the same way that they access their car radio, while keeping their eyes on the road and their hands on the wheel.

Our advocated technical framework has technology similarity to the Virtual Network Computing (VNC) and the emerging TV projection technology. However, our approach focuses on supporting the use case of highly dynamic screen display (up to 30 frames/sec at HD resolution) with real-time reverse control and vehicle sensing capabilities.

2. THE GEMINI ARCHITECTURE

The Gemini system architecture is depicted in Fig.1. The system consists of two devices: a vehicle infotainment module and a smartphone. The vehicle infotainment module provides abundant vehicle sensors as well as a number of user I/O capabilities, which are highly optimized for the driving environments, while the smartphone provides up-to-date capabilities of communication, computing, and storage. There are 4 major mechanistic building blocks based on the system architecture above:

Remote screen projection. In Gemini, the smartphone captures its raw screen frames, encodes them with a H.264 hardware encoder, and transmits to the vehicle infotainment module. The vehicle re-renders the received frames on the in-vehicle infotainment screen. Similarly, audio and other meta information can also be captured, transmitted, and rendered from the smartphone to the vehicle.

Reverse control channels. The user input, such as screen touches and voice control, can be captured on the vehicle and forwarded back to the smartphone. Meanwhile, vehicle sensor readings as well as further inferred vehicle context information, such as GPS, vehicle speed, and driver status (i.e. fatigued driving), can also be forwarded back to the smartphone.

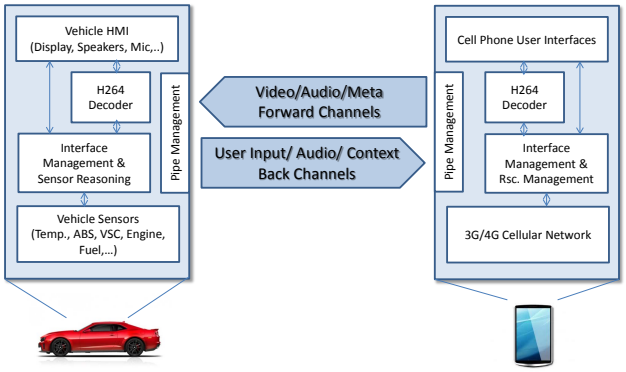

Figure 1: The Gemini Architecture.

Table 1: Technical Performance of Gemini Prototype

Frame Rate	25-30 Frames/Sec
Resolution	1280p x 720p
Color Depth	16 bit
Delay	250 Milliseconds

Interface and resource management. The interface and resource management components on both sides dynamically allocate and manage a variety of local resources, such as computation threads, wireless bandwidth, and memory, while coordinating the operations between the two devices. This way, Gemini presents a unified system for rendering a smooth user experience.

Pipe management. With the help of pipe management, remote screen projection and user input back channels will be able to dynamically select communication pipes, such as wired and wireless pipes, to achieve an improved quality of service and energy efficiency.

3. PROTOTYPE

We have developed a functioning prototype of the Gemini system. The prototype was developed based on two Android devices: a Samsung Galaxy Note 2 and a Google Nexus 10 tablet. Note 2 represents a personal smartphone, and Nexus 10 tablet emulates a vehicle infotainment module. The prototype has implemented two main features of our proposed Gemini architecture: (1) remote screen projection and (2) user input back channel. As shown in Table 1, the performance of this preliminary prototype is satisfactory.