Journal of Industrial Information Technology and Application Vol.1 No.1 (2017)
ISSN(Online) : 2586-0852

Enabling In-Vehicle Infotainment with Bluetooth Connectivity

Hyoseok Yoon[1)*], Se-Ho Park[1)]
[1)] Korea Electronics Technology Institute, Seoul, Korea

Abstract. Next generation of vehicles known as intelligent vehicles or connected vehicles open new application areas. In this setting, an efficient and flexible method for connecting in-vehicle components and passengers is essential for realizing futuristic applications and enabling user interaction on smart vehicles. In this paper, we review several Bluetooth application scenarios to gain insights and propose an in-vehicle infotainment use case with Bluetooth connectivity.

Keywords; intelligent vehicles; connected vehicles; bluetooth; digital audio broadcasting; in-vehicle infotainment

1. Introduction

With rapid developments of electronic parts for vehicles, vehicle built-in systems are becoming more connected, intelligent and usable. To realize this notion of next generation future cars, novel technologies focusing on "smart car" [1] and "connected car" [2][3][4] are being actively researched and developed. Coppola and Morisio defined connected car as having following four characteristics [2], including connectivity capabilities and "advanced infotainment features to the driver and passengers."

> *A connected car is a vehicle —capable of accessing the Internet at anytime, using either a built-in device or brought-in user devices; —equipped with a set of modern applications and dynamic contextual functionalities, offering advanced infotainment features to the driver and passengers; —capable of interacting with other smart devices on the road or in mechanical shops, leveraging vehicle-to-road infrastructure communication technologies; —capable of interacting with other vehicles, leveraging vehicle-to-vehicle communication technologies.*

[*] Corresponding author: hyoon@keti.re.kr
Received: 2017.3.15; Accepted: 2017.5.15; Published: 2017.6.12

To realize such advanced in-vehicle infotainment systems, smart connectivity technology has become an indispensable component of intelligent and connected vehicles. The roles of smart connectivity technology cover intra-vehicular network of vehicle components, social interaction of on-board passengers and V2X communication with external infrastructure and facilities. Especially, various use cases of V2X communication including vehicle-to-sensor on-board (V2S), vehicle-to-vehicle (V2V), vehicle-to-road infrastructure (V2R), and vehicle-to-Internet (V2I) are being developed [4].

In this paper, we first identify application areas that use Bluetooth in general or in vehicles from previous literature to gain insights. Then based on these insights, we specifically propose Bluetooth-based use cases and applications in an in-car infotainment context.

2. Bluetooth Application Scenarios

2.1. Localization

Bluetooth is used to identify locations of Bluetooth devices or track users of Bluetooth devices. In a museum setting, Alletto et al. implemented a wearable device to acquire localization information using a Bluetooth low energy (BLE) infrastructure [5]. When a Bluetooth connection of the user's wearable device is detected, the detected user's position is used by the processing center for providing localization services. For example, a localization service can be used to speed up the image-processing algorithm by selecting a fine-tuned database. To do so, proximity of a user holding a Bluetooth device and BLE tags on the environment is estimated based on RSSI (Received Signal Strength Indicator) [5].

- Insight: In an application where many Bluetooth devices are used, depending on RSSI or proximity, different level of service can be provided. For an in-car infotainment context, different services can be provided based on a relative proximity metric to driver (relatively closer) or passengers (relatively further away).

2.2. Intelligent Traffic Monitoring

Bluetooth embedded vehicles have demonstrated a number of use cases for intelligent traffic systems [6][7] where Bluetooth in vehicles are used to identify vehicles and estimate their travel time in a route. Bluetooth Media Access Control (MAC) scanners and loops data are fused to estimate the trajectories of the Bluetooth vehicles and the estimated trajectories are used for finding travel time statistics [8]. Intelligent traffic monitoring is made possible by using unique MAC of Bluetooth vehicles and keeping track of a series of detected timestamps.

- Insight: Managing a record of Bluetooth device such as inquiry, advertisement,

and discovery can give an indication of Bluetooth device based interaction. For example, in-vehicle infotainment system may need to keep a record of Bluetooth interaction history, to better serve different users (adapting to user preference and device configurations).

2.3. Intra-vehicular Wireless Sensor Network

Bluetooth is also used within a vehicle to form an intra-vehicular network with sensors and IoT devices [9]. Lin et al. proposed to use Bluetooth Low Energy (BLE) in an intra-vehicular wireless sensor network (IVWSN) [10]. Lin et al. demonstrated that BLE is effective technology for IVWSN applications since it requires low-power and low-cost. In Artemisa [11], which is a smartphone and OBD/Bluetooth device based driving assistant, various in-car information such as vehicle telemetry, vehicle location road photo, and weather conditions are collected to make recommendations to reduce the fuel consumption. Specifically, an OBDII/Bluetooth adapter on OBD port is used to send and receive data via Bluetooth.

- Insight: Smart/Intelligent/Connected cars can be viewed as a central system composed of many components including sensors, devices and displays. Bluetooth can serve as a main communication protocol to connect all these components. In this setting, an in-vehicle infotainment system may bring up and visualize different information from those connected components.

2.4. Crowd and Social Interaction

Basalamah proposed an approach based on Bluetooth low energy (BLE) tagging to sense the crowds and reconstruct the routes of the participants [12]. Since BLE devices can advertises itself, BLE-enabled smartphone scans the environment to detect those advertised BLE devices. This sensing is used to check for existence of BLE devices to infer their location, interaction with other devices, and their mobility. Zheng and Li have proposed an unsupervised approach that learns from one's dynamic proximity relations with others to identify their social circles from the Bluetooth sensed data recording [13]. A vehicle can also communicate with the multi-tier network infrastructure as in vehicle-to-infrastructure (V2I) communication [14] or form vehicular social network [15].

- Insight: Bluetooth can cover and communicate with both within car and near-infrastructure ranges. Within car ranges, Bluetooth can be used to provide the driver and passengers with controllability of the infotainment system or make and receive calls [16], whereas external connection is used to retrieve useful information from infrastructure in vicinity.

3. Bluetooth Connected In-Car Infotainment

In this section, we propose a use case for Bluetooth connected in-car infotainment. Figure 1 shows a concept of Bluetooth connected in-car infotainment. We use previous definition of "connected car" by Coppola and Morisio [2] in this paper to propose use cases in an infotainment context.

Figure 1. Bluetooth connected in-car infotainment

3.1. Multiple Bluetooth Profiles

There are various Bluetooth profiles to serve different devices and roles. Traditional profiles include 3DSP, A2DP, AVRCP, BIP, BPP, CTN, DI, DUN, FTP, GAVDP, GNSS, GOEP, GPP, HCRP, HDP, HFP, HID, HSP, MAP, MPS, OPP, PAN, PBAP, SAP, SPP, SYNCH and VDP. Different profiles have different usages. For example, audio streaming applications use A2DP and AVRCP. For connecting input devices, a Bluetooth device with HID is used. For general data communication, Bluetooth SPP can be used. In Bluetooth connected in-car infotainment, multiple Bluetooth profiles can be used. In-car infotainment can feature "connected audio" by using A2DP, AVRCP with multiple Bluetooth devices including speakers. Also various controller and input devices can be connected by using HID. Similarly, SPP can be used to send and receive control commands.

3.2. Applications for Digital Radio and Software Defined Radio

In an in-car infotainment, digital radio data can be used for main audio source. There are multiple digital radio standards including DRM, DAB, and HD-Radio. Since different standards require different configurations, software defined radio (SDR) for controlling and changing required parameters by software update can enhance in-car infotainment. Sending and receiving control commands from a user's Bluetooth device such as a smartphone [17] to the in-car infotainment can be realized by using SPP (Serial Port Protocol). Multiple Bluetooth devices (e.g., wearable device, smartphone, headphone, speaker) of passengers in a car can be managed to communicate audio, video and data for navigation, entertainment, and informational applications. Figure 2 depicts an exemplar configuration for in-vehicle infotainment platform. The in-vehicle infotainment platform uses Bluetooth for streaming audio, video and data as well as interfacing users with the infotainment system through smartphones and wearable devices.

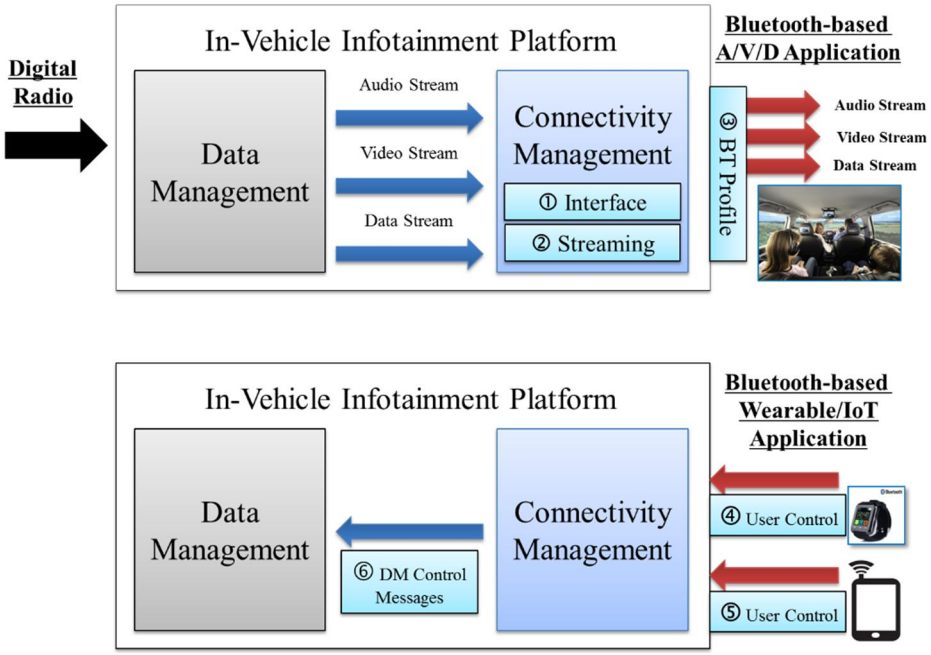

Figure 2. An examplar configuration for in-vehicle infotainment platform

4. Conclusion

In this paper, we reviewed Bluetooth application scenarios and proposed Bluetooth in-car infotainment use case based on multiple Bluetooth profiles and a concept of software defined radio. Bluetooth is a viable smart connectivity solution for intelli-

gent and connected car environment that can enable localization, intelligent traffic monitoring, intra-vehicular network and crowd/social interaction. For future work, we will explore novel automotive user interfaces [18][19] and user expectations [16] for car infotainment systems, including HMD (head-mounted display) for AR (Augmented Reality) [20] and HUD (head up display) [21] for naturalistic information presentation and user interaction.

Acknowledgement

This research was supported by the Ministry of Trade, Industry and Energy (MOTIE) and Korea Evaluation Institute of Industrial Technology (KEIT). [10063286, Development of RF SoC and Smart Convergence Platform for SDR (Software Defined Radio)]

References

[1] S. C. Huang, B. H. Chen, S. K. Chou, J. N. Hwang, and K. H. Lee, "*Smart Car [Application Notes],*" *IEEE Comput. Intell. Mag.*, vol. 11, no. 4, pp. 46–58, November 2016.

[2] R. Coppola and M. Morisio, "Connected Car: Technologies, Issues, Future Trends," *ACM Comput. Surv.*, vol. 49, no. 3, Article 46, October 2016.

[3] M. Swan, "Connected Car: Quantified Self becomes Quantified Car," *J. Sens. Actuator Netw.*, vol. 4, no. 1, pp. 2–29, February 2015.

[4] N. Lu, N. Cheng, N. Zhang, X. Shen and J. W. Mark, "Connected Vehicles: Solutions and Challenges," *IEEE Internet Things J.*, vol. 1, no. 4, pp. 289-299, August 2014.

[5] S. Alletto, R. Cucchiara, G. D. Fiore, Luca Mainetti, V. Mighali, L. Patrono, and G. Serra, "An Indoor Location-Aware System for an IoT-Based Smart Museum," *IEEE Internet Things J.*, vol. 3, no. 2, pp. 244–253, April 2016.

[6] M. R. Friesen and R. D. McLeod, "Bluetooth in Intelligent Transportation Systems: A Survey," *Int. J. ITS Res.*, vol. 13, no. 3, pp. 143–153, September 2015.

[7] J. J. V. Díaz, A. B. R. González, and M. R. Wilby, "Bluetooth Traffic Monitoring Systems for Travel Time Estimation on Freeways," *IEEE Trans. Intell. Transp. Syst.*, vol. 17, no. 1, pp. 123–132, January 2016.

[8] A. Bhaskar, M. Qu, and E. Chung, "Bluetooth Vehicle Trajectory by Fusing Bluetooth and Loops: Motorway Travel Time Statistics," *IEEE Trans. Intell. Transp. Syst.*, vol. 16, no. 1, pp. 113–122, February 2015.

[9] D. K. Oka, T. Furue, L. Langenhop and T. Nishimura, "Survey of Vehicle IoT Bluetooth Devices," *In Proceedings of the 7th International Conference on Service-Oriented Computing and Applications*, pp. 260–264, 2014.

[10] J.-r. Lin, T. Talty and O. K. Tonguz, "On the Potential of Bluetooth Low Energy Technology for Vehicular Applications," *IEEE Commun. Mag.*, vol. 53, no. 1, pp. 267–275, January 2015.

[11] V. C. Magana and M. Munoz-Organero, "Artemisa: A Personal Driving Assistant for Fuel Saving," *IEEE Trans. Mobile Comput*., vol. 15, no. 10, pp. 2437–2450, October 2016.

[12] A. Basalamah, "Sensing the Crowds Using Bluetooth Low Energy Tags," *IEEE Access*, vol. 4, pp. 4225–4233, August 2016.

[13] J. Zheng and L. M. Ni, "An Unsupervised Learning Approach to Social Circles Detection in Ego Bluetooth Proximity Network," *in Proc. UbiComp 2013*, pp. 721–724, 2013.

[14] E. Ndashimye, S. K. Ray, N. I. Sarkar, and J. A. Gutiérrez, "Vehicle-to-Infrastructure Communication over Multi-Tier Heterogeneous Networks: A Survey," *Computer Networks*, vol. 112, pp. 144–166, January 2017.

[15] A. M. Vegni and V. Loscrí, "A Survey on Vehicular Social Networks," *IEEE Commun. Surveys Tut.*, vol. 17, no. 4, July 2015.

[16] B. Pfleging, S. Schneegass, and A. Schmidt, "Exploring User Expectations for Context and Road Video Sharing While Calling and Driving," *In Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp.132–139, 2013.

[17] J. P. Espada, V. G.Díaz, R. G. Crespo, O. S. Martínez, B. C. P. G-Bustelo, and J. M. C. Lovelle, "Using Extended Web Technologies to Develop Bluetooth Multi-platform Mobile Applications for Interact with Smart Things," *Information Fusion*, vol. 21, pp. 30–41, January 2015.

[18] J. Sonnenberg, "Service and User Interface Transfer from Nomadic Devices to Car Infotainment Systems," *In Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 162–165, 2010.

[19] R. Swette, K. R. May, T. M. Gable, and B. N. Walker, "Comparing Three Novel Multimodal Touch Interfaces for Infotainment Men us," *In Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 100–107, 2013.

[20] A. Bolton, G. Burnett, and D. R. Large, "An Investigation of Augmented Reality Presentations of Landmark-based Navigation using a Head-up Display," *In Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 56–63, 2015.

[21] K. Bark, C. Tran, K. Fujimura, and V. Ng-Thow-Hing, "Personal Navi: Benefits of an Augmented Reality Navigational Aid Using a See-Thru 3D Volumetric HUD," *In Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Article 1, 2014.