A study toward the practical use of WLAN-based vehicular network systems

（課程博士・様式７）（Doctoral qualification by coursework,Form 7）

学 位 論 文 要 旨

Abstract of Doctoral Thesis

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論文題目：A study toward the practical use of WLAN-based vehicular network systems
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Abstract：Vehicular networks realize cooperative awareness and collective perception and improve road safety, traffic management, and driving experiences. Under disaster conditions, vehicular networks can also be utilized as a communication system because they can work without standing communication infrastructures like cellular networks. Although the expectation for vehicular networks keeps growing, there are only a few precedents of deploying vehicular network systems to the real world due to expensive costs for installing network equipment to vehicles, implementating onboard units and their software, and legislating. Especially, operation validation of vehicular network systems cannot be easily performed in the real world due to high preparation cost of vehicles and network equipment and legal permission to use public roads. There are two ways to validate the operation of the vehicular network system implementations: Field testing and network emulation. Field testing reveals the practical performance of the vehicular network system in the actual field. Therefore, the measurement results of the real field performance of vehicular network systems are invaluable for developing vehicular network systems, but there are not enough empirical reports, especially, the bulk data transmission performance in vehicular networks using new wireless LAN technologies. Although the bulk data transmission in the vehicular network is significant for sharing photos and videos in disaster conditions and disseminating in-car infotainment contents, it is difficult to estimate their practical performance and validate whether the evaluation results in a testbed match the practical performance. Meanwhile, network emulation enables the vehicular network system to work in a virtual network in which a network simulator reproduces the vehicles' mobility and signal propagation. Almost all existing network emulators focus on link emulation based on Ethernet virtualization technologies such as a TUN/TAP device and allow a network simulator to capture data packet flows using the TUN/TAP devices and apply the bandwidth limitation, delay insertion, and packet loss for the captured packet flow based on radio

propagation and mobility models. However, the existing network emulators are insufficient to be used for vehicular network emulation because they cannot reproduce the behavior of the vehicular network protocols, such as IEEE 802.11p and ETSI De-centralized Congestion Control (DCC). The vehicular network protocols adaptively control transmission power based on received signal strengths to avoid interference, and their behavior is a significant factor for operation validation of the vehicular network systems. Therefore, it is important to emulate the behavior of the vehicular network protocols as they perform in the real world. This dissertation presents two contributions to encourage developing vehicular network systems. The first contribution is a novel wireless network emulator with wireless network tap devices. The wireless network emulator can reproduce the behavior of the Linux IEEE 802.11 protocol stacks and network applications in a virtual network as they perform in the practical IEEE 802.11 network. The wireless LAN emulator allows the Linux IEEE 802.11 protocol stacks and a network simulator to exchange IEEE 802.11 frame flows and IEEE 802.11 device configuration flows, such as transmission power change and received signal strength notification, by using the wireless network tap devices, which is a virtual IEEE 802.11 device developed by the author. This study shows that the wireless network emulator can reproduce the behavior of an actual WLAN-based network by using the real Linux IEEE 802.11 implementation and network applications. This study also proposes some techniques to improve the real-time property of network emulation with the proposed emulator. The effectiveness of the techniques is validated through experiments. The second contribution is empirical measurement of field performance of link setup time and bulk data transmission in WLAN-based inter-vehicular communications. This study presents the first empirical report of the initial link setup time reduction for IEEE 802.11-based inter-vehicular communication using Fast Initial Link Setup (FILS) and Wi- Fi Protected Access with Protected Extensible Authentication Protocol (WPA-PEAP). The performance evaluation reveals that FILS enables the initial link setup to complete within about 130 ms between vehicles with a high relative speed of 80 km/h, ten times shorter than WPA2-PEAP authentication, and transfer a maximum of 75 MB while the vehicles are passing each other.

記入上の注意

１）論文要旨は、日本語２,０００字または英語８００語程度とする。

２）余白は、上３０mm、左３０mm、下及び右１５mm とする。

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１）The abstract should be about 800 words in English or 2,000 characters in Japanese.

２）Ample margins should be left, e.g., top, 30mm; bottom, 15mm; left, 30mm; right, 15mm.

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