# 論文 / 著書情報
# Article / Book Information

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| 題目(和文) | |
| Title(English) | Radio Resource Management for mmWave V2V Communications |
| 著者(和文) | 殷越 |
| Author(English) | Yue Yin |
| 出典(和文) | 学位:博士(学術),<br>学位授与機関:東京工業大学,<br>報告番号:甲第11844号,<br>授与年月日:2022年3月26日,<br>学位の種別:課程博士,<br>審査員:阪口 啓,廣川 二郎,TRAN GIA KHANH,西尾 理志,藤井 輝也,藤井 威生 |
| Citation(English) | Degree:Doctor (Academic),<br>Conferring organization: Tokyo Institute of Technology,<br>Report number:甲第11844号,<br>Conferred date:2022/3/26,<br>Degree Type:Course doctor,<br>Examiner:,,,,, |
| 学位種別(和文) | 博士論文 |
| Category(English) | Doctoral Thesis |
| 種別(和文) | 論文要旨 |
| Type(English) | Summary |

（博士課程）
Doctoral Program

# 論 文 要 旨

THESIS SUMMARY

| 系・コース：<br>Department of, Graduate major in | Electrical and Electronic | 系<br>コース | 申請学位（専攻分野）：<br>Academic Degree Requested | 博士<br>Doctor of | (Philosophy) |
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| 学生氏名：<br>Student's Name | YIN Yue | | 指導教員（主）：<br>Academic Supervisor(main) | Kei Sakaguchi | |
| | | | 指導教員（副）：<br>Academic Supervisor(sub) | | |

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words )


This dissertation develops new radio resource management schemes for scalable mmWave V2V relays systems by coping with the three problems: (1) co-channel inter-link interference; (2) scalability of mmWave V2V communications; (3) efficient radio resource management mechanism. While the main focus is on overtaking traffic situations, some ideas are also applicable for other traffic situations like safe driving at crossroads. It is noted that the definition of scalability in this study is one-dimensional. The scalability means that for all vehicles in a single-lane two-sides scenario, the E2E throughput is always higher than the required data rate in multi-hop relay systems. The propagation direction of the signal is opposite to the driving direction of the vehicles.

**Chapter 2**: We introduced basic and general mmWave V2V relays scenarios on the basis of scenario complexity and introduced single straight road, horizontal curve, and slope on the basis of road scenarios. We established ray-tracing channel models of mmWave V2V communications in three typical road scenarios and summarized the characteristics of these typical road scenarios. The co-channel interference was evaluated in different scenarios. The simulation results show that (1) the ground reflection is the main co-channel interference in all road scenarios; (2) the co-channel interference is strangest in the case of equal inter-vehicle distance for mmWave V2V communications with relay; (3) the maximum height at which the direct co-channel interference signal (more precisely, first-order Fresnel zone) is completely blocked by the metal body of the vehicle is optimal antenna height because it has the strongest suppression of co-channel interference.

**Chapter 3**: We proposed a ZigZag antenna configuration to mitigate the co-channel interference for mmWave V2V communications with relay. The intrinsic principle is to increase the angle between each reflected co-channel interference path and the antenna main beam. This increased angle can reduce the antenna directivity of each reflected interference path. Eventually, the total received power of co-channel interference can be reduced. Next, the performance of the proposed method with that of conventional antenna configuration was compared by the simulation based on standard IEEE 802.11ad. Numerical evaluations using realistic channels from ray-tracing simulations show that the ZigZag antenna configuration significantly suppresses the co-channel interference and satisfies the over 1 Gbps required data rate. Finally, we demonstrated the effectiveness of ZigZag antenna configuration by outdoor experiments. The measured E2E throughput with ZigZag antenna configuration is about 1.3 Gbps when the inter-vehicle distance varies from 1 m to 30 m.

**Chapter 4**: We theoretically analyzed the required data rate for safe automated driving in an overtaking scenario with multiple Ego vehicles. The simulation results revealed that the increase of Ego vehicles alleviates their required data rate. With these preparations, we developed a distributed radio resource management scheme that integrates spatial, frequency, and power domains for two transmission ranges (short/long). In the spatial domain, ZigZag antenna configuration is utilized to mitigate the co-channel interference, which plays a decisive role in the short inter-vehicle distance. In frequency and power domains, two resource blocks are allocated alternately, and transmit power is controlled to suppress the co-channel interference, which has a decisive impact on co-channel

interference mitigation in the long inter-vehicle distance. The simulation results demonstrated that our proposal ensures the achievable E2E throughput is always higher than the required data rate for each vehicle. It also verified the scalability of the proposed scheme for dynamics of mmWave V2V communications topology.

The main contributions of this research are summarized as follows:
(1) It can extend one-hop mmWave V2V communications to multi-hop relay V2V communications.
(2) It can improve radio resource management efficiency because it uses a distributed mechanism and manages radio resources only based on inter-vehicle distance.