平成29年度修士論文

Cloud-assisted Resource Allocation for Vehicle-to-Vehicle Communication using Successive Interference Cancellation

逐次干渉除去を用いた車車間通信のためのクラウド連携リソース割り当て法

学生番号	1631171
氏名	渡辺 裕太
情報・ネットワーク工学専攻	情報通信工学プログラム
主指導教員	藤井 威生 教授
指導教員	山尾 泰 教授
提出日	平成30年1月29日

修 士 論 文 の 和 文 要 旨

研究科・専攻	大学院　情報理工学研究科　情報・ネットワーク工学専攻　博士前期課程		
氏　　　名	渡辺　裕太	学籍番号	1631171
論 文 題 目	Cloud-assisted Resource Allocation for Vehicle-to-Vehicle Communication using Successive Interference Cancellation		

要 旨

車車間 (V2V: Vehicle-to-Vehicle) 環境における通信の信頼性向上を目的とし，逐次干渉除去 (SIC: Successive Interference Cancellation) を考慮した際の効率的なリソース割り当て法について検討する．SIC は同時に受信された複数の信号で構成される混成信号から，逐次的に復調した信号を引き抜くことで複数の信号を復調する技術であり，SIC によって引き抜きやすい組み合わせの信号を適切にスケジューリングすることで大きく通信の性能を向上させることが可能となる．しかし，周囲の干渉や受信信号電力を各車両が予測することは特に V2V 環境など変動が大きい電波環境では困難である．そこで，クラウド連携を用いて各車両の位置情報などをクラウドに集約し，クラウドが各車両をスケジューリングすることで全体の通信の信頼性向上を検討する．クラウドは各車両の位置情報から送受信車両間の距離減衰を推定することで，SIC が働く電力差を持つ送信車両同士を同じ時間スロットに割り当てる．道路を一定間隔で区切ったセル毎に時間スロットを分配したうえでスケジューリングを行ない，また十分離れたセル同士では時間スロットを再利用することで信頼性向上を図りながら高効率化を目指す手法を提案する．計算機シミュレーションによって提案手法の優位性を示す．

和文概要

本論文では車車間 (V2V: Vehicle-to-Vehicle) 環境における通信の信頼性向上を目的とし，逐次干渉除去 (SIC: Successive Interference Cancellation) を考慮した際の効率的なリソース割り当て法について検討する．現在規定されている車車間通信のプロトコルであるCSMA/CA(Carrier Sense Multiple Access with Collision Avoidance) はキャリアセンスによって，車両が周囲の環境を認識しながら自律分散的に通信を行なうものである．しかし，CSMA/CA では隠れ端末問題として知られているキャリアセンスが適切に働かずにチャネルが空いていると勘違いした車両同士の信号衝突問題や，多くの車両が送信待機状態になることで送信機会が減少し信号の遅延時間が増大してしまうさらし端末問題が存在しているため，今後 SIC は同時に受信された複数の信号で構成される混成信号から，逐次的に復調した信号を引き抜くことで複数の信号を復調する技術であり，SIC によって引き抜きやすい組み合わせの信号を適切にスケジューリングすることで大きく通信の性能を向上させることが可能となる．しかし，周囲の干渉や受信信号電力を各車両が予測することは特に V2V 環境など変動が大きい電波環境では困難である．そこで，クラウド連携を用いて各車両の位置情報などをクラウドに集約し，クラウドが各車両をスケジューリングすることで全体の通信の信頼性向上を検討する．クラウドは各車両の位置情報から送受信車両間の距離減衰を推定することで，SIC が働く電力差を持つ送信車両同士を同じ時間スロットに割り当てる．また道路を一定間隔で区切ったセル毎に時間スロットを分配したうえでスケジューリングを行ない，十分離れたセル同士では時間スロットを再利用することで信頼性向上を図りながら高効率化を目指す手法を提案する．計算機シミュレーションによって提案手法の優位性を示す．

Abstract

In this thesis, we discuss a resouce allocation method considering successive interference cancellation (SIC) to improve the reliability of communication in a Vehicle-to-Vehicle (V2V) environment. SIC is a multi-user detection technique by extracting sequentially demodulated signals from a composite signal consisting of simultaneously received signals. It is possible to greatly improve the performance of communication by appropriately allocating resources considering SIC. However, it is difficult for each vehicle to communicate while predicting surrounding interference and received signal power, especially in a radio wave environment with large variations such as V2V environment. Therefore, we study the improvement of the reliability of communication by scheduling using the information of each vehicle aggregated in the cloud. By estimating the pathloss propagation using the the position information of each vehicle, the cloud allocates transmission vehicles with power differences on which SIC works, to the same time slot. We also propose a method of distributing time slots for each cell that divides the road and reusing time slots among cells that are far away. Computer simulation shows the superiority of the proposed method.

Contents

Chapter 1

Introduction

Vehicle-to-vehicle (V2V) communication is one of the effective method for intelligent transport systems (ITS). However, carrier sense multiple access with collision avoidance (CSMA/CA), the random access scheme used in current V2V standard IEEE 802.11p [1], degrades reliability and becomes high latency when many vehicles communicate simultaneously [3]. Therefore, CSMA/CA based original IEEE 802.11p MAC is unsuitable for the future V2V communication.

In this thesis, in order to solve the problem of reliability in V2V communication, we consider the combination with successive interference cancellation (SIC) technique and a scheduling algorithm to improve the reliability. SIC is a multiuser detection technique that simultaneously decodes multiple signals from the signals simultaneously transmitted from multiple transmitters. ALOHA-type random access technique with SIC has been studied widely such as [4]. In addition, the performance of R-ALOHA protocols with power capture for V2V networks is analyzed in [7]. In the power based SIC with the capture effect, a receiver decodes the strongest signal and considers the rest of the signals as noise. After that, the decoded signal is subtracted from the original composite signal by using the replica of decoded signal for detecting the second strongest data from the received signal. In SIC, since the decoded performance depends on the signal to interference plus noise power ratio (SINR), the expected SINR can be used for design the scheduling algorithm.

In current V2V networks in US and Japan, the location of vehicles can be known by the iterative beacon signal transmitted from each vehicles. In this thesis, we propose a cloud-assisted scheduling method working with SIC by estimating the SINR from the location of the vehicles in V2V networks. This process is operated through the cloud using the shared information of location and the communication pair. Time resources are allocated to cells separated by a fixed distance on the road, and scheduling is performed by the cloud while considering SIC within the cell. In addition, time resources are reused to improve the frequency efficiency among cells that are separated by a sufficient distance that the influence of interference is small.

Chapter 2

Vehicle-to-Vehicle Communication

In this chapter, we describe the V2V communication that is one of the key technology for ITS.

2.1 IEEE 802.11p

Currently, IEEE 802.11p [1] is used as a communication standard of the V2V communication system. IEEE 802.11p is based on IEEE 802.11a [2], is a standard corresponding to V2I and V2V toward the ITS, the broadcast type carrier sense multiple access with collision avoidance (CSMA/CA), as Media Access Control (MAC) protocol is adopted. In CSMA/CA, each tramsmitting vehicle senses the surrounding channels (i.e. Carrier Sense) and to avoid simultaneous transmission. However, when the number of vehicles is large, many transmission waiting vehicles increase the delay time, so it is considered difficult to maintain sufficient communication quality in an environment like automatic driving where real time property is required [3].

2.2 CSMA/CA

2.1 shows the flowchart of CSMA/CA. In CSMA/CA, each transmitting vehicle senses the surrounding channels and if the channel state is idle, the transmitting vehicle shifts to the transmission standby state. Otherwise, if busy, the vehicle waits for the channel to empty while continuing carrier sense. In order for a channel to be considered idle, vehicles are required to wait for Distributed Coordination Function Inter Frame Space (DIFS) period. If the channel is determined idle, the vehicle shifts to the transmission state after a backoff time. Backoff time is calculated by multiplying slot time and random integer value in the range of contention window (CW). Although the range of CW increases every time packet retransmission occurs, since ACK response for collision detection is not

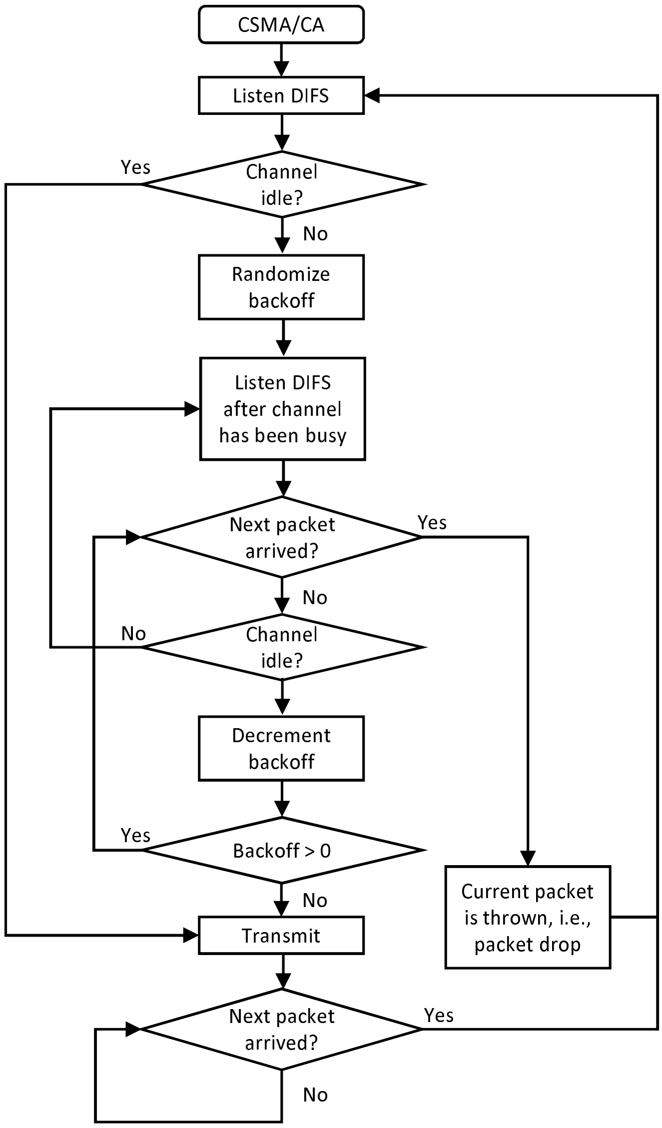

Figure 2.1: CSMA/CA [9]

performed in broadcast type CSMA/CA, so the range of CW remains unchanged.

By the above, vehicles with CSMA/CA try to avoid collison. However, as the number of vehicles increases, transmission opportunities decrease and transmission standby time increases, so poor efficiency and delay in high traffic environments are considered problematic. In addition, channel propagation and influence of shielding objects (known as hidden terminal problem) cause collisons and decline the reliability.

Chapter 3

Successive Interference Cancellation

In this chapter, we describe the SIC.

SIC is one of the multi-user detection technique that simultaneously decodes multiple signals from the signals simultaneously transmitted from multiple transmitters. It is possible to decode a plurality of signals by successively extracting the successfully decoded signals from the composite signal composed of received signals. Assuming a composite signal $S = S_1 + S_2 + \cdots + S_n + N_0$ of n ovelapping signals S_1 to S_n plus the noise signal N_0 is received at a receiver. With SIC, one of the simultaneously received signals S_i is decoded first while the rest of the signals are considered as noise. After S_i is decoded, the decoder reconstructs the corresponding analog signal and subtracts it from the original composite signal S. At this stage, the remaining signal is free from the interference of signal S_i. The same technique is applied repeatedly to decode the remaining.

There are two types of SIC, code domain and power domain.

In code domain SIC, throughput can be increased by using time-domain diversity by transmitting packets multiple times [6]. ALOHA-based protocol adopting SIC is widely studied [4–6]. In these scheme, collison is resolved by using copy of the packet has been successfuly decoded in the time slots where no collison occured. Figure 3.1 gives an example for explaining code domain SIC. In slot 2, two packets are transmitted and colliding. However, one packet can be removed by the replica of the packet successfully decoded in slot 4 (because it is singleton), so that also the other packet can be decoded. Similarly, the collison at slot 7 can be resolved using the replica of the packet in slot 4. After that, the collison at slot 5 can also be resolved.

On the other hand in power domain SIC, capture effect is considered, a receiver decodes the strongest signal and considers the rest of the signals as noise in a time slot. After that, the decoded signal is subtracted from the original composite signal by using the replica of decoded signal for detecting the second strongest data from the received signal. In power

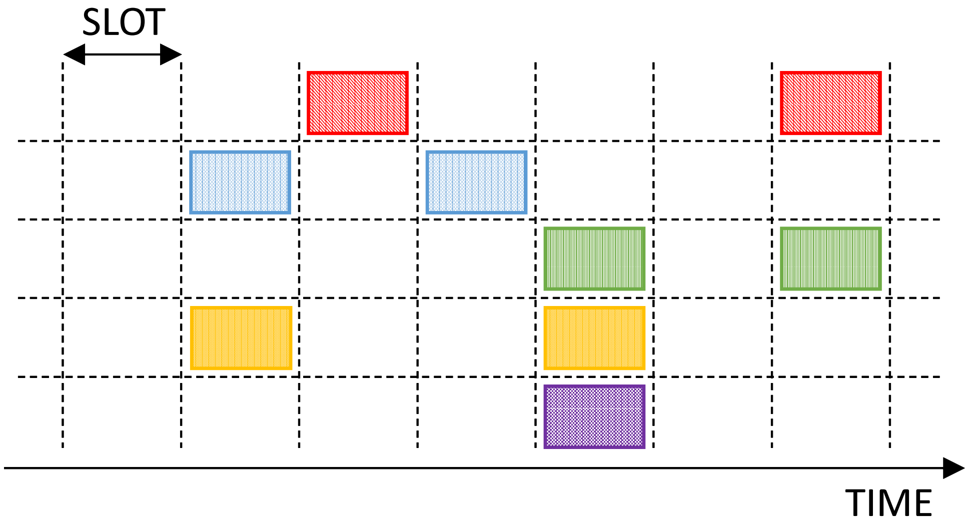

Figure 3.1: Code domain SIC

domain SIC, since the decoded performance depends on the signal to interferenceplus noise power ratio (SINR). The SINR constraints in the presence of SIC is given by,

$$\text{SINR} = \frac{P}{I + N_0} \geq \Gamma, \tag{3.1}$$

where I is the aggregate interference power, N_0 is additive white Gaussian noise (AWGN), and Γ is the required SINR.

When a composite signal consisting of K signals composed of $P_1 \geq P_2 \geq \cdots \geq P_K > 0$ is received and signal removal by SIC is perfect, the condition that P_k required is expressed by the following equation [13],

$$P_k = \Gamma N_0 (1 + \Gamma)^{K-k}. \tag{3.2}$$

In this thesis, power-based SIC exploiting capture effects is considered for the resource allocation.

Chapter 4

Cloud-assisted Resouece Allocation

In this chapter, the scheduling method considering SIC and cloud-assisted resource allocaton method are described.

4.1 Repetitive Cell Interval

Interference between cells is avoided by using different time slots for each cell. Also, reuse of the same time slots between remote cells attempts to improve the frequency efficiency. The cell interval at which time slot reuse is defined as R_c. When time slots are reused from neighboring cells (time division is not done), $R_c = 1$. Assuming that the total time slot number is t_r, the number of time slots allocated to each cell t_c is expressed by the following equation,

$$t_c = \left\lfloor \frac{t_r}{R_c} \right\rfloor . \tag{4.1}$$

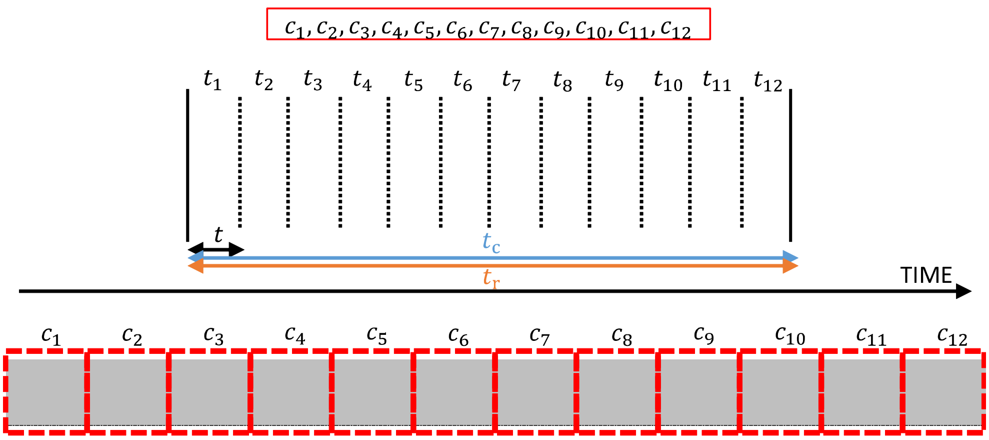

Figure 4.1: $R_c = 1$

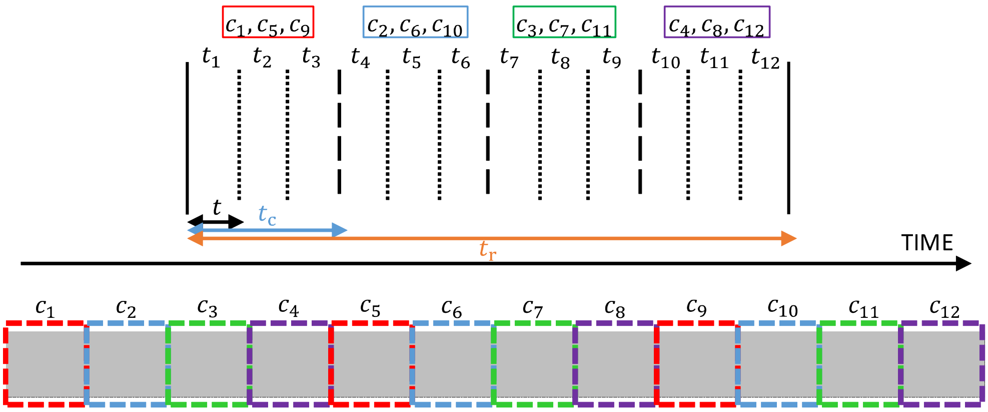

Figure 4.2: $R_c = 4$

In Figure 4.1, all the cells can use all time slots, so that interference occurs with each other. On the other hand, in figure 4.2, by reusing time slots considering interference, the reliability can be increased although the number of time slots per cell is reduced. In this case, the number of time slots per cell $t_c = 3$ derived from (4.1) is allocated to the cells. For example, the cells c_1, c_5, c_9 can use the time slots t_1 to t_3.

4.2 Scheduling Method Considering SIC

After the time slots are allocated to each cell by the cloud, scheduling is performed in consideration of SIC within the time resources. The assignment is performed in order from a pair of unicasts of the shortest distance (a pair estimated to have the highest reception power). Each transmitting vehicle generates a packet once per frame and allocation is done from the beginning slot of the frame. The scheduling procedure is summarized below.

1. If the candidate slot is empty, the current candidate communication link is allocated to the candidate slot.

2. If the candidate slot already has been allocated, the vehicle calculates SINR at the receiver vehicles at allocated links and at current link respectively.

3. If the SINRs of all links satisfy the threshold SINR (i.e., all links can communicate), the current candidate link is allocated to the slot. Otherwise, the allocation step moves on the next time slot and continue the allocation of the current link.

4.3 Margin for threshold

The margin to the reception threshold enables to make allowance between the estimated received powers of the composite signals. The margin strengthens the tolerance for multipath fading and the number of allocations per one time slot decreases. When the margin M is considered for SINR threshold, SINR condition is,

$$\mathrm{SINR} = \frac{P}{I + N_0} \geq \Gamma M. \tag{4.2}$$

4.4 Overall Procedure

The proposed method cloud-assited resource allocation can be summarized as follow:

1. Location information of the vehicle and surrounding road information observed by the vehicle are shared to the cloud.
2. The road is divided into the cells and time resouces are allocated to the cells considering repetitive cell interval by the cloud.
3. In each cells, the cloud schedules the vehicles in the cell within the time slot allocated to the cell.
    - The margin M is designed to eliminate the displacement of scheduling and strengthen the tolerance for multipath fading.

Chapter 5

Numerical Simulations

In this chapter, we evaluate the performance of the proposed method. The simulation parameters are shown in Table 5.1.

Table 5.1: Simulation Parameters

Frequency	5.9[GHz]
Path-loss model	ITU-R P1411.9
Fading model	Rayleigh fading
Shadowing model	Log-normal shadowing
Standard deviation	5[dB]
Transmit Power	20[dBm]
AWGN	-99[dBm]
Desired SINR	7[dB]
Reference distance	10[m]
Communication distance	1-300[m]
Transmitting vehicle density	0.001-0.015[/m^2]
Road width	12[m]
Road length	6000[m]
Cell size	100,200,300,600[m]
Margin M	0,3,5,10,20[dB]
Number of time slots	100
Number of Trials	100

5.1 Simulation model

All the transmitting vehicles are located in a road of 12 m $\times$ 6000 m, and all the receiving vehicles are arranged on a circumference away from a pair of transmitting vehicles by a predetermined communication distance. Cloud estimates the reception power and performs scheduling using the location information uploaded to cloud by vehicles. Each transmitter transmits one packet. For each margin M, the performances are evaluated in different repetitive cell interval R_c by changing the density of vehicles.

5.1.1 Capture Effect

In this thesis, we assume the capture effect that the maximum signal can be demodulated when there is sufficient power difference between simultaneously received signals.

5.1.2 Propagation Model

In this thesis, we assume the radio propagation follows path-loss, Rayleigh fading and log-normal shadowing. The power of received signal is shown below,

$$P_r = P_t - L(d) - G_f - G_s[\mathrm{dB}], \tag{5.1}$$

where P_r is the received power, P_t is the transmitter power, G_f is the Rayleigh fading gain, G_s is the shadowing gain, and $L(d)$ is the path-loss gain at distance d. Path-loss model follows ITU-R P.1411.9 model [14], which is given by

$$L(d) = L_{bp} + 6 + \begin{cases} 20\log_{10}\left(\frac{d}{R_{bp}}\right) & d \leq R_{bp} \\ 40\log_{10}\left(\frac{d}{R_{bp}}\right) & d > R_{bp}. \end{cases} \tag{5.2}$$

The loss at break point L_{bp} and its distance R_{bp} is determined by

$$L_{bp} = \left| 20\log_{10}\left(\frac{\lambda^2}{8\pi h_b h_m}\right) \right|, \tag{5.3}$$

$$R_{bp} = \frac{4h_b h_m}{\lambda}, \tag{5.4}$$

where λ denotes wave length, h_b and h_m represent the heights of base station and mobile station respectively.

5.2 Throughput Performance

Normalized throughput is evaluated as the number of demodulated packets per the number of time slots.

Figure 5.1-5.20 provide the results of throughput performance. The results indicates that the margin M can improve the throughput when the vehicle density is low or when R_c is small. In other words, the margin M works when the time resources are sufficinet for the number of vehicles. In a low vehicle density situation, the scheduling considering SIC slants because the signals are overlapped from the front in order to transmit signals as much as possible in time slot even if the back time slot is vacant. In a situation where Rc is small, the number of time slots per cell increases, so that the time resources are increased with respect to the number of vehicles. Displacement of scheduling is eliminated by strict assignment criteria by margin. Also, the margin strengthens the tolerance for multipath fading.

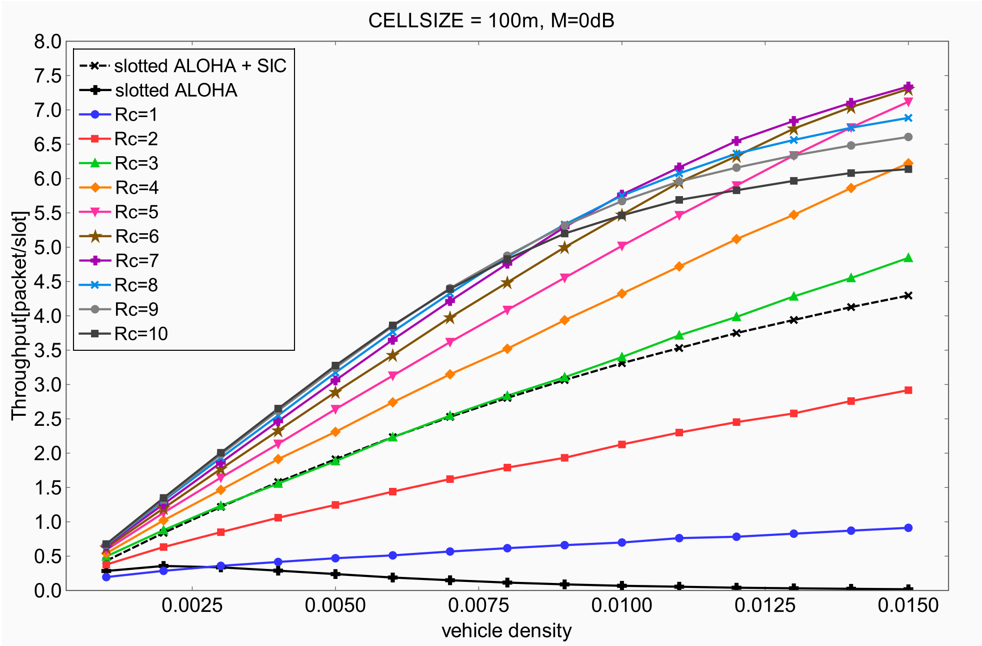

Figure 5.1: Throughput performance for CELLSIZE:100m, $M = 0$[dB]

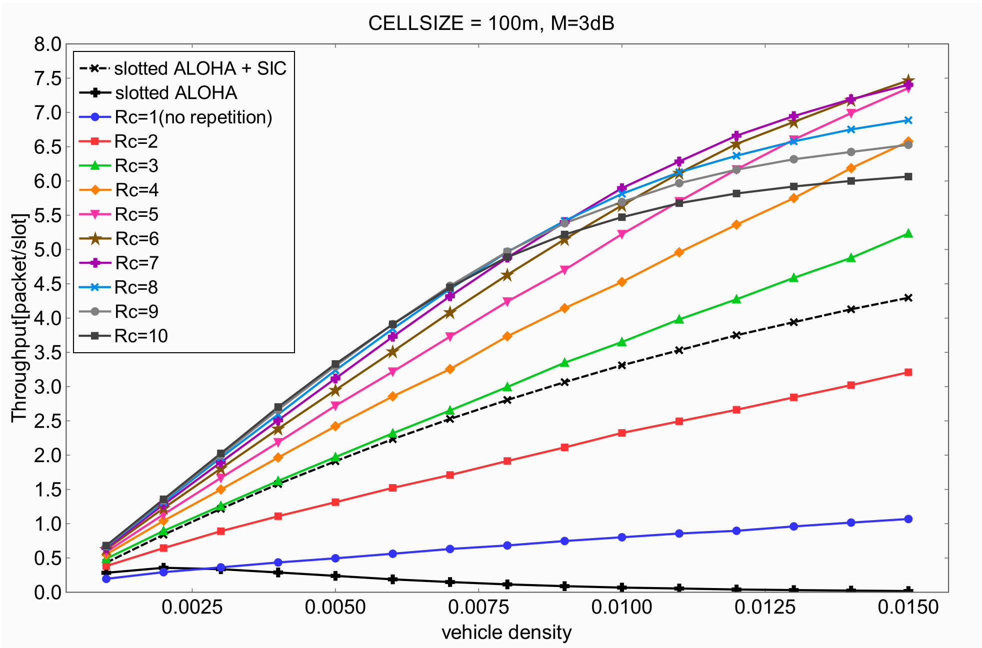

Figure 5.2: Throughput performance for CELLSIZE:100m, $M = 3$[dB]

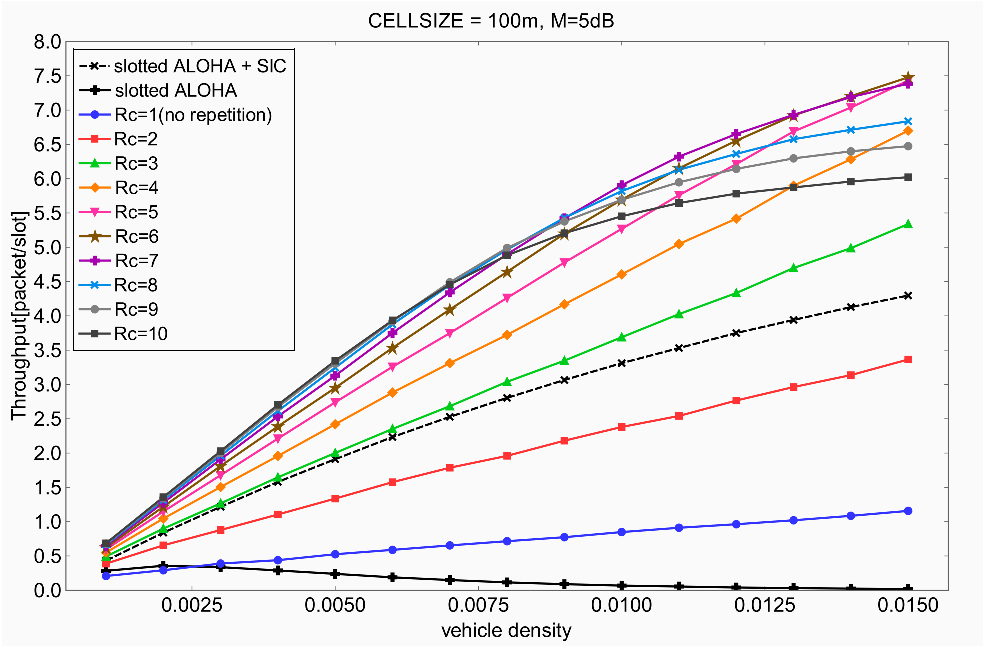

Figure 5.3: Throughput performance for CELLSIZE:100m, $M = 5$[dB]

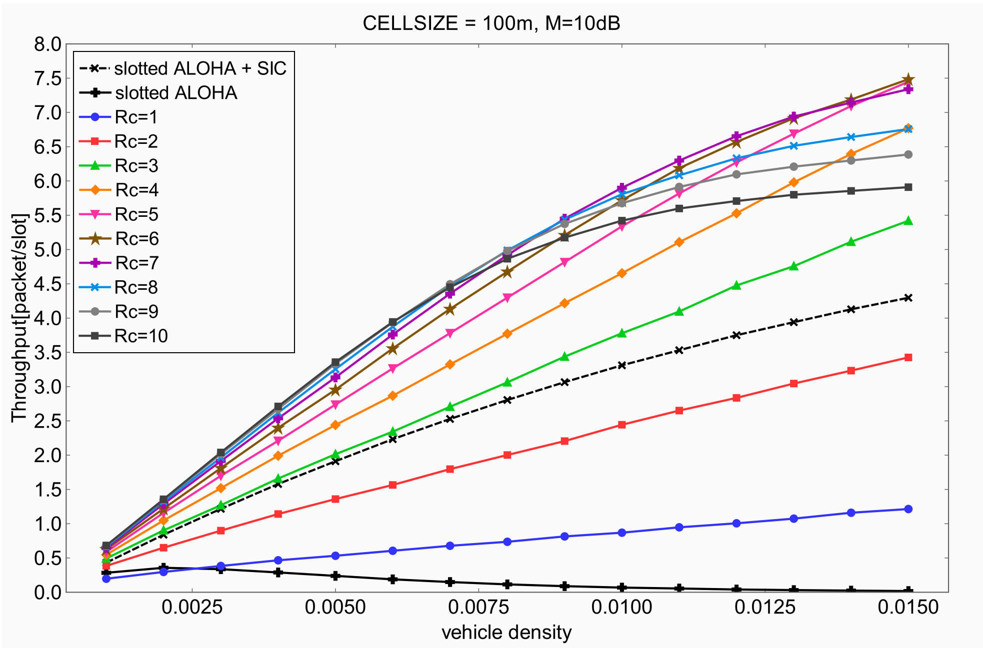

Figure 5.4: Throughput performance for CELLSIZE:100m, $M = 10$[dB]

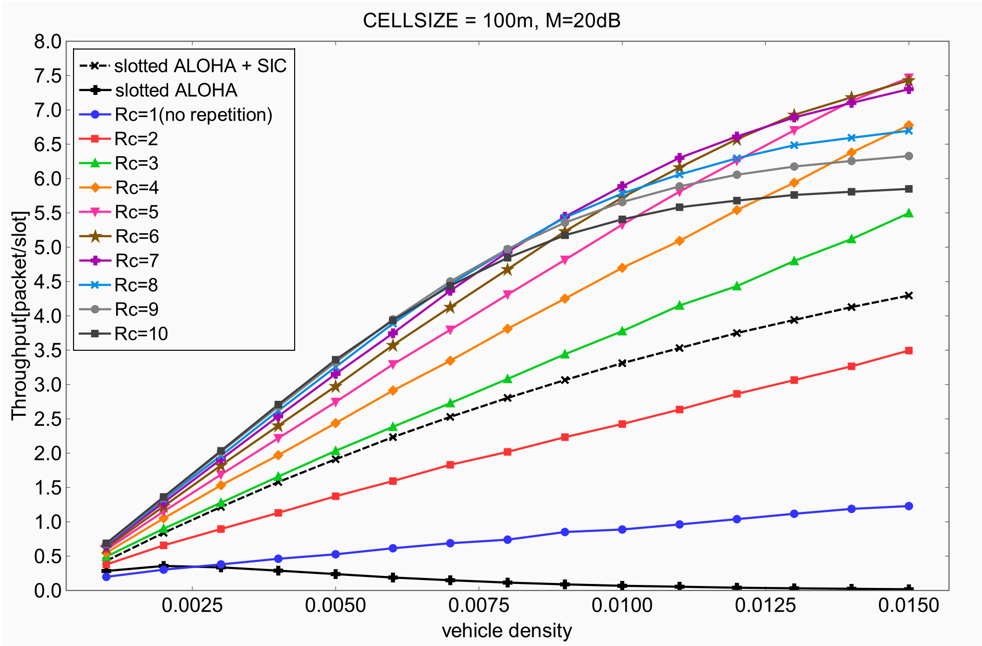

Figure 5.5: Throughput performance for CELLSIZE:100m, $M = 20$[dB]

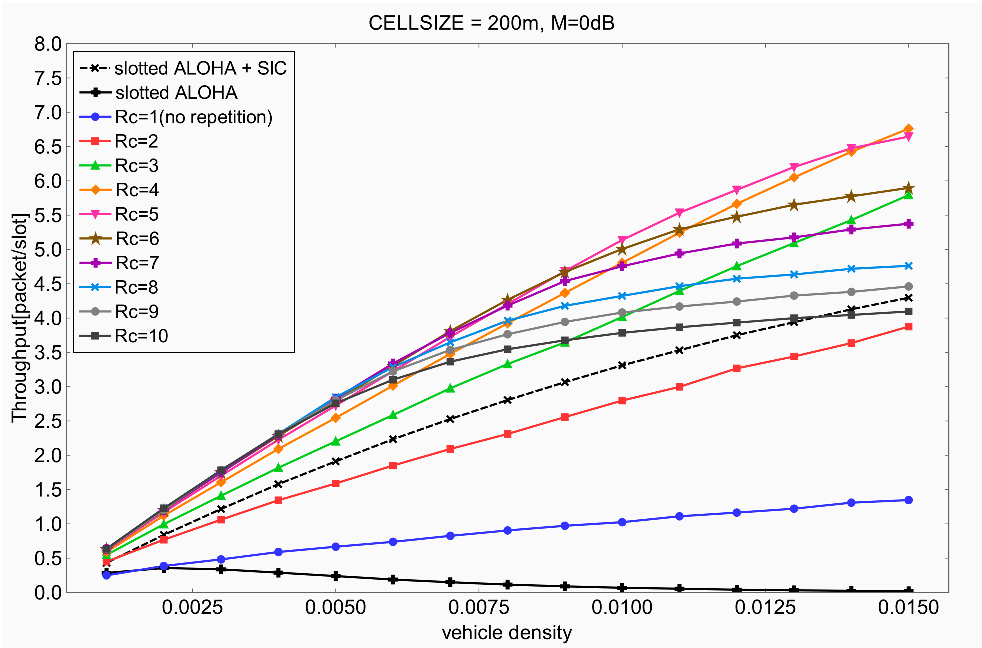

Figure 5.6: Throughput performance for CELLSIZE:200m, $M = 0$[dB]

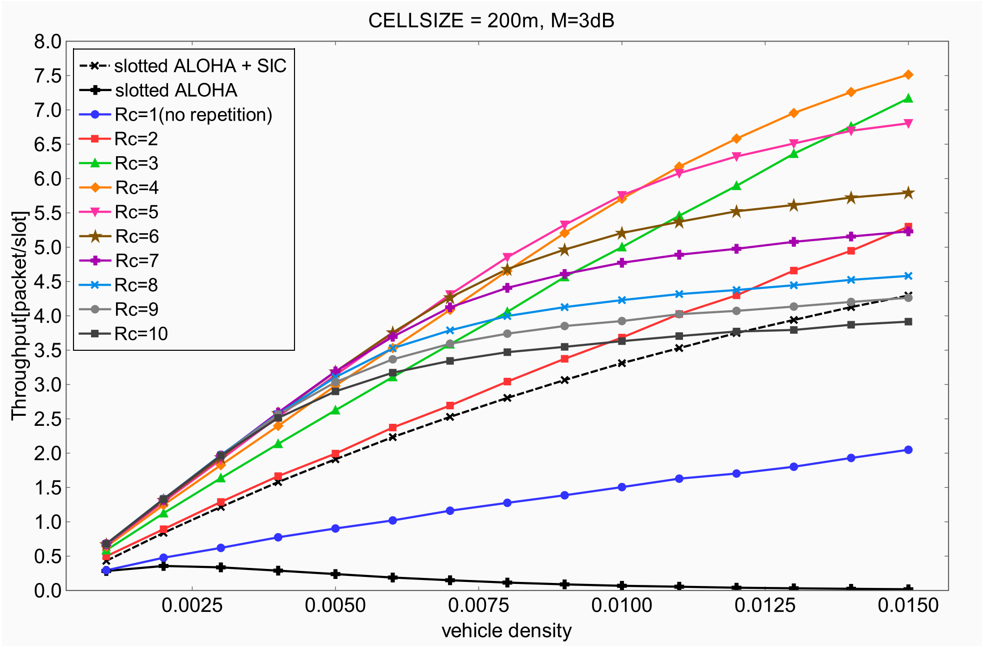

Figure 5.7: Throughput performance for CELLSIZE:200m, $M = 3$[dB]

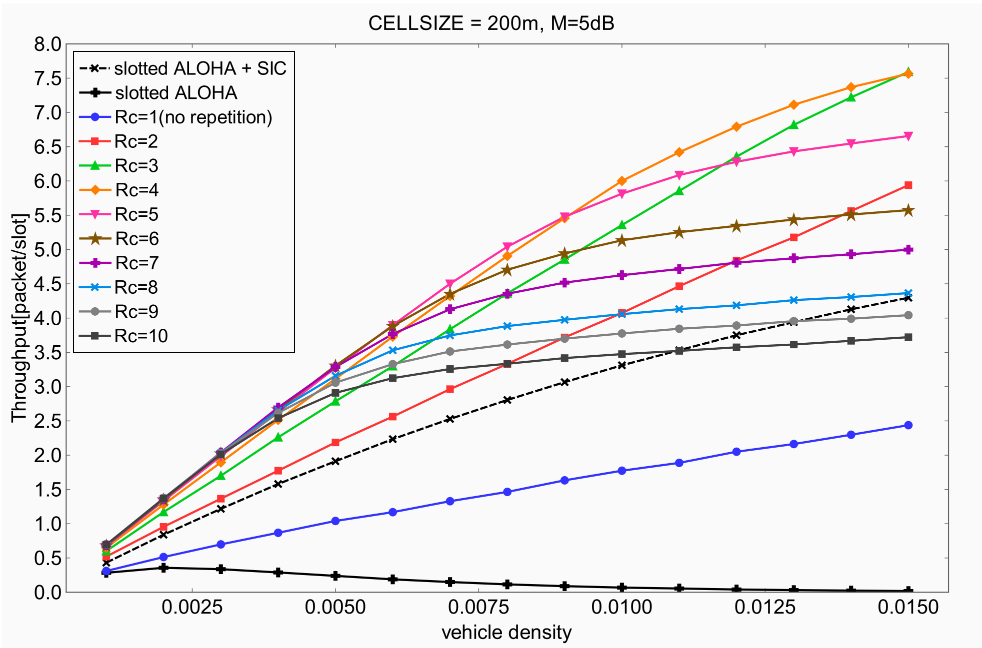

Figure 5.8: Throughput performance for CELLSIZE:200m, $M = 5$[dB]

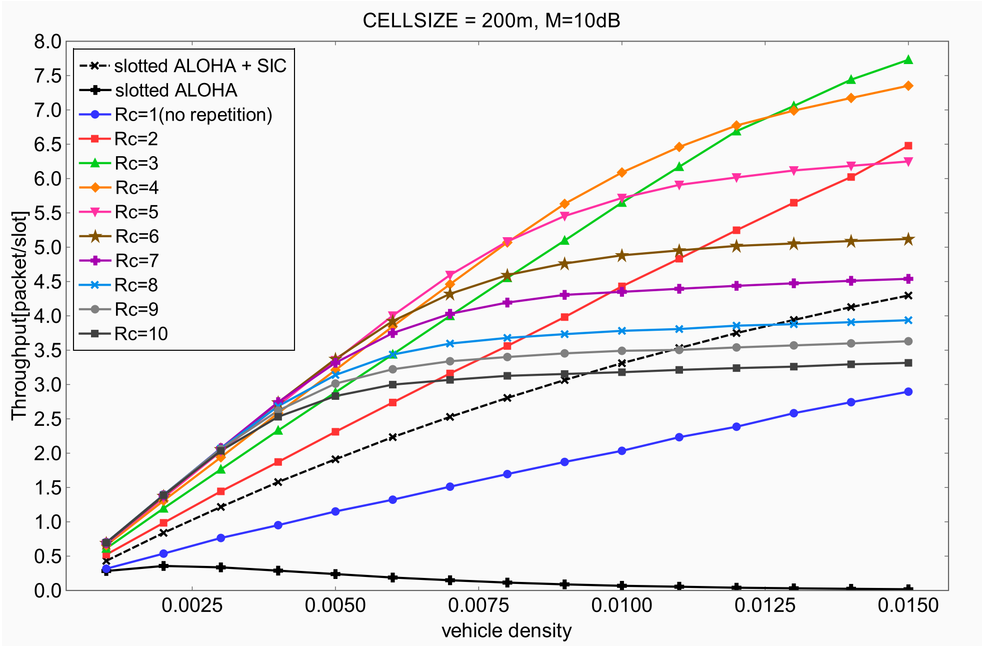

Figure 5.9: Throughput performance for CELLSIZE:200m, $M = 10$[dB]

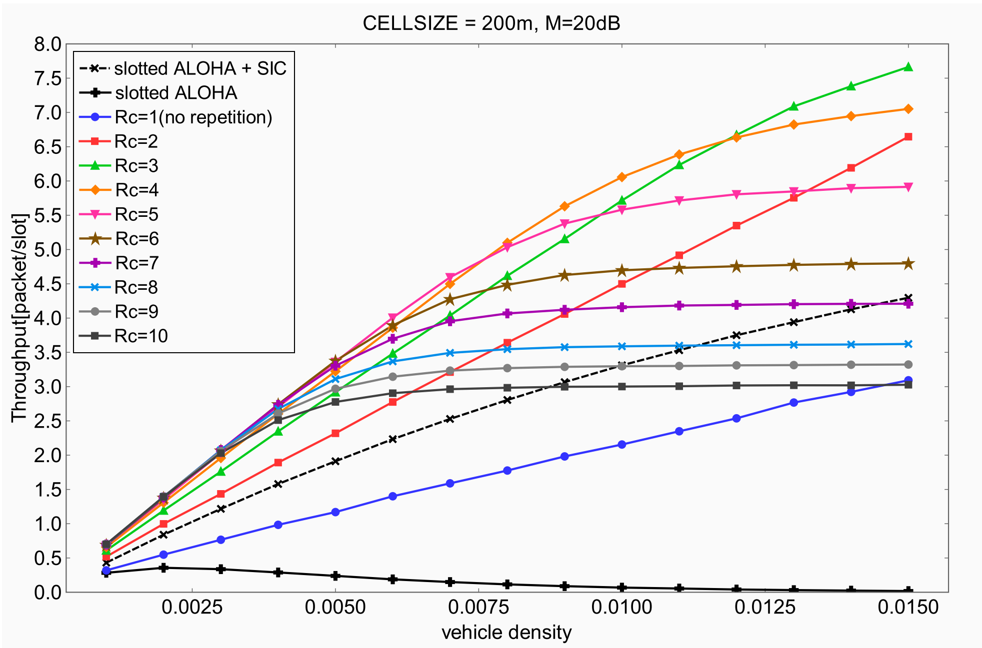

Figure 5.10: Throughput performance for CELLSIZE:200m, $M = 20$[dB]

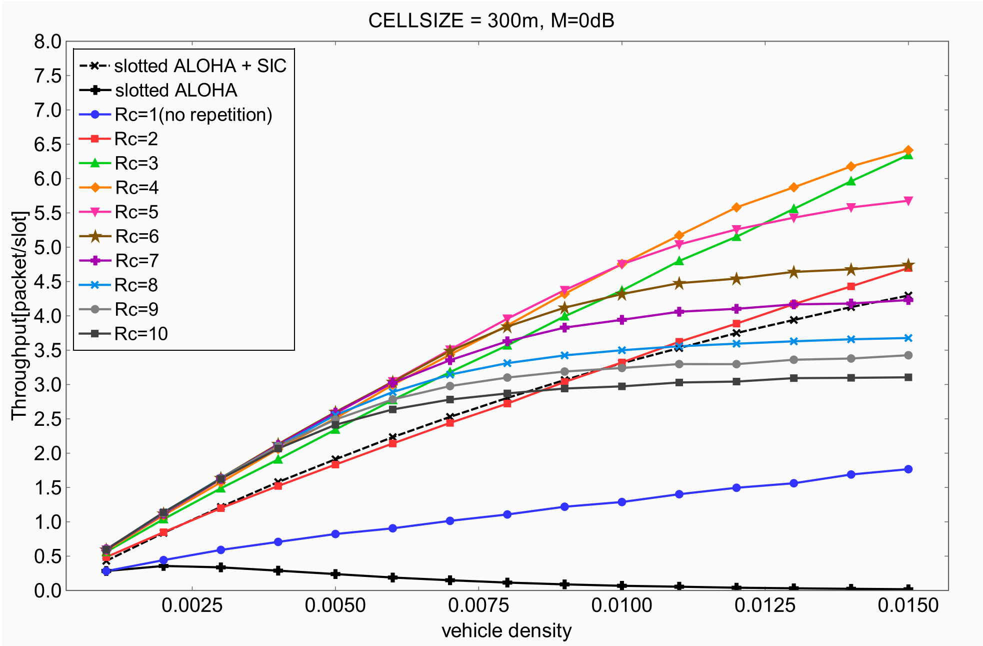

Figure 5.11: Throughput performance for CELLSIZE:300m, $M = 0$[dB]

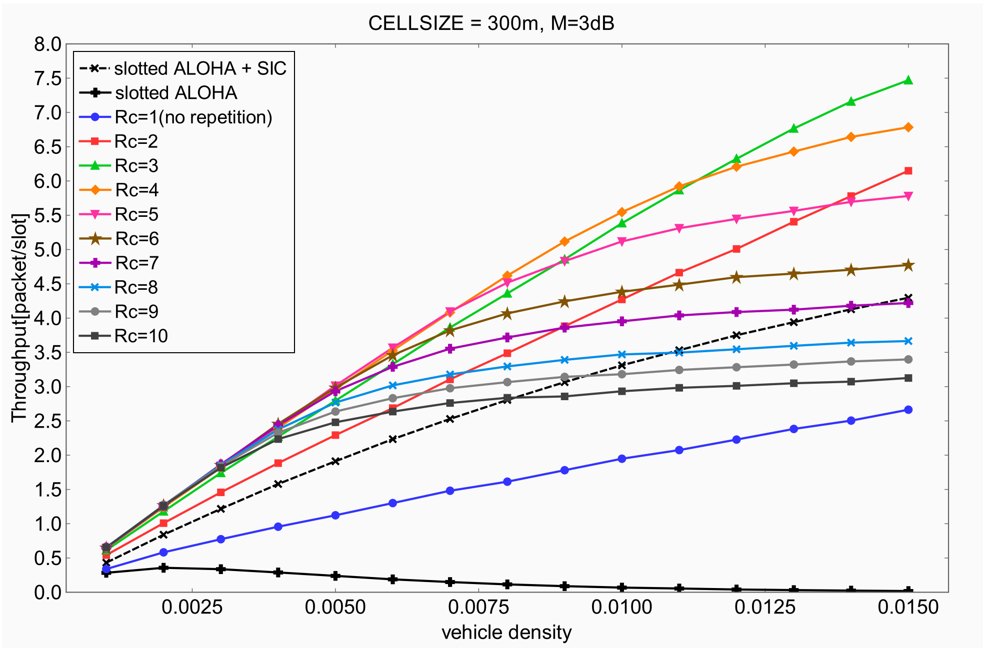

Figure 5.12: Throughput performance for CELLSIZE:300m, $M = 3$[dB]

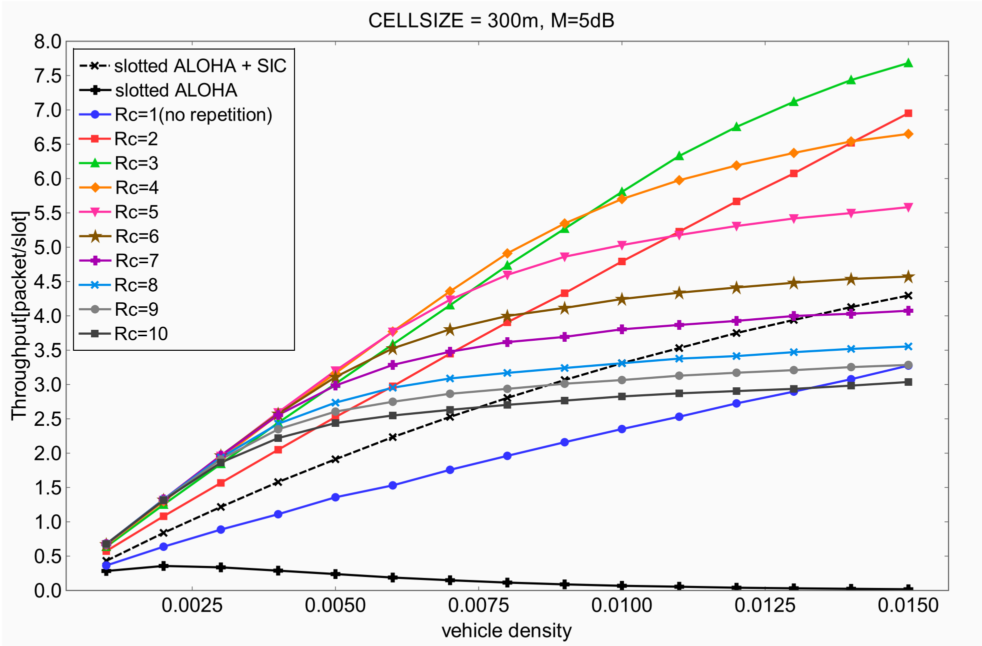

Figure 5.13: Throughput performance for CELLSIZE:300m, $M = 5$[dB]

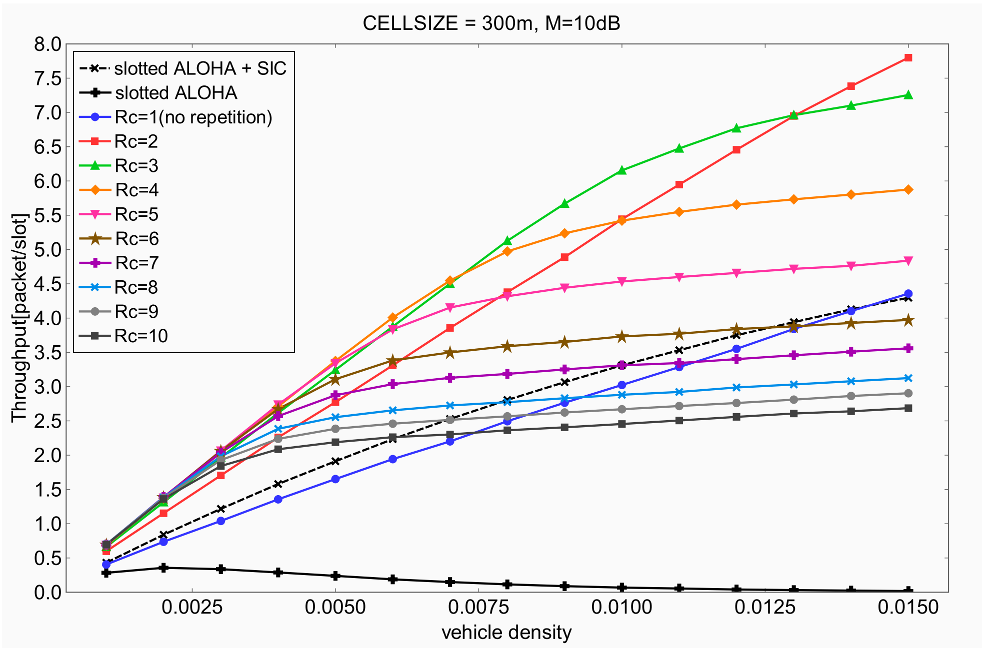

Figure 5.14: Throughput performance for CELLSIZE:300m, $M = 10$[dB]

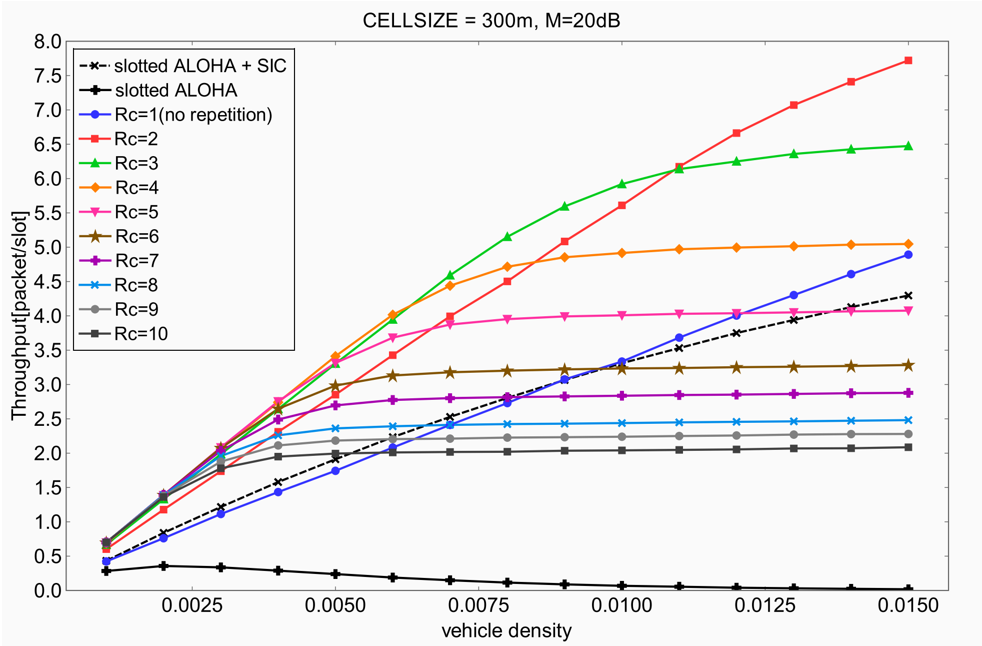

Figure 5.15: Throughput performance for CELLSIZE:300m, $M = 20$[dB]

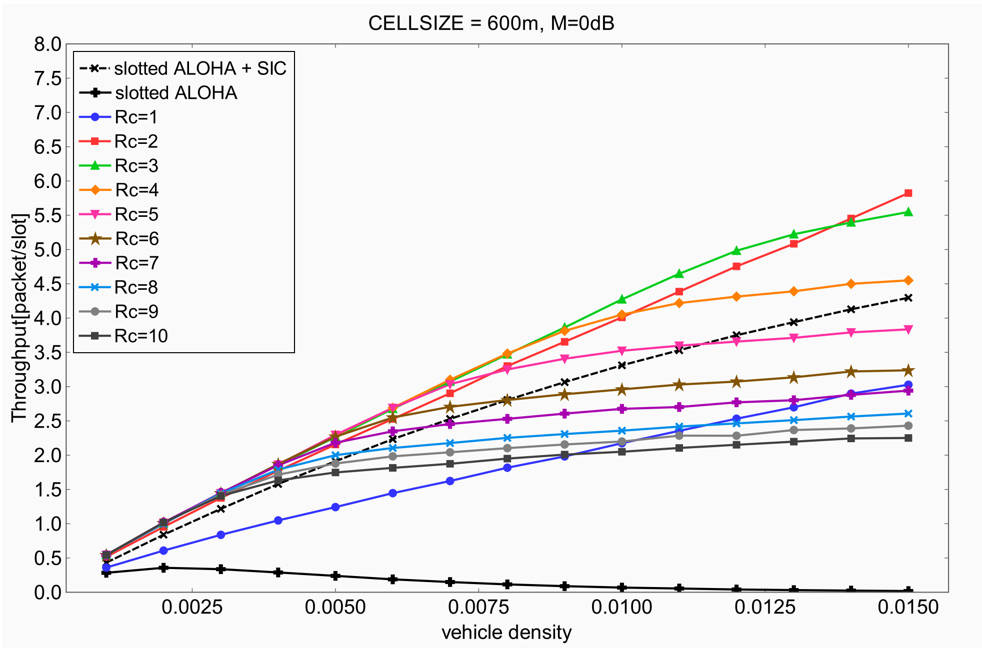

Figure 5.16: Throughput performance for CELLSIZE:600m, $M = 0$[dB]

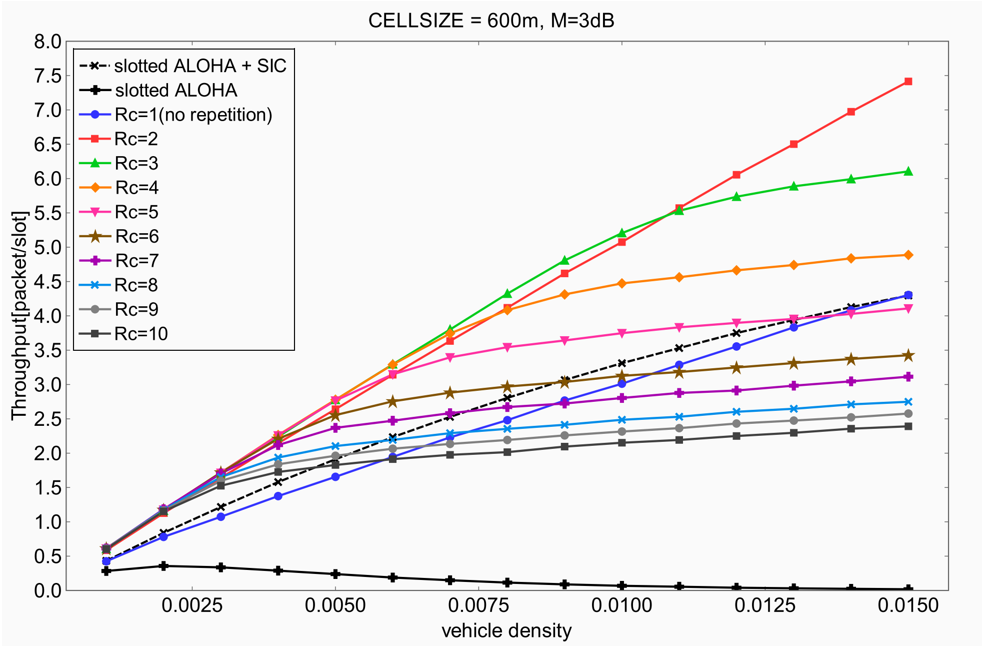

Figure 5.17: Throughput performance for CELLSIZE:600m, $M = 3$[dB]

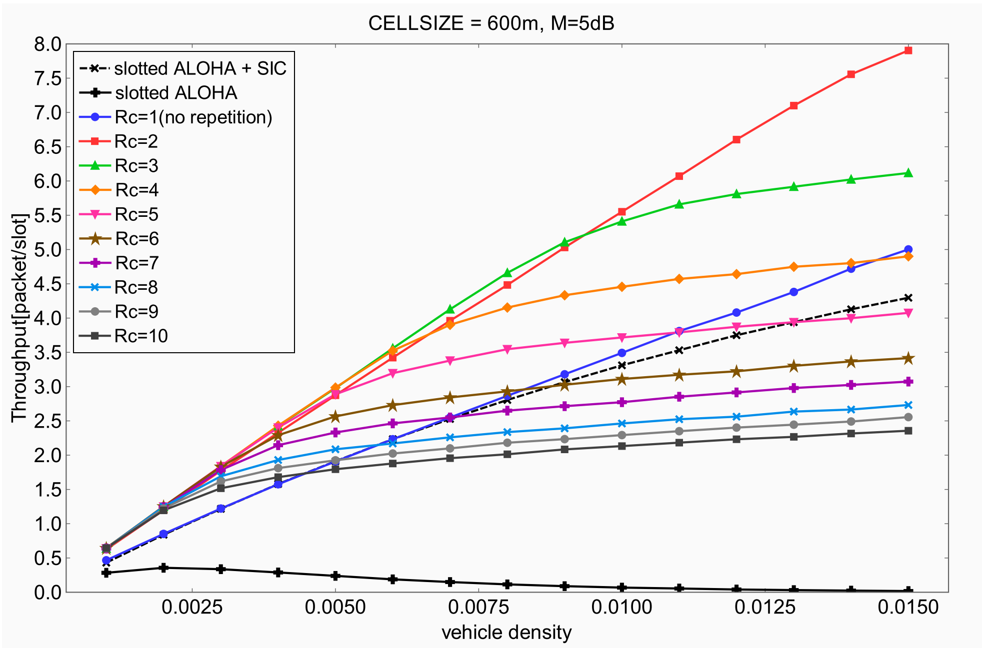

Figure 5.18: Throughput performance for CELLSIZE:600m, $M = 5$[dB]

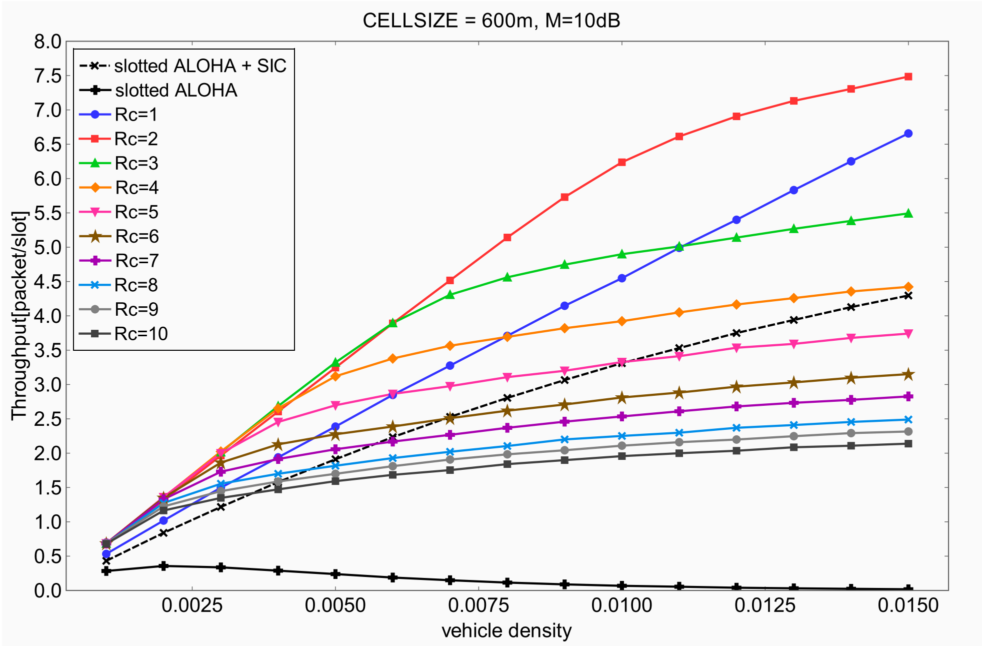

Figure 5.19: Throughput performance for CELLSIZE:600m, $M = 10$[dB]

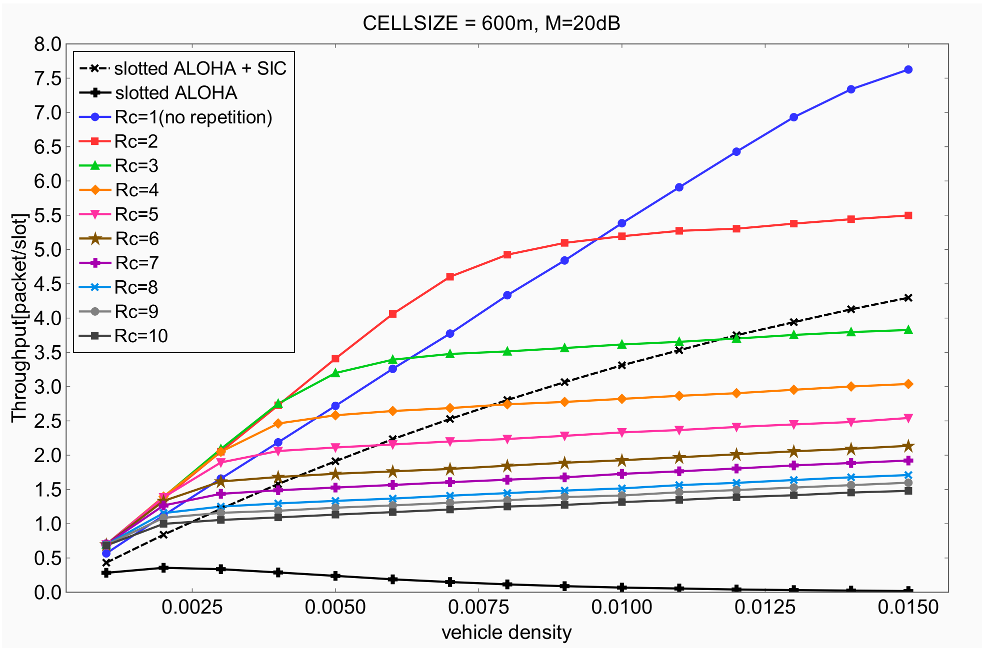

Figure 5.20: Throughput performance for CELLSIZE:600m, $M = 20$[dB]

5.3 Packet Error Rate Performance

Figure 5.21-5.40 provide the results of packet error rate (PER) performance.

Among the generated packets, the ratio of the packet that failed to demodulate including the packet that has not been allocated (i.e., thrown packet) is evaluated. The larger the cell size, the wider the range in which interference is considered, so the influence of interference from surrounding cells becomes smaller and PER improves. In addition, as R_c increases, the number of time slots allocated per cell decreases. Therefore, if Rc is large in an environment with high vehicle density, the performance is deteriorated due to insufficient resources. Consequently, when dividing by 600 m of cells at $M = 10$dB no repetition ($R_c = 1$) achieves the lowest PER when the density of vehicles is larger than 0.06 per square meter. This is because there are sufficient time slots in the cell and the superposition of SIC is also averaged by the margin, resulting in the fact that the number of vehicles in the cell and the time resources corresponded appropriately.

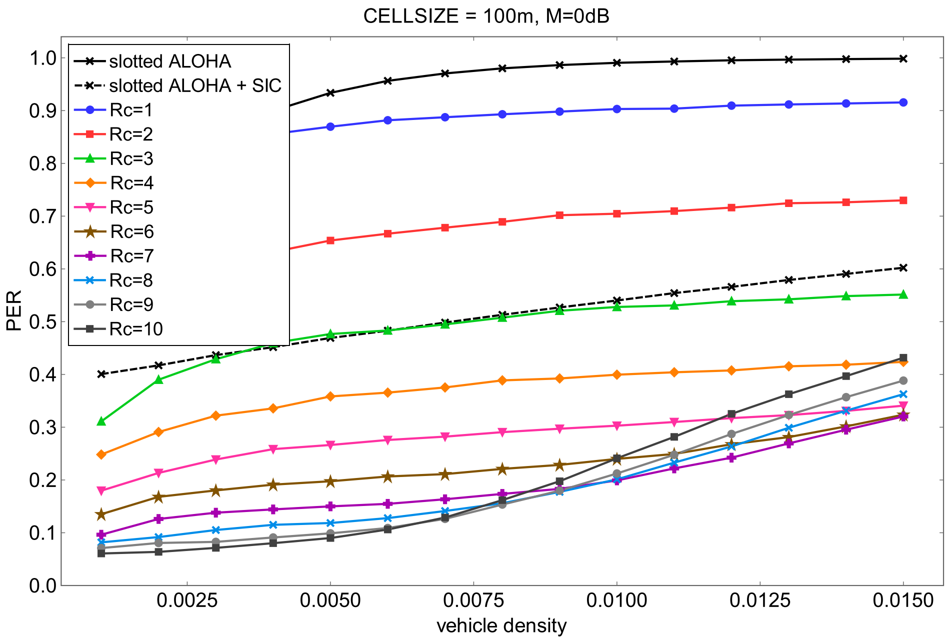

Figure 5.21: Packet Error Rate performance for CELLSIZE:100m, $M = 0$[dB]

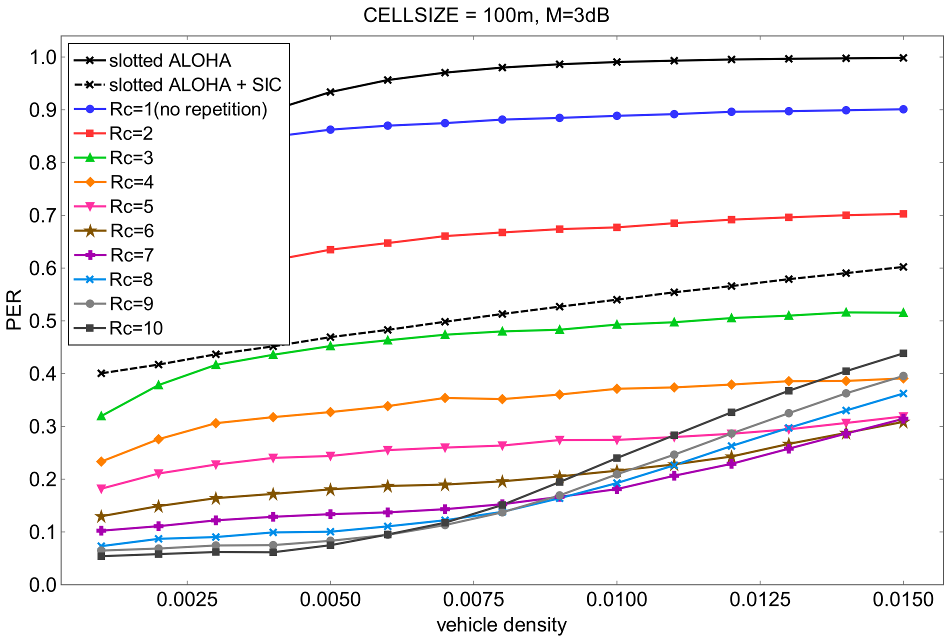

Figure 5.22: Packet Error Rate performance for CELLSIZE:100m, $M = 3$[dB]

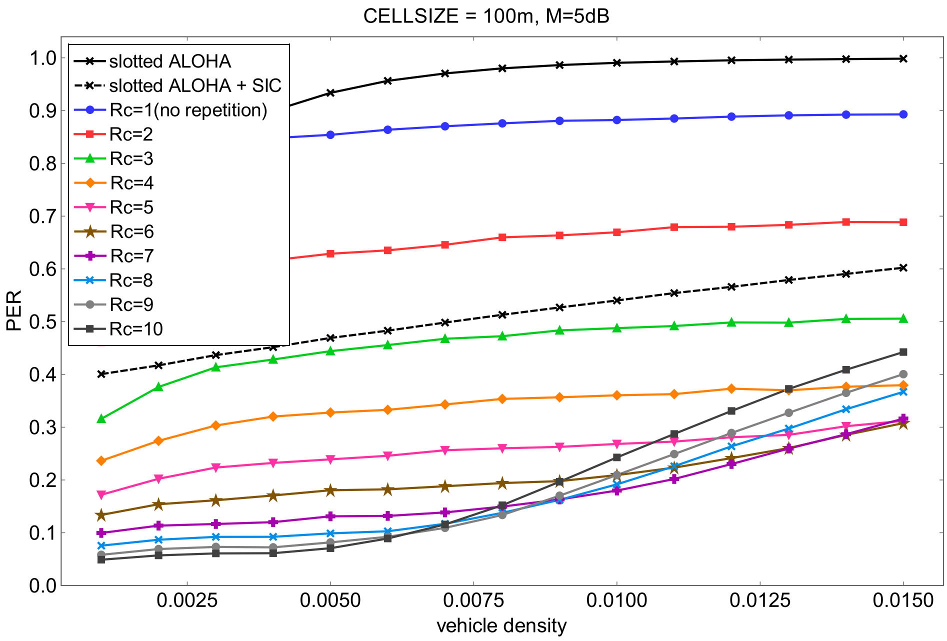

Figure 5.23: Packet Error Rate performance for CELLSIZE:100m, $M = 5$[dB]

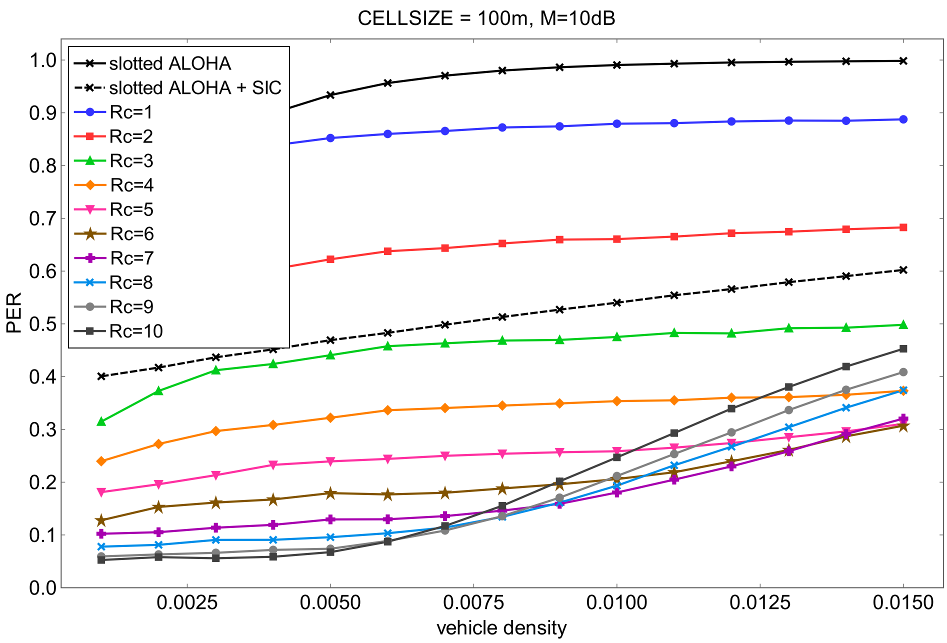

Figure 5.24: Packet Error Rate performance for CELLSIZE:100m, $M = 10$[dB]

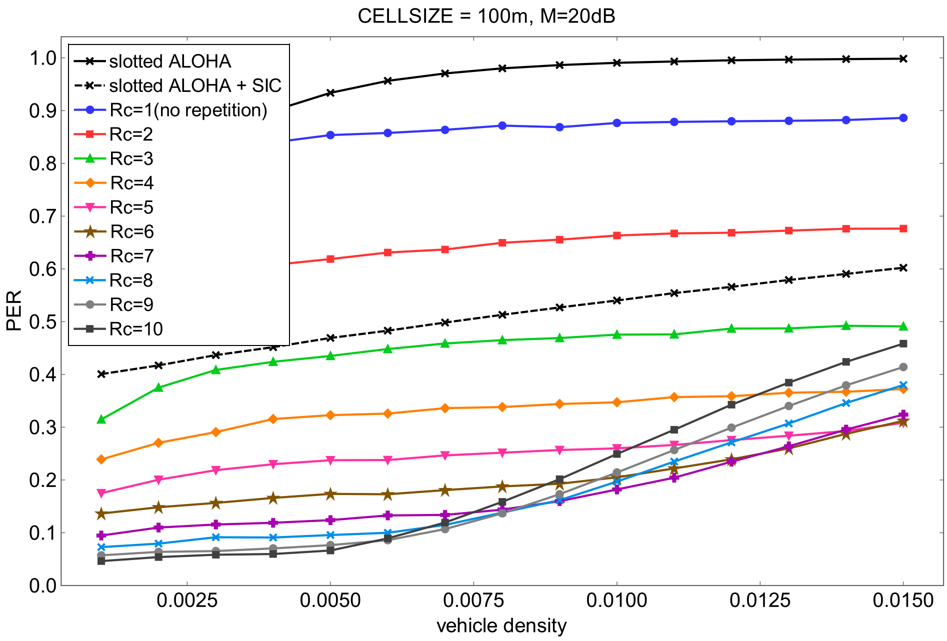

Figure 5.25: Packet Error Rate performance for CELLSIZE:100m, $M = 20$[dB]

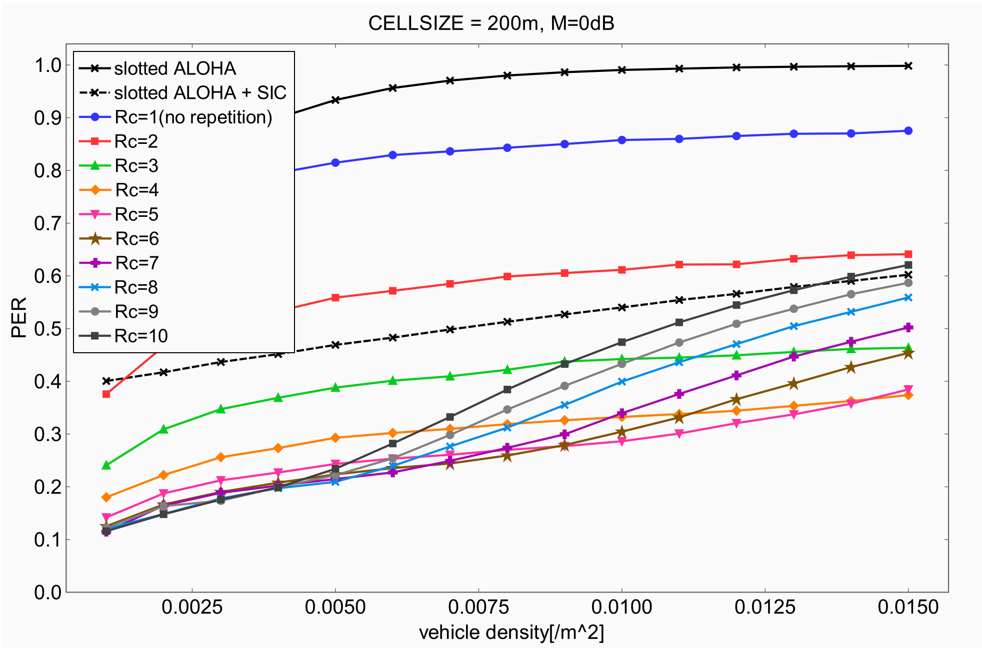

Figure 5.26: Packet Error Rate performance for CELLSIZE:200m, $M = 0$[dB]

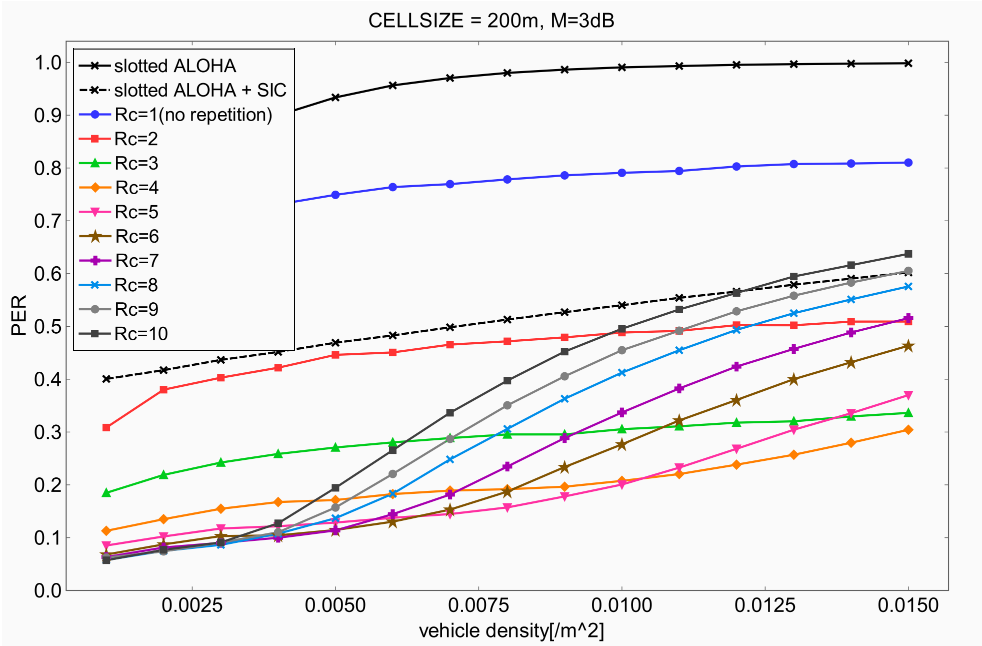

Figure 5.27: Packet Error Rate performance for CELLSIZE:200m, $M = 3$[dB]

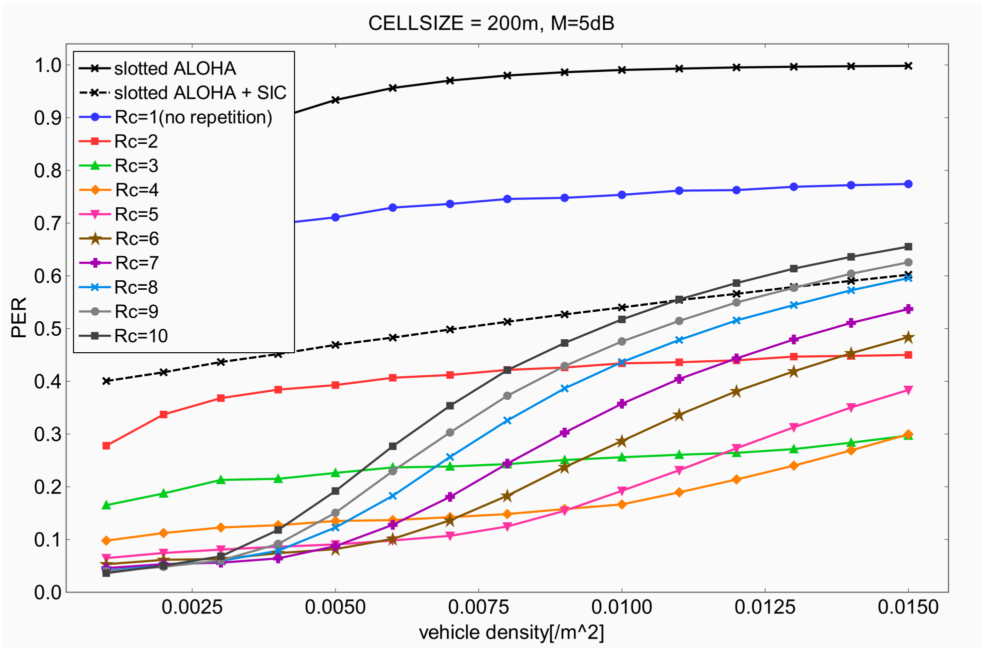

Figure 5.28: Packet Error Rate performance for CELLSIZE:200m, $M = 5$[dB]

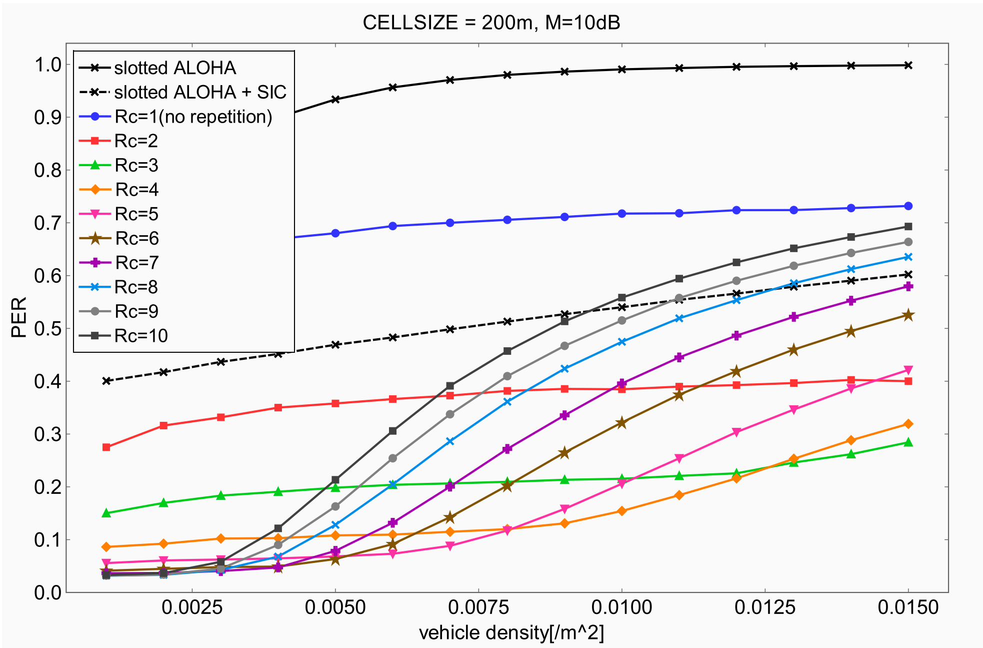

Figure 5.29: Packet Error Rate performance for CELLSIZE:200m, $M = 10$[dB]

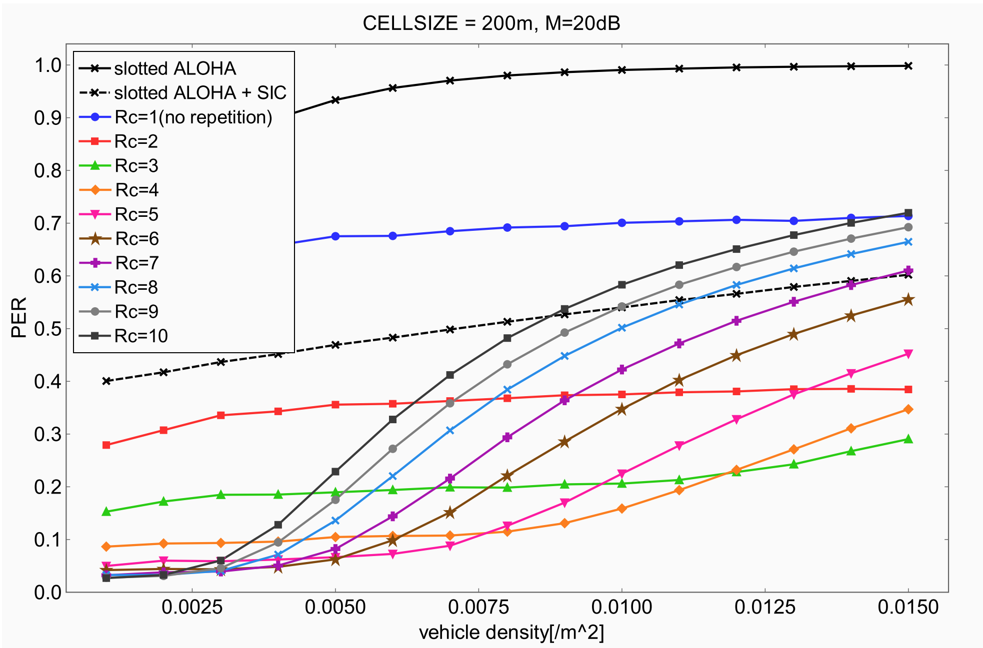

Figure 5.30: Packet Error Rate performance for CELLSIZE:200m, $M = 20$[dB]

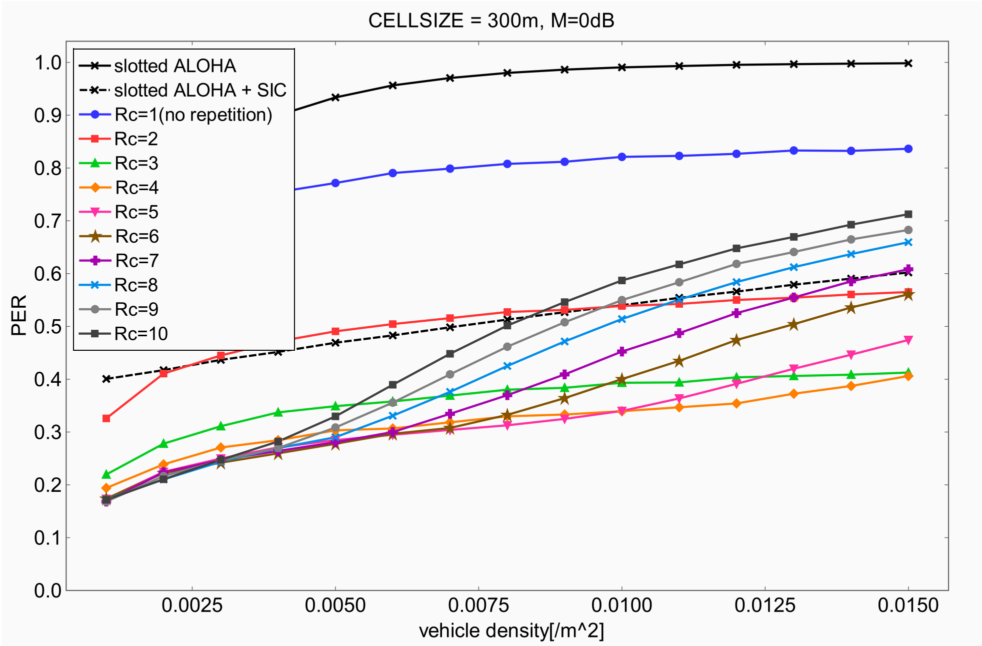

Figure 5.31: Packet Error Rate performance for CELLSIZE:300m, $M = 0$[dB]

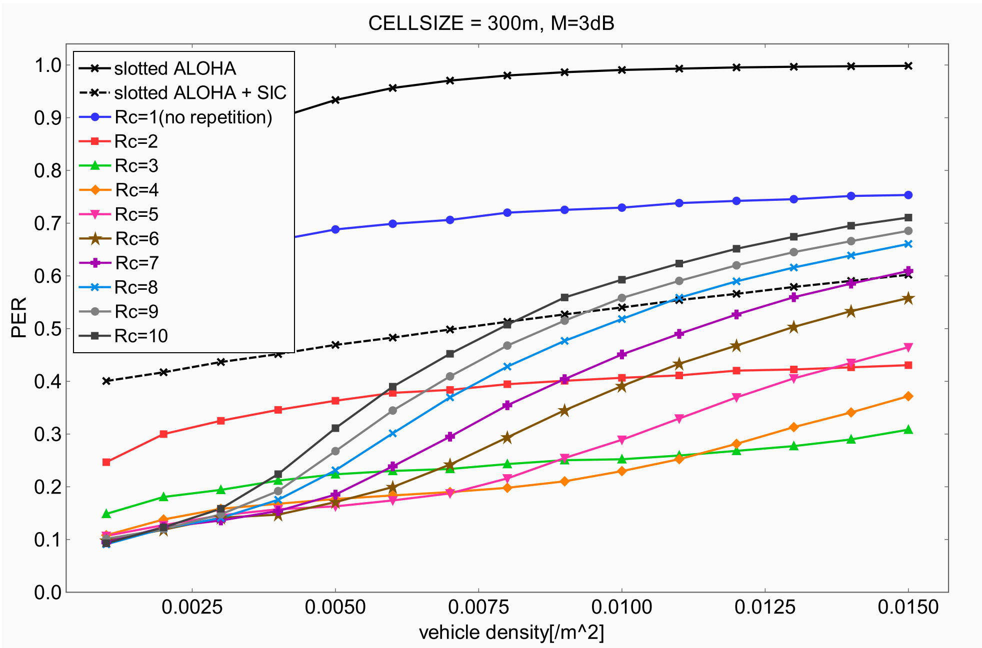

Figure 5.32: Packet Error Rate performance for CELLSIZE:300m, $M = 3$[dB]

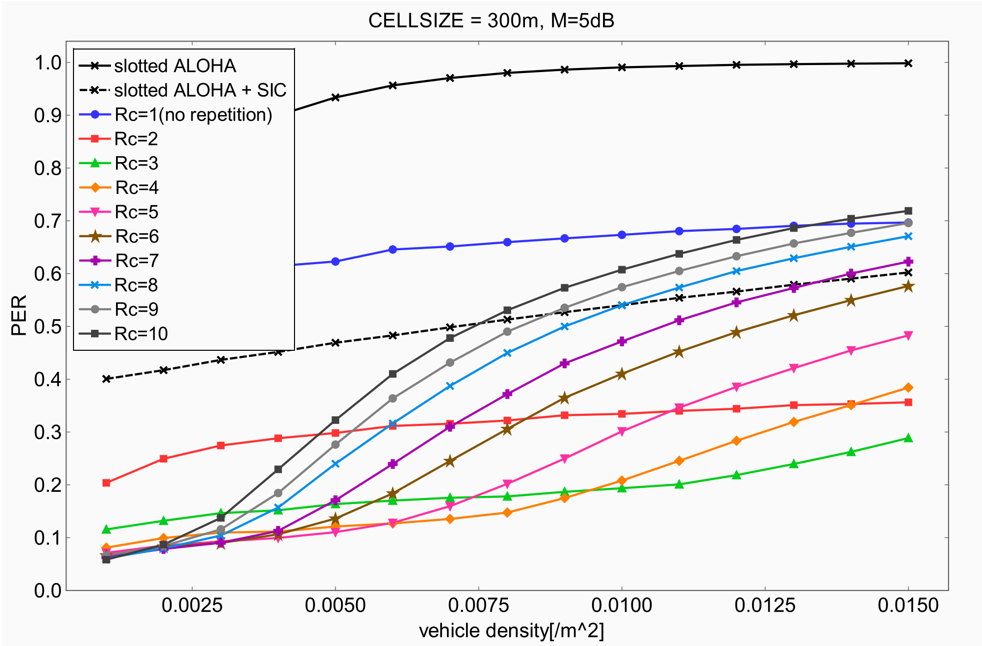

Figure 5.33: Packet Error Rate performance for CELLSIZE:300m, $M = 5$[dB]

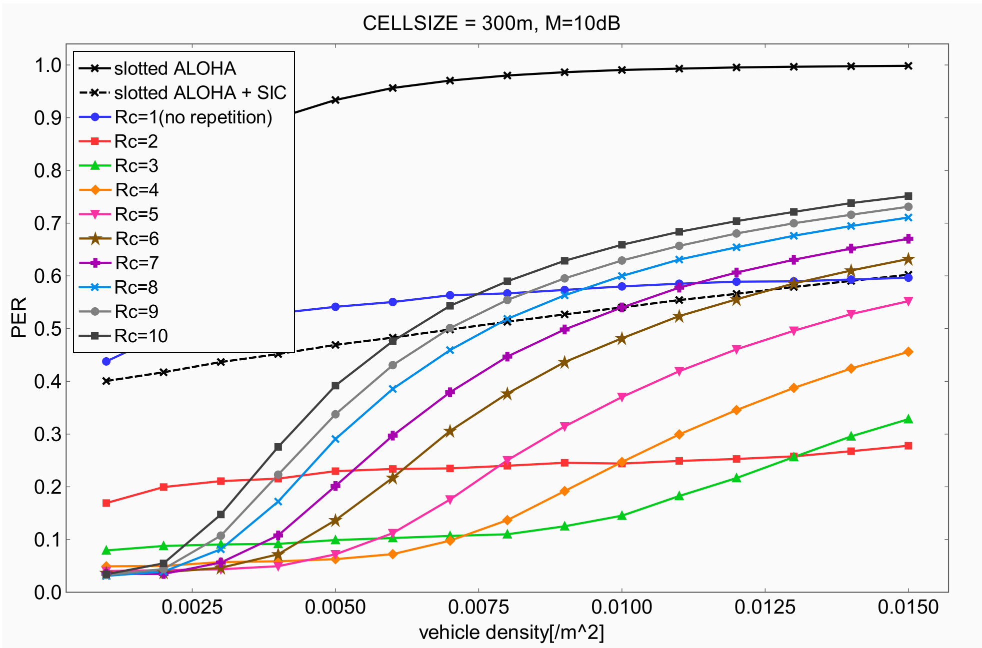

Figure 5.34: Packet Error Rate performance for CELLSIZE:300m, $M = 10$[dB]

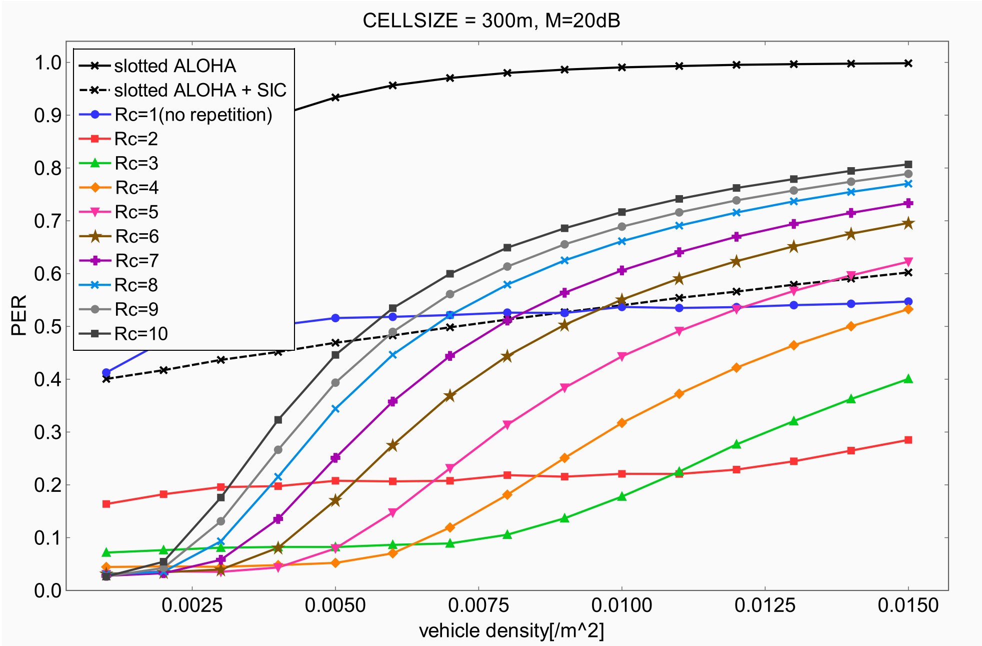

Figure 5.35: Packet Error Rate performance for CELLSIZE:300m, $M = 20$[dB]

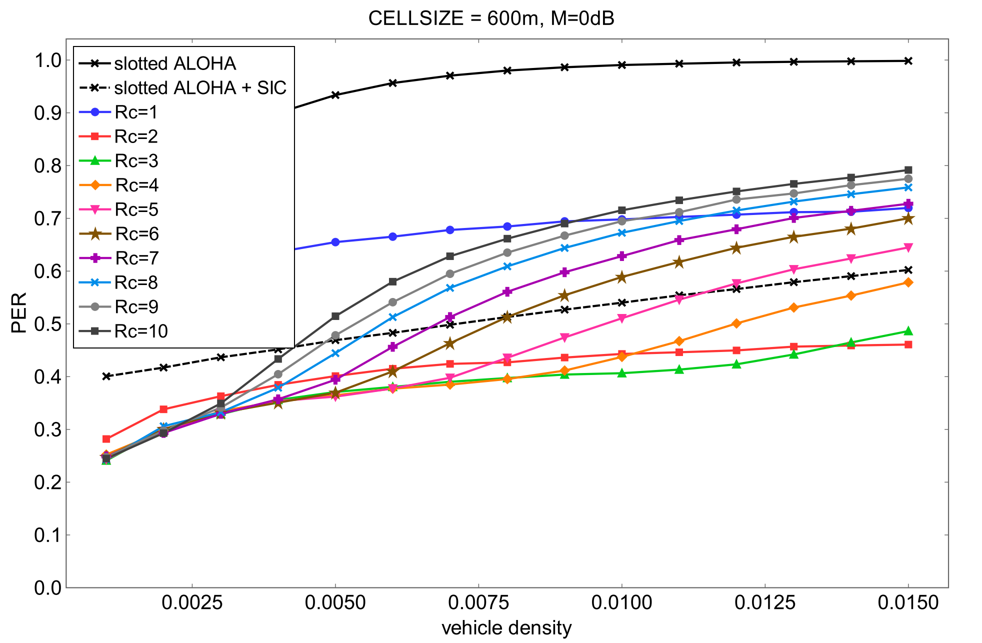

Figure 5.36: Packet Error Rate performance for CELLSIZE:600m, $M = 0$[dB]

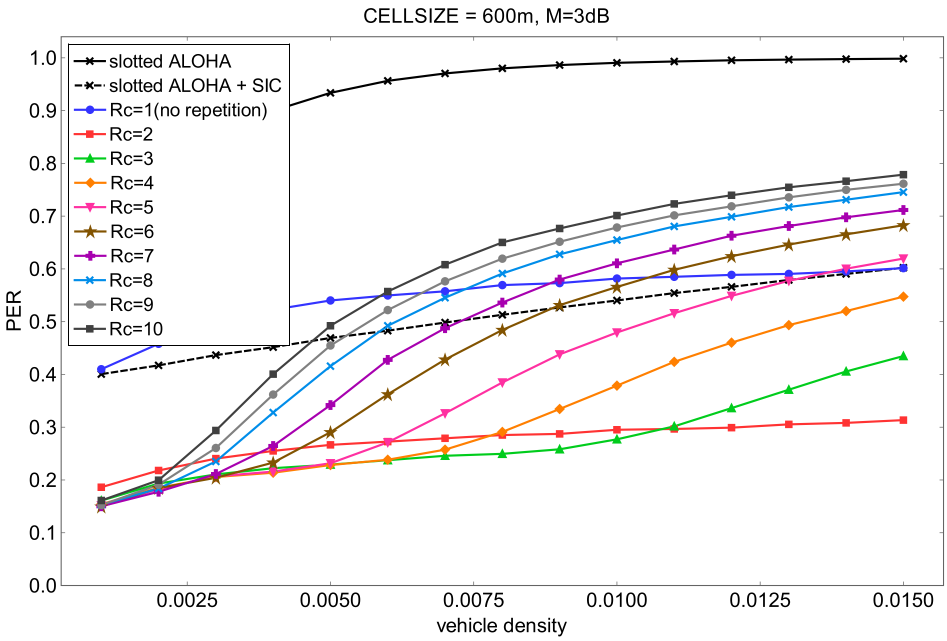

Figure 5.37: Packet Error Rate performance for CELLSIZE:600m, $M = 3$[dB]

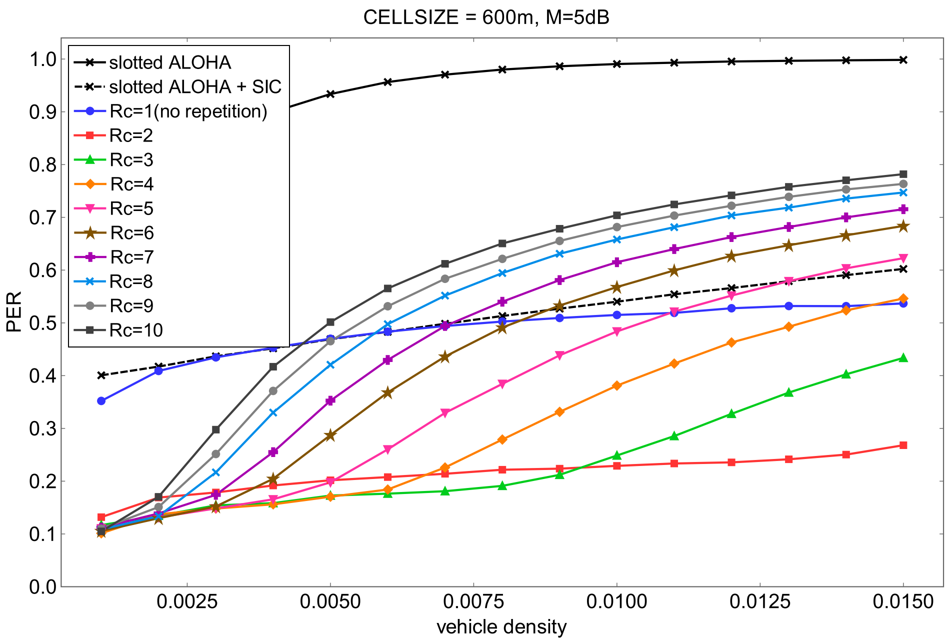

Figure 5.38: Packet Error Rate performance for CELLSIZE:600m, $M = 5$[dB]

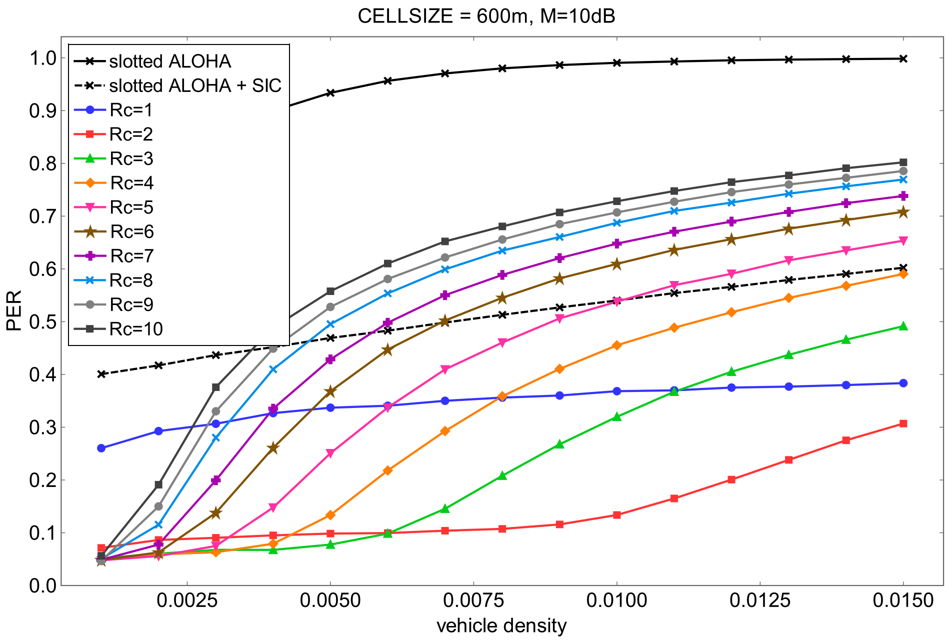

Figure 5.39: Packet Error Rate performance for CELLSIZE:600m, $M = 10$[dB]

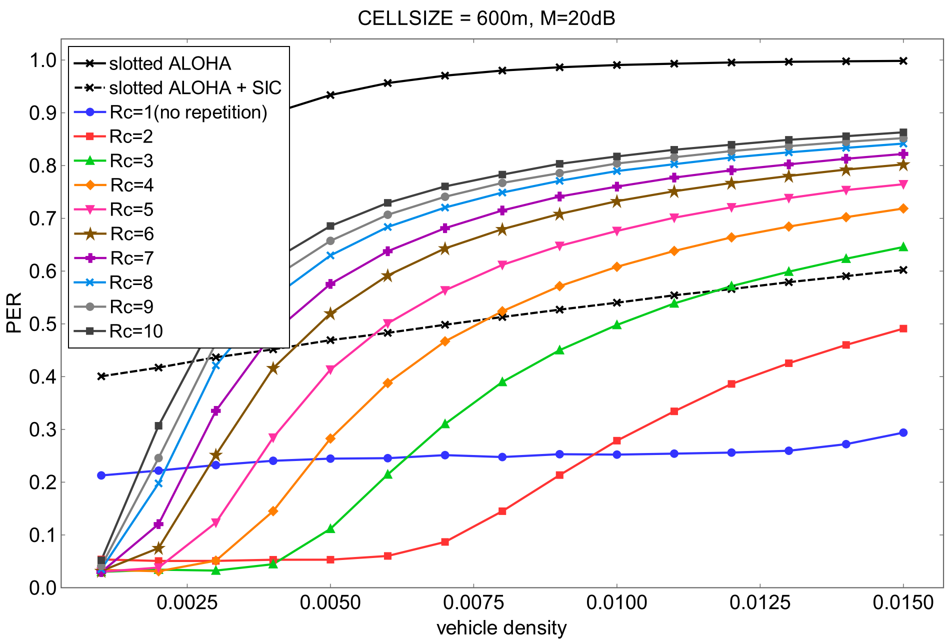

Figure 5.40: Packet Error Rate performance for CELLSIZE:600m, $M = 20$[dB]

Chapter 6

Conclusions

In this thesis, a cloud-assited resource allocation method considering SIC for communication in V2V envrionment was discussed. The road is divided into cells and time slots are allocated to the cells by the cloud considering reuse of time slots. In each cells, scheduling for the vehicles in the cell is performed using location information shared to the cloud. The simulation results show that our proposed method can improve the reliability of communication in V2V environment. These results incicate that the cloud-assited resouce allocation method considering SIC can be applied to environments requiring highly reliable communication like automatic driving system.

Acknowledgments

I would like to experss immeasurable gratitude to Prof. Fujii who always gives me great opportunities and provide me a kindly feedback with valuable comments. Also, I have been helped and encouraged by Prof. Yamao, associate Prof. Ishibashi, associate Prof. Adachi. Dr. Onur Altintas, Dr. Takayuki Shimizu who belong to the Toyota InfoTechnology Center also have gave me great advice and a meaningful discussison. and all the members of their laboratories. I have got a great deal of supervision from Ph.D. Koya Sato and all the members of laboratories.

References

[1] IEEE, "Wireless Access in Vehicular Environments," IEEE, Std 802.11p-2010, Jul. 2010.

[2] "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications," IEEE, Std 802.11a-1999, 1999.

[3] M. Wellen, B. Westphal and P. Mahonen, "Performance evaluation of IEEE 802.11-based WLANs in vehicular scenarios," in Proc. IEEE VTC2007 Fall, April. 2007.

[4] E. Casini, R. De Gaudenzi, and O. Herrero, "Contention resolution diversity slotted ALOHA (CRDSA): An enhanced random access scheme for satellite access packet networks," IEEE Trans. Wireless Commun., vol. 6, no. 4, pp.1408-1419, April. 2007.

[5] G. Liva, "Graph-based analysis and optimization of contention resolution diversity slotted ALOHA," IEEE Trans. Commun., vol. 59, no. 2, pp.477-487, 2011.

[6] D. Jia, H. Yu, C. Sun, Z. Fei, and J. Kuang, "Feedback-aided Irregular Repetition Slotted ALOHA," WCSP2017, pp. 04, 2017.

[7] L. G. Roberts, "ALOHA packet systems with and without slots and capture, " ARPANET System Note 8 (NIC11290), June 1972.

[8] X. Ma, P. Hrubik, H. Refai, and S. Yang, "Capture effect on R-ALOHA protocol for inter-vehicle communications," Proc. IEEE VTC2005-Fall, Dallas, TX, Sep. 2005.

[9] K. Bilstrup, E. Uhlemann, E. G. Strom, and U. Bilstrup, "On the Ability of the 802.11p MAC Method and STDMA to Support Real-Time Vehicle-to-Vehicle Communication," Journal on Wireless Communications and Networking, EURASIP, Vol.2009, pp.1-13, Jan. 2009.

[10] Shaohe Lv, Weihua Zhuang, Ming Xu, Xiaodong Wang, Chi Liu, and Xingming Zhou, "Understanding the scheduling performance in wireless networks with succes-

sive interference cancellation," IEEE Transactions on Mobile Computing, vol. 12, no. 8, pp. 1625-1639, 2013.

[11] Shaohe Lv, Weihua Zhuang, Xiaodong Wang, and Xingming Zhou, "Scheduling in Wireless Ad Hoc Networks with Successive Interference Cancellation," Proc. IEEE INFOCOM, pp. 1282-1290, 2011.

[12] Chongbin Xu, Li Ping, Peng Wang, Sammy Chan, and Xiaokang Lin, "Decentralized Power Control for Random Access with Successive Interference Cancellation," IEEE J. Sel. Areas Commun., vol. 31, no. 11, pp. 2387-2396, Nov. 2013.

[13] J. G. Andrews and T. H. Meng, "Optimum power control for successive interference cancellation with imperfect channel estimation," IEEE Trans. Wirel. Commun., vol. 2, no. 2, pp. 375383, 2003.

[14] Recommendation ITU-R P.1411-9, "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz," 2017.

Publications

i. 渡辺裕太, 佐藤光哉, 藤井威生, "逐次干渉除去を用いた自動運転向け V2V ネットワークのためのスケジューリングに関する一検討, " ソサイエティ大会 B-17, 2016 年 9 月.

ii. Yuta Watanabe, Koya Sato, and Takeo Fujii, "A Scheduling Method for V2V Networks Using Successive Interference Cancellation, " Proc. IEEE VNC2016, Ohio, USA, Dec. 2016.

iii. 右手達也, 渡辺裕太, 佐藤光哉, 藤井威生, "V2V ネットワーク信頼性向上のためのマルチアンテナ逐次干渉除去に関する研究, " 信学技報, SR2017-58, July 2017.

iv. Tatsuya Ute, Yuta Watanabe, Koya Sato, Takeo Fujii, Takayuki Shimizu, and Onur Altintas, "Multi-Antenna Successive Interference Cancellation to Improve Reliability of V2V Communication, " Proc. IEEE VNC2017, Torino, Italy, Nov. 2017.