平成29年度修士論文

Highly Reliable Vehicle-to-Vehicle Communication using Prior Information by Spectrum Environment Map

電波環境マップによる事前情報を利用した高信頼車車間通信

学生番号	1631097
氏名	鶴見 俊介
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
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修士論文の和文要旨

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氏　　名	鶴見　俊介	学籍番号	1631097
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要旨

近年，自動車の高度化による自動走行システムに注目が集まっている．自動走行システムには，加速，操舵，制動を同時に自動車がドライバーのアシストをする高度運転支援や，加速，操舵，制動を全て自動車がコントロールする完全自動走行といったシステムがあるが，この技術は，交通事故の低減，交通渋滞の緩和，運転の快適性の向上といった効果が期待され，国内外での研究開発が盛んにおこなわれている．また自動運転システムへの応用を目指して，高度道路交通システム (ITS: Intelligent Transport Systems) の研究がすすめられている．ITS では車車間通信（V2V:Vehicle-to-Vehicle）や路車間通信（V2I:Vehicle-to-Infrastructure）により，車両同士または路側器と車両間で逐次通信をすることが考えられている．しかし，車両が常に移動していることから，受信信号品質は，周辺構造物，地形，周辺の他車両台数，送信車両からの距離などに応じて複雑に変動する．そのため自動運転システムに寄与するような安定通信の実現に課題がある．

この問題を解決するために，通信を行っている車両を観測ノードとみなし，パケット受信時の受信電力およびパケットの復調可否を取得し，その地点での無線環境情報として，位置情報と共にネットワーク上に設置するデータベースに集約することを考える．集約された情報はデータベースと連携した統計サーバで統計化処理を行い，位置情報と共にデータベースに蓄積し，車両からのリクエストに応じて，その周囲の無線環境として提供することで，通信を行おうとしている車両での事前情報を利用することで，目的車両間の通信の高信頼化を図る．

この事前情報を利用することで,，通信を行うときに周辺環境を考慮した適切なパラメータの選択により通信の効率化を図る事が可能になる．事前情報を利用して変更する通信パラメ-タとして，中継車両，送信電力，変調方式を検討し特性の評価を行った．

和文概要

近年，自動車の高度化による自動走行システムに注目が集まっている．自動走行システムには，加速，操舵，制動を同時に自動車がドライバーのアシストをする高度運転支援や，加速，操舵，制動を全て自動車がコントロールする完全自動走行といったシステムがあるが，この技術は，交通事故の低減，交通渋滞の緩和，運転の快適性の向上といった効果が期待され，国内外での研究開発が盛んにおこなわれている．また自動運転システムへの応用を目指して，高度道路交通システム (ITS: Intelligent Transport Systems) の研究がすすめられている．ITS では車車間通信（V2V:Vehicle-to-Vehicle）や路車間通信（V2I:Vehicle-to-Infrastructure）により，車両同士または路側器と車両間で逐次通信をすることが考えられている．しかし，車両が常に移動していることから，受信信号品質は，周辺構造物，地形，周辺の他車両台数，送信車両からの距離などに応じて複雑に変動する．そのため自動運転システムに寄与するような安定通信の実現に課題がある．

この問題を解決するために，通信を行っている車両を観測ノードとみなし，パケット受信時の受信電力およびパケットの復調可否を取得し，その地点での無線環境情報として，位置情報と共にネットワーク上に設置するデータベースに集約することを考える．集約された情報はデータベースと連携した統計サーバで統計化処理を行い，位置情報と共にデータベースに蓄積し，車両からのリクエストに応じて，その周囲の無線環境として提供することで，通信を行おうとしている車両での事前情報を利用することで，目的車両間の通信の高信頼化を図る．

この事前情報を利用することで，通信を行うときに周辺環境を考慮した適切なパラメータの選択により通信の効率化を図る事が可能になる．事前情報を利用して変更する通信パラメ-タとして，中継車両，送信電力，変調方式を検討しそれぞれの特性の評価を行った．

Abstract

In recent years, attention has been focused on an automatic traveling system due to advancement of automobiles. Automatic traveling systems include advanced driving assistance that automobiles assist drivers at the same time as acceleration, steering, and braking, as well as systems that fully automate the vehicle's control of acceleration, steering, and braking. This technology is expected to have effects such as reduction of traffic accidents, relaxation of traffic congestion, improvement of comfort of driving, research and development in and outside the country is actively carried out. For the application to automatic driving systems, research on Intelligent Transport Systems (ITS) is advancing. In ITS, it is considered to communicate successively between vehicles or between a roadside unit and a vehicle by inter-vehicle communication (V2V: Vehicle-to-Vehicle) or roadside communication (V2I: Vehicle-to-Infrastructure). However, since the vehicle is constantly moving, the received signal quality varies complicatedly depending on peripheral structures, terrain, the number of other vehicles in the vicinity, the distance from the transmitting vehicle, and the like. Therefore, there is a problem in realizing stable communication which contributes to the automatic driving system.

To solve this problem, we consider the vehicle that is communicating as an observation node and acquire the reception power and packet delivery rate with location information at the time of packet reception and consolidate it in the database installed on the network as radio environment information at that point. The aggregated information is statistically processed by a statistical server in cooperation with the database and accumulated in the database together with the position information. In response to a request from the vehicle, it is provided as a wireless environment around the vehicle, so that high-reliability communication between the target vehicles is attempted by using advance information in vehicles trying to communicate.

By using this a priori information, it becomes possible to improve communication efficiency by selecting appropriate parameters considering the surrounding environment when communicating. As a communication parameter to be changed by using advance information, relay vehicle, transmission power, modulation method were examined and their characteristics were evaluated.

Contents

Chapter 1

Introduction

1.1 Research Background

Recently the interests of driving systems increases from the viewpoints of, reduction of traffic accidents, mobility support for elderly people, improvement in driving comfort. Autonomous driving system is a system in which the vehicle autonomously accelerates, steers, and brakes. As a result, the driving assistance of the driver and the vehicle itself drives autonomously in a final stage. Research on Intelligent Transportation System (ITS) has been actively conducted as an existing system aiming at application to an automatic driving system. ITS is a system that exchanges information among people, infrastructure and vehicles and solves traffic problems such as accidents and congestion. Major applications of ITS include support for safe driving, optimization of traffic management, support for public transportation, support for emergency vehicles, efficiency of commercial vehicles, etc. The 760 MHz band is assigned in Japan, and the 5.9 GHz band are assigned in Europe and the US as dedicated frequencies.In ITS, mutual information sharing is indispensable for innumerable vehicles to safely travel, so utilization of V2V/V2I is being studied as shown in Fig.1 [1] [2] [3]. I explain V2V and V2I.

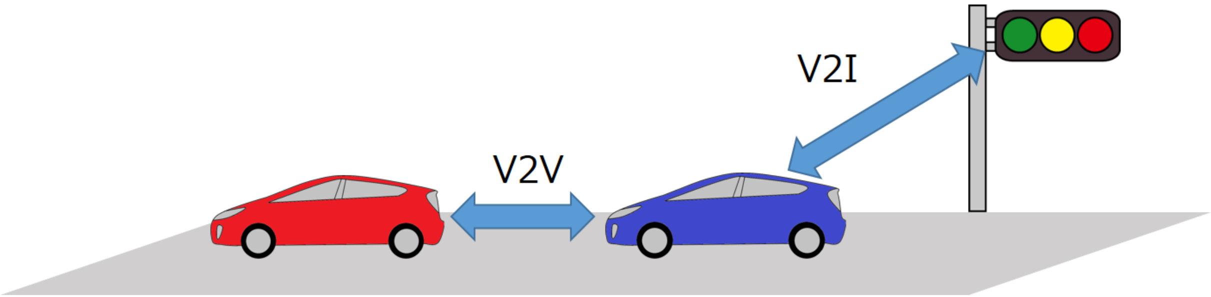

Figure 1.1: V2VV2I.

As shown in Fig. 1.1, V2V / V2I is a technology to communicate between vehicles, vehicles and roadside units.

V2V is a system that obtains information (position, speed, vehicle control information, etc.) of surrounding vehicles by wireless communication between vehicles, and performs safe driving support to the driver as necessary. V2V can receive services by exchanging information between vehicles equipped with in-vehicle devices of ITS safe driving support radio system, and can enjoy services in unspecified places where infrastructure facilities are not in place. Therefore, there is an advantage that service can be received even in places where installation of infrastructure equipment is difficult.

V2I means that a vehicle can acquire information (signal information, regulation information, road information, etc.) from infrastructure by wireless communication between a vehicle and an infrastructure (a roadside device or the like). Thus, it is a system that can provide safe driving support to drivers as necessary. V2I can receive services by a driver by receiving information from infrastructure (such as roadside equipment).

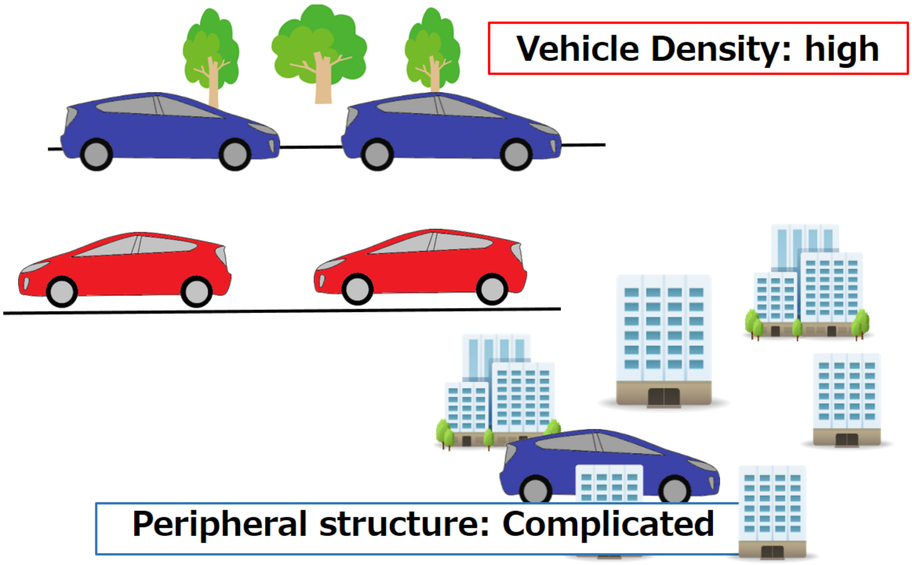

Figure 1.2: Problem of V2V.

1.2 Purpose of Research

As shown in the Fig. 1.2, in V2V and V2I, it is considered that the signal reception power fluctuates complicatedly according to peripheral structure, terrain, communication congestion situation, distance from the transmission point etc., as the vehicles communicate while moving each other. For these reasons, if the received signal power level drops, there is a fear that the desired communication reliability cannot be obtained geographically and temporally in the conventional V2V/V2I communications, and instantaneous control such as exchange of control information in autonomous operation. V2V and V2I need to share information in a similar way and it becomes a problem directly related to safety, so realizing highly reliable communication is an urgent issue.

In order to solve this problem, this paper considers the vehicle that is communicating as an observation node, and acquires the reception power at the time of packet reception and the possibility of demodulating the packet. Further, as wireless environment information at that point, we consider to aggregate it together with location information in a database installed on the network. The aggregated information is statistically processed by a statistical server in cooperation with the database and accumulated in the database together with the position information. By providing the surrounding wireless environment in response to a request from a communication vehicle, by using advance information in vehicles trying to communicate, it is intended to make the communication between the target vehicles highly reliable.

In this paper, we evaluate the characteristics of error rate and throughput by changing three communication parameters based on the collected prior information.

Chapter 2

Radio Propagation Environment Information

In this section, we describe the types of data to be aggregated as prior information and how to plot them on a dynamic map. Furthermore, based on actual observation data, describe a dynamic map in real environment.

2.1 Statistical Information of Radio Propagation Environment

As mentioned above, one of the problems of V2V / V2I is instability of communication due to fluctuation of received signal power caused by vehicle movement. In order to solve this problem, this paper considers the vehicle that is receiving packet as an observation node, and acquires received power at packets reception and demodulation availability information of packet. We consider aggregating wireless environment information and location information at that point into a database on the network. The aggregated information is statistically processed by a statistical server in cooperation with the database and accumulated in the database together with the position information. In response to a request from the vehicle, the vehicle can receive a surrounding radio environment, and vehicles try to communicate using prior information to achieve high reliability of communication between target vehicles. Example of the statistical information are shown as follows,

- Average received power
- Packet delivery rate
- Vehicle density and distance between vehicles
- Time variation of these statistical information

and so on.

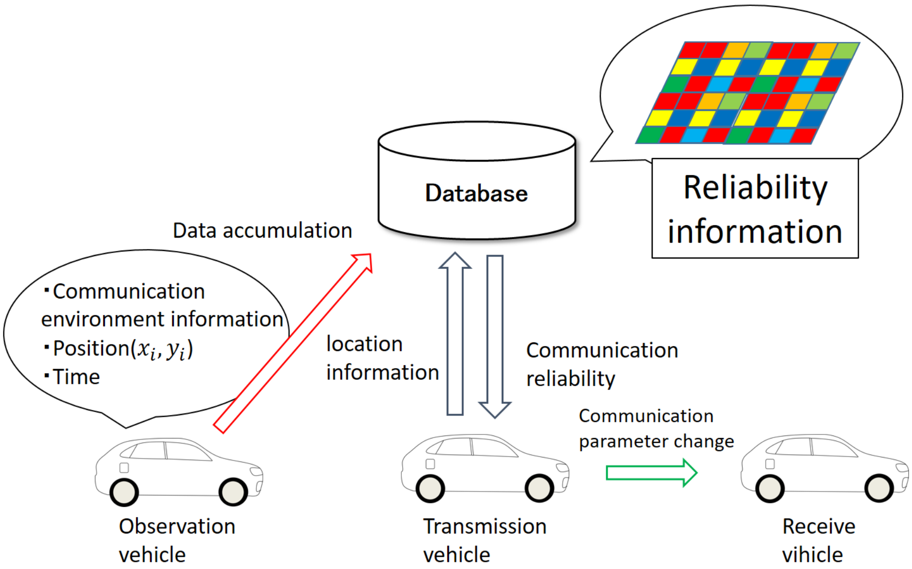

Figure 2.1: Statistical information collection and use.

The flow of actually using statistical information is described in Fig. 2.1. First, the receiving vehicle demodulates the signal transmitted from the transmitting vehicle and registers the observed received power and packet error rate in the remote shared database server and accumulation it. At that time, the position information of each of the transmitting vehicle and the receiving vehicle is similarly registered, and a dynamic map of the radio wave environment based on the position information is created. By referring to this dynamic map, each vehicle can appropriately select appropriate communication parameters.

2.2 Dynamic Map

Dynamic map on traffic has been created with the purpose of displaying road information, traffic jam information, accident information, parking lot information and the like on a map, providing comfort for traffic and providing additional services. [5] In this paper, we consider adding information on the environment and reliability of wireless communication as information of this dynamic map and verify its effect.

Dynamic map of radio environment plots radio environment information on actual map. Fig.2.2 shows an example of the radio environment dynamic map. Here, radio environment information is generated, aggregated and accumulated from the transmission signal from the reference vehicle position observed in the area in the square type mesh, and the average value of these information is plotted.

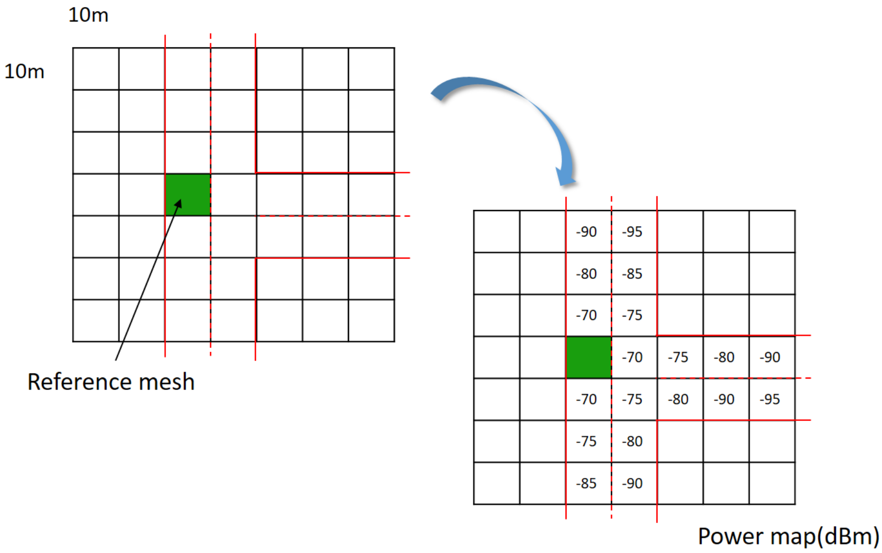

Figure 2.2: Statistical information collection and use.

As an actual application example, when the position of a certain transmitting vehicle is set as the reference mesh, the information of the dynamic map is used to refer to the power value information, the packet success rate, etc. in the mesh where the destination vehicle exists. At that time, when judging that desired communication reliability cannot be secured by communication with the target vehicle, packet relay through other vehicles, increasing transmit power and so on can be used for guarantee highly reliable communication.

2.3 Measurement Campaign of Radio Environment Map

To demonstrate the creation of a dynamic map of the radio environment, the authors conducted measurement campaign on the JARI Urban Test Course operated bythe Japan Automobile Research Institute in Kari, Tsukuba, Ibaraki Prefecture, on December 3 and 4, 2015. The course map of the measurement site is shown in Fig. 2.3. For the purpose of grasping the use tendency of radio propagation, experiments were conducted to observe the received signal power and packet error of the packets transmitted from vehicles installed in the same area.

Table 2.1: Experimental equipment parameters

Observation item	Observation equipment
Power value	RSA 306 (Real Time Spectrum Analyzer manufactured by Tektronix)
Packet loss	In-vehicle equipment
Position, time	Garmin GPS 18x

Table 2.2: Experimental configuration parameters

Observation frequency	760MHz
Communication standard	ARIB STD T109
Number of observation vehicles	3
Number of vehicles generating traffic	1

2.3.1 Outline of Measurement Campaign

As a configuration of the experiment, a communication vehicle that generates the packet every 100 [ms] is installed in the JARI test course shown in Fig. 2.3. We run three vehicles equipped with the observation device shown in Table 2.1 in the course, observe and accumulate information on the power value and the packet with respect to the position acquired from the GPS. After that, we mapped the observation result to the position of the test course and created a dynamic map.

The GPS module used in this experiment can express information up to 0.09 m mesh. However, if observation information with 0.09 m as it is, there will be a huge amount of information to be registered in the database, possibly requiring large capacity storage. In addition, since it is expected that the processing load at the time of information provision becomes very large, we divide the map space into meshes of 10 m square. The data in each mesh is statistically averaged as a corresponding observation information as the spatial statistical information.

The items to observe are shown in the Table 2.2. The observed frequency is 760 MHz and the communication standard is ARIB STD T109 [6]. This is a communication standard of V2X in Japan, which is a standard similar to IEEE 802.11p. Also as mentioned earlier, number of observation vehicles is 1, number of vehicles generating traffic is 1, and place it in the place shown in the Fig. 2.3.

Figure 2.3: Observation course.

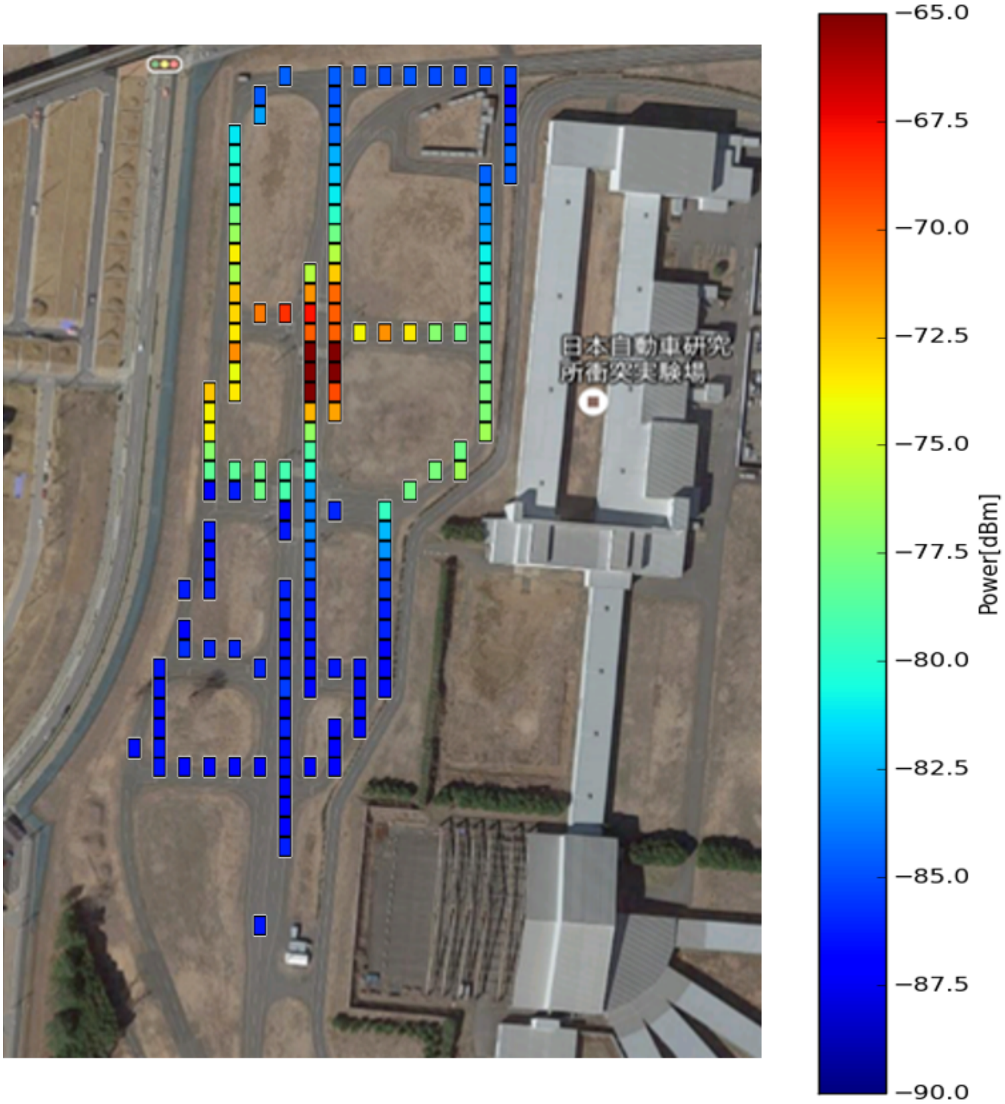

Figure 2.4: Recieved power map.

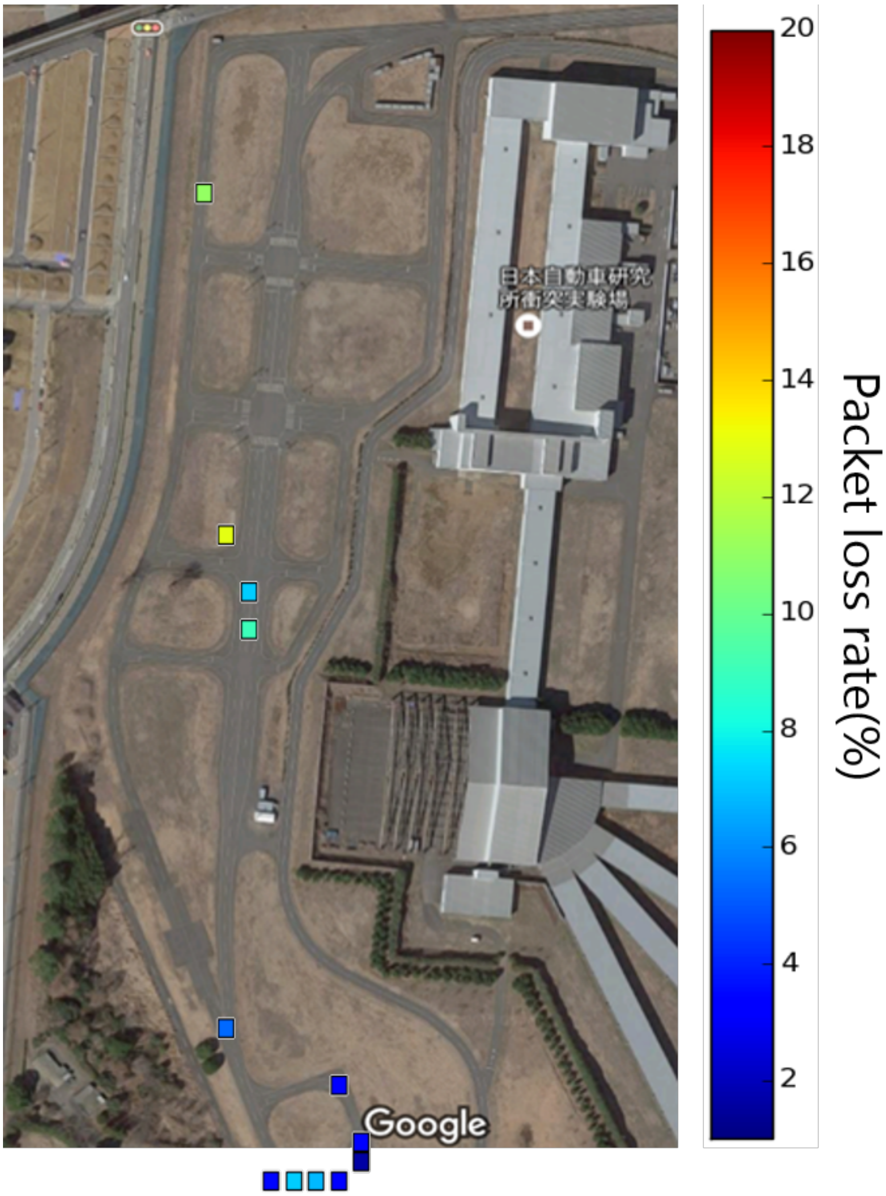

Figure 2.5: Packet loss rate map.

2.3.2 Experimental Results

Fig. 2.4 shows the map of the received power. In Fig. 2.4, we can understand the received power is higher as it is closer to the transmitting node, and it is lower as it goes away. In the vicinity of the circulation circuit on the south side of the course, it is almost occupied by the noise component, and the beacon of the transmitting node can be observed only as low as about -90 [dBm]. As we can see at Fig. 2.5, the packet loss is scattered from the transmitting node away from a certain distance similarly to the power value. As described above, it is thought that power drops due to distance attenuation, and the packet does not receive at the receiver vehicle. By referring to the packet loss map shown in Fig. 2.5, it is possible to confirm the received state of the signal according to the vehicle locations. However, in a real environment, not only a good-looking environment such as the course used in the experiments this time, but also communication in an environment where many vehicles exist in the surroundings or surrounding structures are very complicated. In such a case, besides the decreasing the received power and increasing the packet loss rate corresponding to the distance as in the experimental result this time, the communication result is according to the shielding object and congestion situation. For that reason, there is a possibility that a desired communication quality cannot be ensured regardless of the distance from the transmission point, so it is considered that prior information such as collected / statistical processing will be useful.

In this experiment, radio waves were transmitted from the vehicle using the transmitter of V2V communication, but because of the experimental configuration, the position of the transmitting vehicle was fixed, which is equivalent to the experiment under V2I environment. Under the V2V environment, since both the transmitting vehicle and the receiving vehicle are running, and multiple maps corresponding to the transmission position are created.

Chapter 3

Relay communication

In this chapter, communication using a transit vehicle will be explained based on acquired advance information.

3.1 Relay terminal

When the radio environment map information is used, not only the information on the destination vehicle from the transmitting vehicle but also the radio propagation information corresponding to the position of the surrounding vehicle can be obtained in the same way. Therefore, we consider the use of the routing protocol [4] for V2V / V2I and the radio wave environment map, which can use the surrounding vehicles as relay vehicles and increase the reliability of communication by relay transmission.

When communicating between vehicles, shadowing may occur due to structures existing in the vicinity or between vehicles. There are environments in which direct communication can not be performed. Especially at intersections and merging roads, there is a possibility of a collision at the encounter, so it is necessary to conduct stable communication.

3.2 VANET

One technique for solving these problems is routing. Routing is a method of communicating by selecting a communication route by using terminals existing in the periphery when communicating to the destination host. Also, the use of mobile ad hoc network (MANET) is considered for V2V. MANET is a network composed only of terminals (nodes) without requiring base stations for mobile communication, access points for wireless LAN and fixed networks. If two nodes are in the communication range, they communicate directly,

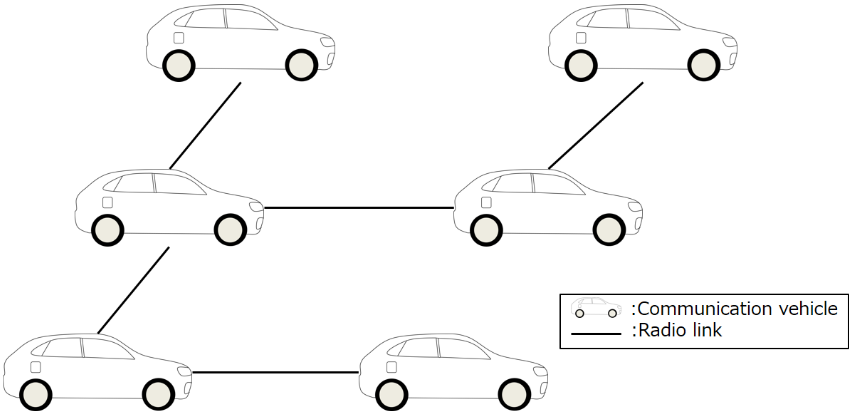

Figure 3.1: VANET.

and if they are outside the communication range, they communicate with other nodes via multiple links.

An ad-hoc network applied to V2V communication is called VANET (Vehicular Ad hoc NETwork). As shown in the Fig.3.1, similar to MANET, each vehicle autonomously constructs a routing path. For automobiles, car navigation systems that use GPS and digital road maps are becoming standard equipment, and by using these, it is possible to distribute information more efficiently than conventional MANET. As mentioned earlier, this technology is considered to be a promising technology for preventing traffic accidents between vehicles and grasping the traffic situation in the surroundings.

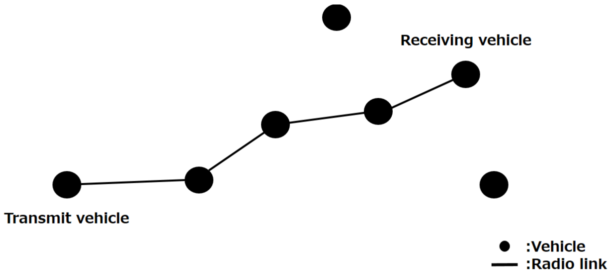

Figure 3.2: Unicast method.

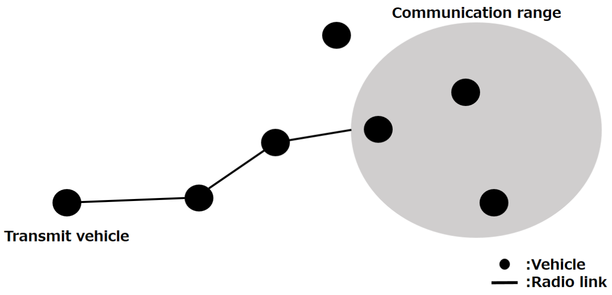

Figure 3.3: Geocast method.

3.3 Routing in VANET

In VANET, it is difficult to use the link state type routing method and the distance vector type routing method normally used in MANET because of the unique high mobility of vehicles. Therefore, in many cases, geometric routing method is used. In the geometric routing method, each terminal is equipped with a device that acquires position information such as GPS and recognizes its own position information. From the location information of the destination node, the source node forwards the packet so that it approaches the destination node. In the geometric routing method, there is a unicast method in which the source-to-destination is one-to-one and a geocast method in which the source-to-destination is one-to-many exist. As shown in Fig 3.3, in the geocast, all the terminals existing in the destination range are addressed, and transmission is completed when reaching within the destination range. This can be realized with a natural extension of specifying a range for a position to be transmitted by unicast.

A typical geometric routing protocol is GPSR [7]. This is a method of selecting a node closest to the destination node as Greedy and searching for a detour when there is no node closer to itself. In VANET, a GPCR is a protocol applied in consideration of the unique movement characteristics of the vehicle. In the GPCR, the building is considered to be a radio wave shield, and the intersection is identified from the vehicle density within the communication range, and the packet is transferred in preference to the vehicle at the intersection.

In an environment with a low vehicle density, a method called Carry and Forward, or Delay Tolerant Networks (DTN) is used, in which the vehicle moves while holding a packet and resumes packet forwarding when it finds a vehicle that can forward the packet. Routing methods have been proposed to prevent loss of packets caused by link disconnection using these.

In this way, many routing protocols have been proposed assuming a vehicle density above a certain level such as an urban area, but routing methods that can be uniformly used even in an urban area with remarkably low vehicle density are not much suggested. In addition, a method considering the surrounding environment has been proposed, but there is no relay method linked with the database.

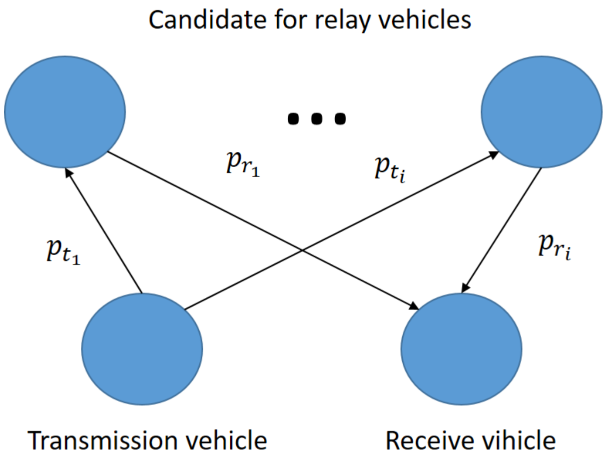

Figure 3.4: Selection of relay vehicle.

3.4 Routing using advance information

Each vehicle floods its own position and the presence of surrounding vehicles every 100 ms, so that the positional relationship of each vehicle is updated as needed, and it is assumed that each vehicle knows them. By referring to these positional relationships and map information, it is assumed that all the reliability information of the surrounding vehicles can be understood. At this time, routing is performed for vehicles that do not exceed a certain reliability threshold.

As shown in Fig.3.4, when communicating using one relay vehicle, the received power p_{t_i} reached from the transmitting vehicle to the relay vehicle, the received power p_{r_i}, and uses the lower value as the reliability information p_{x_i} of the relay vehicle. p_x for k vehicles in the neighborhood is expressed as $p_{x_1}, ...p_{x_i}, ...p_{x_k}$. Similarly, k vehicles existing in the vicinity perform similar processing and select the maximum p_{x_i}.

Chapter 4

Change of Communication Parameters when using Advance Information

In this chapter, we explain how to change the communication parameters by using the radio wave environment map. Here, two parameters that can be adaptively changed according to received power will be described.

4.1 AMC

It is necessary to perform communication at an optimum transmission speed according to the radio propagation environment.It is important to select the communication method that realizes it. When the propagation path is poor, if communication is performed by selecting a high-speed communication method, many errors occur on the receiving side, and the effective speed, that is, the throughput decreases. In order to avoid this, it is necessary to select a communication method with lower speed and robustness. In that case, it will be sufficient for continued communication at a lower transmission rate, resulting in higher throughput. In this way, adaptive control that adaptively controls the communication system according to the propagation path condition or the like is indispensable in high-speed communication. Among the communication schemes, Modulation and Coding Scheme (MCS) is combined with a modulation scheme and coding rate, and the one that focuses on this and performs control is called Adaptive Modulation and Coding (AMC).A communication method using AMC is examined in [8] [9], [10]. in V2V. This time we will explain the AMC using the eyes environment map.

4.1.1 Parameter

Regarding the modulation scheme and the coding rate, it is conceivable that each of them is controlled independently and the case where the modulation scheme and the coding rate are controlled integrally as MCS. The relationship between the MCS and the transmission rate is described below.

Table 4.1: MCS

Transmission speed	MCS
12Mbps	QPSK(R=1/2)
18Mbps	QPSK(R=3/4)
24Mbps	16QAM(R=1/2)
36Mbps	16QAM(R=3/4)
48Mbps	64QAM(R=2/3)
54Mbps	64QAM(R=3/4)

It can be predicted that the control method suitable for the propagation path becomes possible by controlling the modulation method and the coding rate independently. However, since the system becomes complicated, in actual systems many of them control by MCS unit in this way, there is no such thing as completely independent of modulation scheme and coding rate.

4.1.2 Control unit

In adaptive control, it is distinguished as follows depending on which unit the various parameters shown in the previous subsection are controlled.

Resource common control

In the resource common control, the same method is applied to all resources. For example, in the case of adaptive modulation of OFDM, a modulation scheme common to all subcarriers is allocated. In this method, since the same scheme is assigned to both resources with good propagation states and bad resources, theoretically it is considered that the performance is inferior to the resource independent scheme described later. However, there is an advantage that control is simplified, further considering the diversity effect by interleaving and error correction encoding, the performance difference is considered not so large, so this method tends to be adopted in a real system.

Resource independent control

In this method, an individual communication method is assigned to each resource. For example, in the case of adaptive modulation of OFDM, a different modulation scheme is assigned to each subcarrier. Since this method is complicated in control, when the number of resources is large, there is a tendency to dislike operation in a real system.

4.1.3 Switching criteria

In the adaptive control, there is a switching criterion for selecting a communication method. As a criterion, the following can be considered.

- Power reference (received power, SNR, SINR)
- Channel reference (channel capacity, channel correlation)
- Error criterion (CRC, Ack)

Standards such as received SNR (Signal to Noise Ratio) or received SIR (Signal to Interference Ratio) are often used. This is because SNR and SIR can be relatively easily measured using known signals and are effective indices of performance when received.

Content to be acquired as prior information is power value and packet loss. In this case, it is considered that optimum modulation can be selected in each environment by combining with the above-described SNR. The modulation switching threshold will be described in the next measure.

4.1.4 MCS

As mentioned above, for MCS switching, a method of changing the modulation method by comparing the measured received power with a threshold value is well known. Therefore, since the upper modulation scheme obtained by comparing the received power P obtained from the radio environment map with the threshold can be switched, the appropriate switching is possible.

The Fig.4.1 shows the relationship between SNR and throughput at each modulation and coding rate in OFDM.

In order to utilize communication applications for automobiles, the IEEE has established the IEEE 802.11p standard. The IEEE 802.11p standard supports six different data rates based on the orthogonal frequency division multiplexing (OFDM) method.

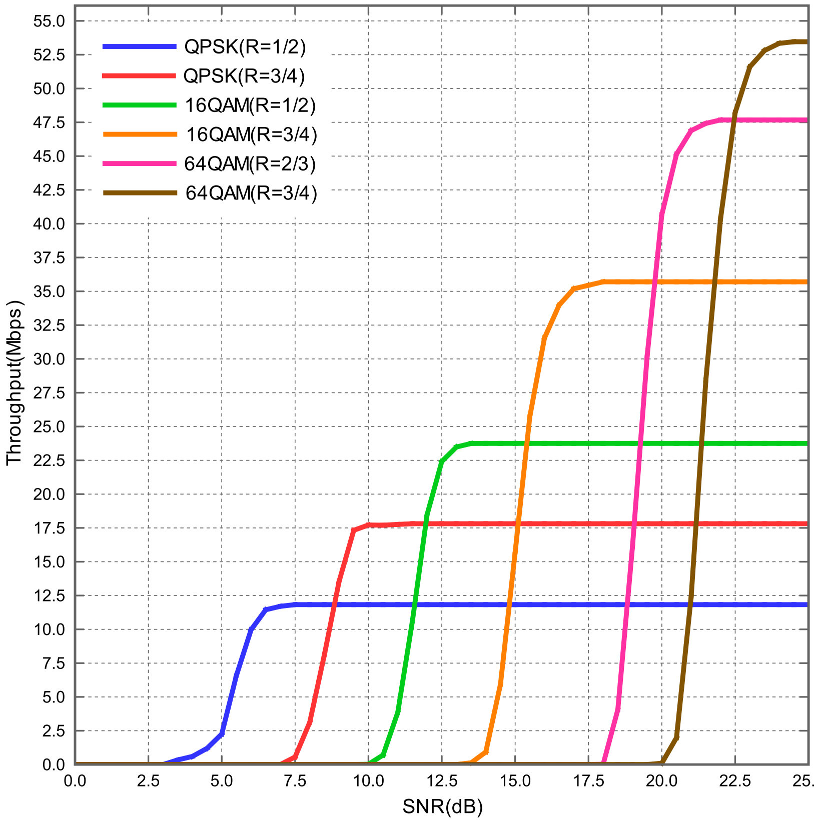

Figure 4.1: Throughput characteristics of each modulation scheme.

The modulation / coding rate to be used this time and the respective Signal to Noise Ratio (SNR) γ thresholds which maintain high throughput are shown below. As shown in the Fig. 0th, each γ is determined from the intersection point with higher order and lower order modulation in each modulation.

Table 4.2: MCS switching threshold

MCS	Threshold
QPSK(R=1/2)	γ(dB) < 8.8
QPSK(R=3/4)	$8.8 < \gamma < 11.8$
16QAM(R=1/2)	$11.8 < \gamma < 15.4$
16QAM(R=3/4)	$15.4 < \gamma < 19.8$
64QAM(R=2/3)	$19.8 < \gamma < 22.5$
64QAM(R=3/4)	$22.5 < \gamma$

4.2 Power control

There is a technique called Transmitter Power Control(TPC) [11] to reduce the power consumption of the terminal and to suppress interference with peripheral terminals. In order to cope with the power degradation mentioned above, it is expected that the communication reliability can be improved by increasing the transmission power. Furthermore, by using the radio wave environment map information, in addition to improving the communication reliability, it is possible to control the transmission power to an appropriate level in consideration of the interference area. It is said that Signal to Interference and Noise Ratio(SINR) needs to exceed a certain threshold in order to secure the reliability in V2V [12]. As the number of surrounding vehicles increases, there is also a deterioration in characteristics due to an increase in interference [13], if we apply power control according to circumstances and increase the value of SINR, it can reduce the error rate and can improve the communication reliability.

There are three types of TPC already proposed. The first type is a type of method in which information such as the position information of the vehicle of the own vehicle and the transmission power etc. are added to the beacon to which each vehicle is periodically transmitted, and the information is transmitted and adjusted based on the information. The second type is a type of method in which the surrounding vehicle density is estimated from the received power when a beacon transmitted periodically is received and the transmission power is changed according to the vehicle density. The third type is a type in which the transmission power is periodically changed regardless of the surrounding environment of the vehicle.

By using the radio wave environment map information, we can control the transmission power to the appropriate level considering the communication reliability and the interference area. It is possible to suppress power consumption and interference power to the surroundings. It is said that Signal to Interference and Noise Ratio(SINR) needs to exceed a certain threshold in order to secure the reliability in V2V. [4] If we apply power control according to circumstances and increase the value of SINR, it can reduce the error rate and can improve the communication reliability.

It is assumed that the received powerregistered at the database is based on 0 [dBm]. Here, let the average received power of each mesh be P_{r_0} [dBm]. If we set the desired received power P_d, $P_d - P_{r_0}$ [dBm] P_t. Here, when the desired received power is achieved with transmission power 0 [dBm], the transmitter transmits the packet with 0 [dBm]. The upper limit of the transmission power is set to 10 [dBm], and even when P_t exceeds

10 [dBm], the maximum transmission power is limited to 10 [dBm].

Chapter 5

Simulation

In this chapter, the computer simulation model and the computer simulation result are described.

5.1 Simulation specification

Representative parameters in simulation are shown in Table 5.1 In this simulation, we evaluated the propagation model including distance attenuation, shadowing, and fading assuming communication in the 760 MHz band. ITU-R.P 1411 [14] is used as a radio wave propagation model. The command of ITU-R.P 1411 is shown below.

$$L_{LoS} = L_{bp} + 6 + \begin{cases} 20\log 10\left(\dfrac{d}{R_{bp}}\right) & d \leq R_{bp} \\ 40\log 10\left(\dfrac{d}{R_{bp}}\right) & d > R_{bp} \end{cases} \tag{5.1}$$

Here, R_{bp} is the distance (m) from the transmission point to a so-called breakpoint, and is given by the following expression.

$$R_{bp} \approx \frac{4h_b h_m}{\lambda} \tag{5.2}$$

Here, $h_b$and h_m are the transmission antenna ground height (m) and the reception antenna ground height (m), respectively, and $lambda$ is the wavelength (m) at the carrier frequency of the radio communication to be used.

L_{bp}(dB) is the propagation loss from the transmission point to the break point and is given by the following expression.

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

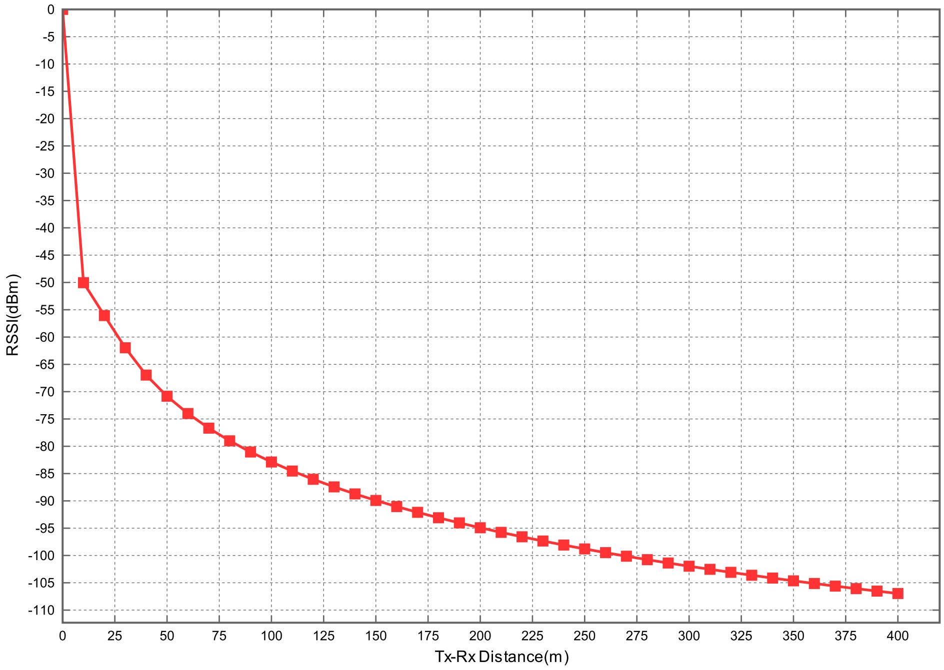

Figure 5.1: Prospect in ITU R.P 1411 Distance attenuation in environment.(transmission power 0 dBm)

Propagation loss in ITU-R.P 1411 prospect communication is shown in Fig. 5.1. For fading, Rayleigh fading at a traveling speed of 40 [km/h] was assumed. Shadowing follows a lognormal distribution. Noise is assumed to be Additive White Gaussian Noise(AWGN), and it is -110 [dBm].

Table 5.1: Simlation paramaters.

Parameter	Value
Frequency	760[MHz]
Modulation	OFDM
Coding	Convolution / Viterbi
Pathloss model	ITU-R P.1411-5
Fading	Rayleigh
Noise	-110[dBm]
Packet length	1112[bits]
Vehicle speed	40[km/h]

5.2 Simulation: Relay terminal

The environment in the simulation is described in the figure. When communicating with a destination vehicle where the transmitting vehicle exists, assume an environment where sufficient reliability can not be obtained. As an example of an environment in which sufficient reliability can not be obtained, it is conceivable that there are large structures between the vehicles in a merging road or when they are in a tunnel. In an environment where certain reliability can not be obtained for a certain vehicle, vehicles present in the vicinity are selected as a relay vehicle by the method described in section 3.1.

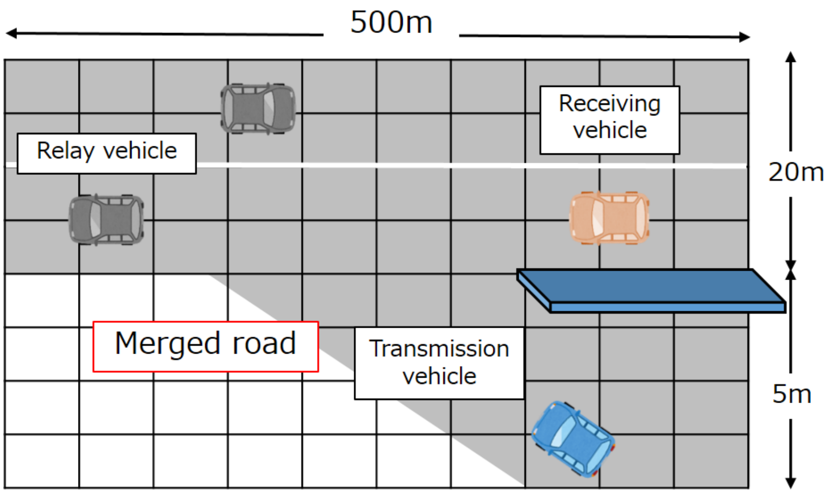

Figure 5.2: Simulation environment.(merged road)

Evaluation items are PER and throughput. Randomly selecting relay vehicles as comparison objects. The respective characteristics are shown in the following figure.

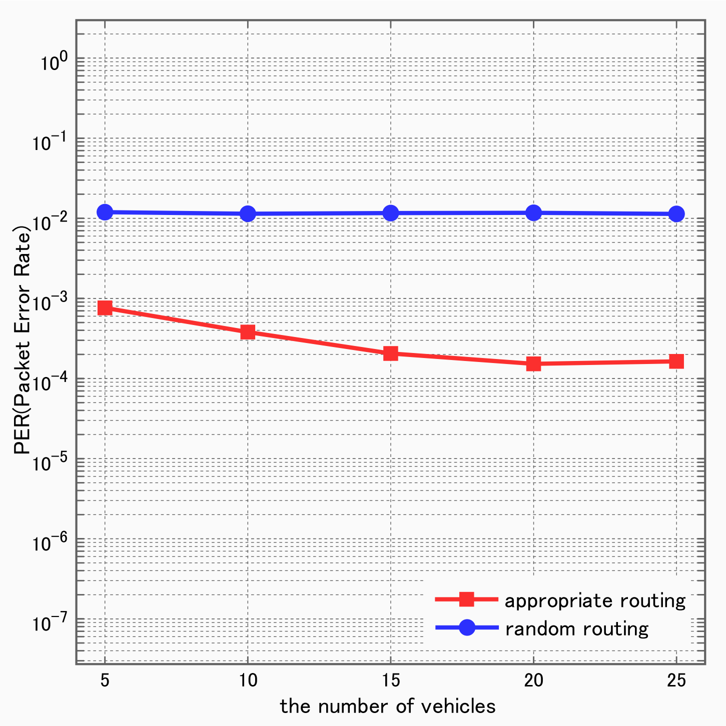

Figure 5.3: PER characteristics by random relay and appropriate vehicle relay.

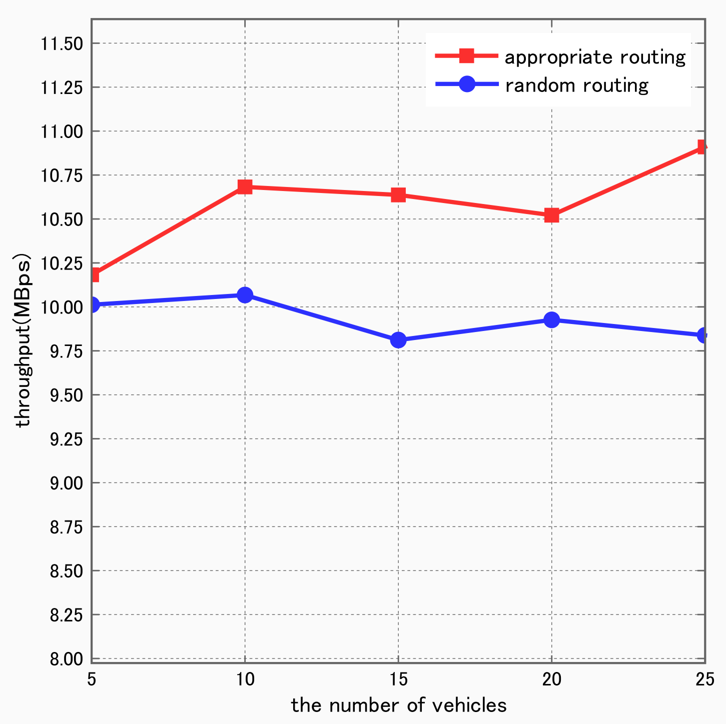

Figure 5.4: Through characteristics by random relay and appropriate vehicle relay.

Fig. 5.3 shows the Packet Error Rate (PER) characteristic under each condition. When relaying with random vehicles, the PER characteristic is about 1% and there is no change. On the other hand, when a vehicle with the maximizing the lowest received signal level is selected as a relay vehicle, PER always shows a lower value than random vehicle relay. As the number of vehicles increased, selectable relay vehicles increased, so it was confirmed that PER characteristics were improved.

The Fig. 5.4 shows throughput characteristics. As with the PER characteristic, the throughput characteristics are also improved as compared to when relaying at random by performing the optimum vehicle relay. When the number of vehicles is 5, the difference in characteristics is about 0.25Mbps, but when the number of vehicles is 25, an improvement of about 1MBps is seen.

5.3 Simulation: Power control

After choosing a relaying vehicle, SINR characteristics under other environments where other surrounding vehicles communicate with each other are evaluated. We try to improve the SINR characteristics achieved by reducing the interference power by performing power control after all the vehicles have taken the radio environment map information into consideration.Here, SINR is expressed by the following equation.

$$SINR = \frac{P_{tr}}{\sum_{i=1}^{N} P_{ir} + \eta_r} \tag{5.4}$$

Where, P_{tr} is the received power of the receiving terminal for the transmitting terminal, η_r is the noise power of the receiving terminal, and P_{ir} is the sum of the received power from the surrounding vehicles.

The transmitting vehicle that obtains the communication reliability information of the destination vehicle performs power control based on the reliability on the receiving vehicle. At this time, power control is performed so that the SNR keeps 15 dB. In this case, we are assuming an environment where carrier sense does not work, and radio waves from surrounding vehicles are all considered as interference components.

The SINR characteristics at this time are shown in the figure. Also, in the area of 10 [m] × 500 [m], the difference in the area of the interference area was verified.

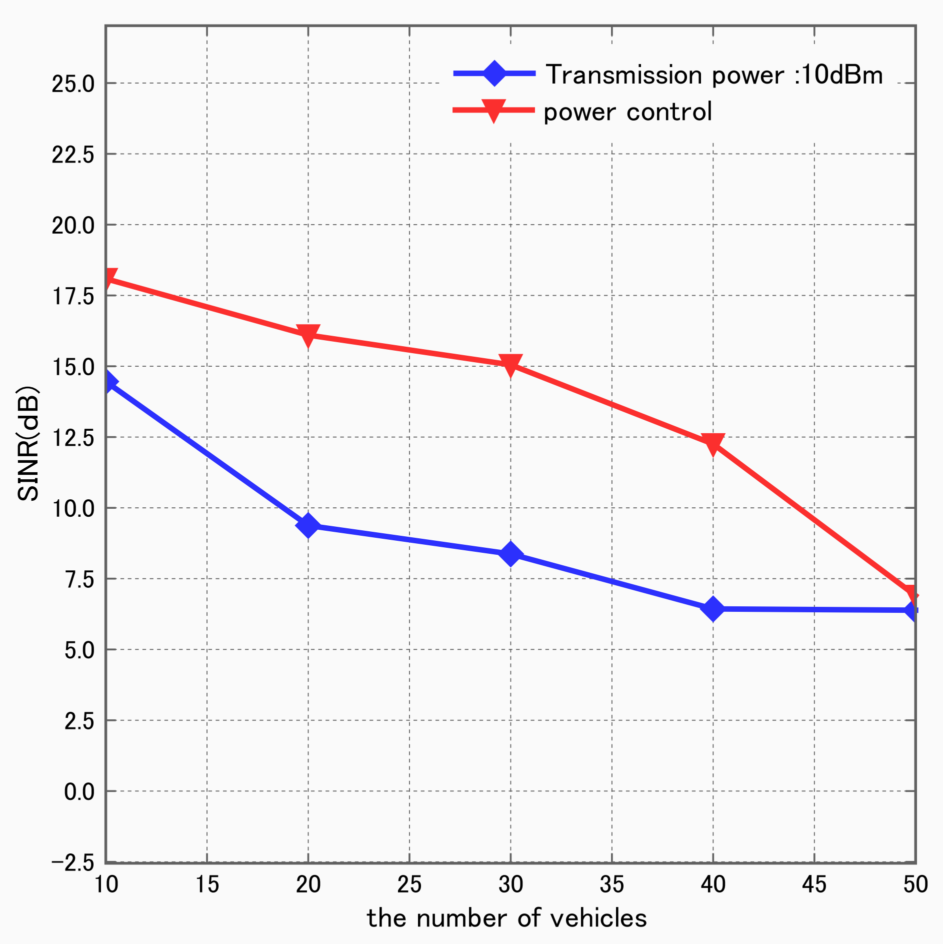

Figure 5.5: SINR characteristics using power control.

Next, when the number of vehicles is 10 in the same area as before, it represents the range where the received power achieves not less than -75 [dBm].

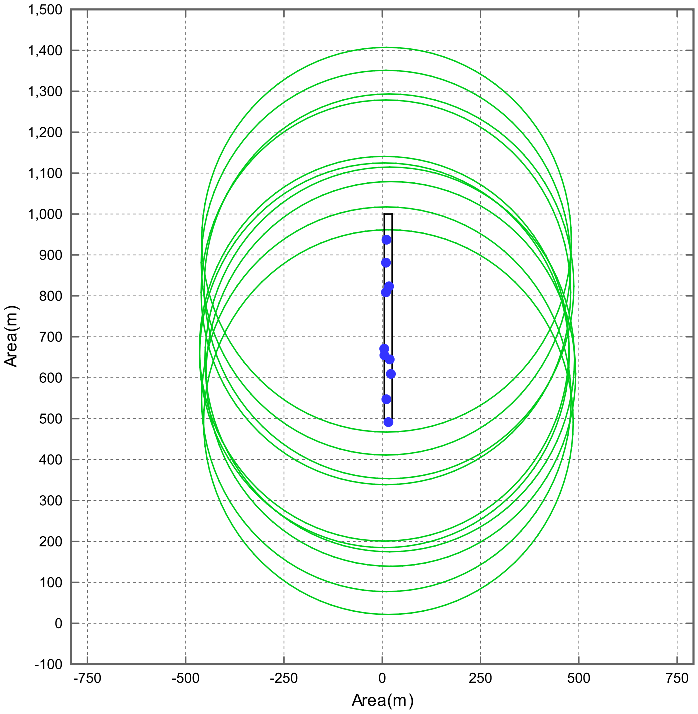

Figure 5.6: SINR characteristics using power control.

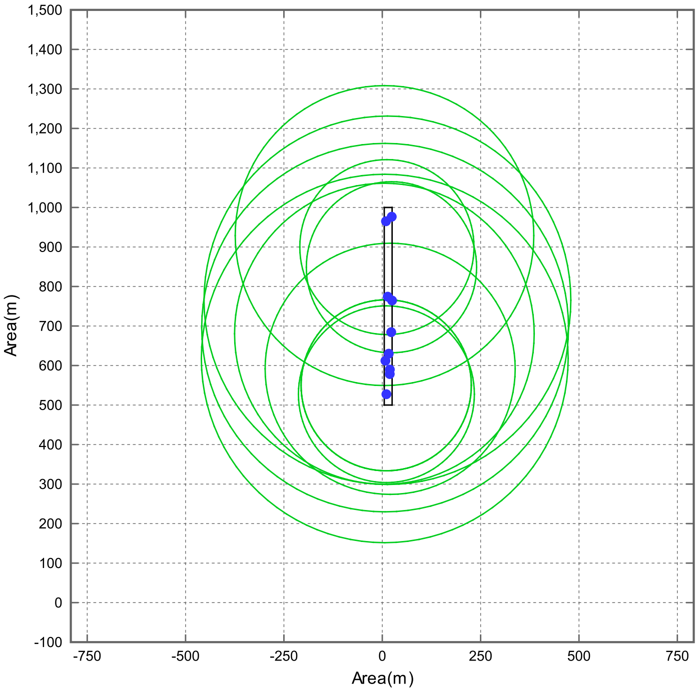

Figure 5.7: SINR characteristics using power control.

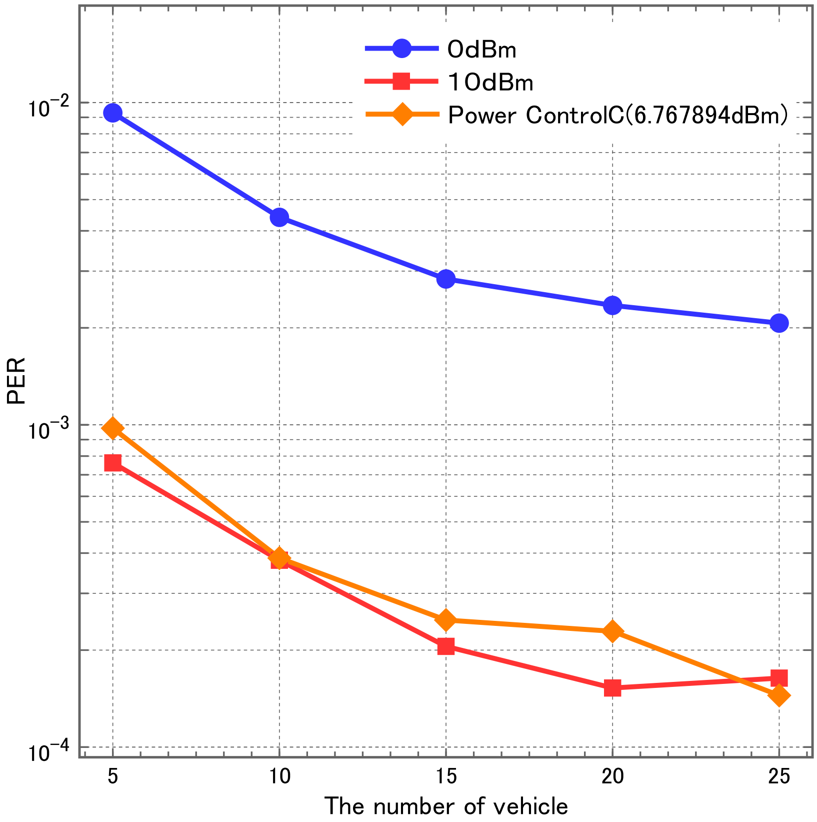

Figure 5.8: PER characteristics using power control.

In Fig.5.5, when the power control is performed, the SINR is generally high as compared with the case where the communication is performed with the fixed transmit power of 10 [dBm]. Improvement in SINR ultimately leads to a decrease in PER and Bit Error Rate (BER), so quality improvement can be expected in environments where multiple users are mixed by power control according to reliability expectations. Furthermore, when comparing Fig. 5.6 and Fig. 5.7, it is understood that the communication range is narrowed when power control using advance information is performed. This shows that the interference range becomes acid.

We also evaluated the PER characteristics when power control was performed. As can be seen from the Fig. 5.8, while performing power control, there is no difference in PER characteristics when transmitting at 10 [dBm]. Furthermore, the average transmission power is also about 6.7 dBm, which shows that it maintains a constant PER by suppressing the power by approximately 3.3 dB.

5.4 Simulation: AMC

Assume the environment described in Section 4.2. After selecting the optimum repeating vehicle, AMC is performed based on the MCS described in the Table 4.2.

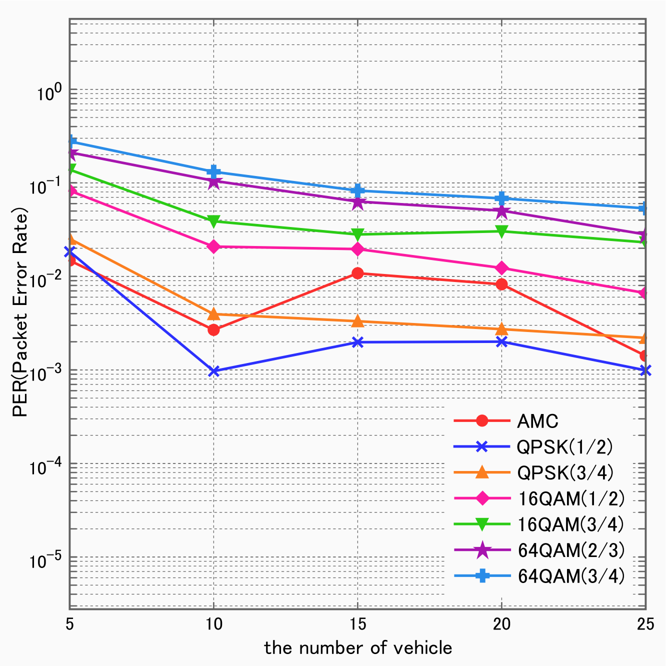

Figure 5.9: PER performance in AMC.

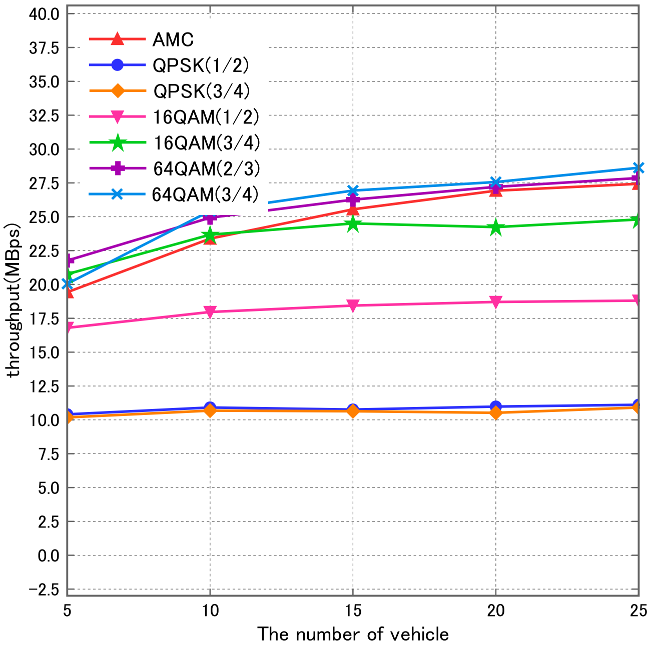

Figure 5.10: Throughput performance in AMC.

Fig.5.9 shows the throughput characteristics when the vehicle relay is performed appropriately with reference to the above-mentioned threshold. When AMC is performed, high throughput which is not different from multi-level modulation is achieved. In addition, Fig.5.10 shows PER characteristics are worse than when using the low-order modulation, it can be seen that the term throughput is achieved while maintaining a constant PER.

Chapter 6

Conclusions

In this paper, we propose a method to aggregate communication reliability information in the real environment and change communication parameters in each environment in order to improve efficiency in the communication field of the autonomous driving system. Specifically, information such as the received power value and the packet arrival rate in each environment is averaged and registered for10 m × 10 m mesh. Based on the reliability information, it can adoptively change the transmission power, the modulation method, and selects the relay terminal. Through simulation, it was confirmed that PER can be reduced and throughput is improved by changing parameters using advance information.

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References

[1] "High Definition Lidar HDL-64E,"http://velodynelidar.com/lidar/products/brochure/HDL-64E%20Data%20Sheet.pdf/(accessed 2015-1-10)

[2] "Intelligent Transport Systems - Extension of map database specification for Local Dynamic Map for Applications for Cooperative ITS", ISO/TS 17931:2013(E).

[3] A. Buchenscheit, F. Schaub, F. Kargl, and M. Weber, "A VANETbased Emergency Vehicle Warning System," Proc. of IEEE 1st VNC, 1/8 (2009)

[4] J. Nzouonta, N. Rajgure, G. Wang and C. Borcea, "VANET routing on city roads using real-time vehicular traffic information," IEEE Trans. Vehicular Technology, vol.58, no.7, pp.3609–3626, Sept. 2009.

[5] Y. Hatakeyama and K. Nakaoka, "Vehicle-infrastructure cooperative safe driving support system using wireless communication,"Panasonic Technical Journal, 61(1), May 2015.

[6] "700 MHz BAND INTELLIGENT TRANSPORT SYSTEMS," https://www.arib.or.jp/english/html/overview/doc/5-STD-T109v1_0-E1.pdf/(accesd 2015-1-10)

[7] Zhang Ning, Yunho Jung, Yan Jin and Kee-Cheon Kim "Route Optimization for GPSR in VANET" Advance Computing Conference(IACC), pp.569–573, March 2009

[8] Wei Song, Qing Shen, M. Ahmad, and Weichang Du, "Opportunistic vehicle-to-vehicle relay with adaptive modulation for drive-thru internet access," Wireless Communications and Mobile Computing Conference (IWCMC), 2014 International, pp.690–694, Aug. 2014.

[9] Do-Wook Kang, Yang-Sun Lee, Ki-Woo Kim, Sung-Eon Cho, Se-Kab Oh and Heau-Jo Kang, "Performance Evaluation of Adaptive Modulation System with STTD in

Vehicle-to-Vehicle Communication Environment," The 2007 International Conference on Intelligent Pervasive Computing, pp.2484–2497, Oct. 2007

[10] Xiaoyu Duan, Yanan Liu and Xianbin Wang, "SDN Enabled 5G-VANET: Adaptive Vehicle Clustering and Beamformed Transmission for Aggregated Traffic," IEEE Communications Magazine, vol. 55, pp.120–127, July 2017.

[11] Danda B. Rawat, Dimitrie C. Popescu, Gongjun Yan, Stephan Olariu "Enhancing VANET Performance by Joint Adaptation of Transmission Power and Contention Window Size" IEEE Transactions on Parallel and Distributed Systems, Vol.22, Issue 9, pp.1528–1535, Sept. 2011

[12] W. Sun, E. G. Strom, F. Brannstrom, K. Sou, and Y. SuiRadio "Resource management for D2D-based V2V communication," IEEE Transactions on Vehicular Technology, Vol.65, no.2, pp.6636–6650, Sept. 2015.

[13] Fuxin Zhang, YuYue Du, Wei Liu, and Peng Li "Model Predictive Power Control for Cooperative Vehicle Safety Systems" IEEE Access, Vol.PP, Issue 99, pp1–1, Jan. 2018

[14] ITU-R: Propagation Data and Prediction Methods for the Planningof Short-Range Outdoor Radiocommunication Systems and Radio Local Area Networks in the Frequency Range 300 MHz to100 GHz, Recommendation ITU-R P.1411-5（,2009)

Publications

i. 鶴見俊介, 藤井威生,“通信信頼度マップデータベースを利用した車車間通信の高効率化,“ 電子情報通信学会ソサイエティ大会, Sept.2016.

ii. 鶴見俊介, 藤井威生, “信頼度マップによる事前情報を利用した高信頼車車間通信,“ 信学技報, SR2017-2, March.2017.

iii. Shunsuke Tsurumi and Takeo Fujii, “Reliable Vehicle-to-Vehicle Communication using Spectrum Environment Map,“ ICOIN 2018, Chang-Mai, Thai, Jan.2018.