Design of Seamless Handoff Control Based on Vehicular Streaming Communications

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Abstract

Because vehicles run in high speed environments, it is difficult to establish the topology of the network. Moreover, data transmission may be interrupted by the handoff of various APs. This study established the network of roadside-to-vehicle (R2V) environment, and used the DSRC (dedicated short range communication) to achieve seamless handoff control on a streaming service. To achieve this goal, this study first used the GPS (global positioning system) to collect vehicular information (e.g., speed, direction, and location), and subsequently exchanged the parameter of vehicular information at both ends by DSRC. Therefore, the computer in the vehicle can predict the link expiration time (LET) between two mobile nodes. Furthermore, this study used two cases of handoff in vehicular networks. One case was non-overlapping handoff, and the other case was overlapping handoff. A simple formula was designed to calculate vehicular total buffer size in these two cases, and to adjust the data flow to the receiver. Finally, this study used the network simulator to simulate the actual situation of vehicular motion and network transmission. This study proved the accuracy and feasibility of mechanism through the simulation result. This study achieved the streaming of seamless handoff control in the network of R2V.

Keywords: Seamless handoff control, Dynamic buffer control, Streaming transmission, Dedicated short range communication, Vehicular communications

1 Introduction

The advancements in wireless network technology have resulted in more convenience in resource sharing, and this technology plays a crucial role in modern life [1-25]. People often use smart phones, personal digital assistants, and vehicular computers for mobile communication. The development of vehicular computers has become a universal trend. Focus on transportation development with the national communication industry is also crucial. Vehicles can communicate with each other through data exchanging and message sharing by using telematics systems. Wireless devices used in vehicles and road-side are called on-board units (OBU) and road-side units (RSU), respectively. The cooperation between OBU and RSU provides intelligent transportation system (ITS) services, such as car safety, fleet management, driver assistance, and emergency roadside assistance. The goal of telematics topics has led many people to research and develop it in the industry field and the academic world. According to statistics from the Netscribes, Inc., the telematics service market has grown to USD 166.77 billion in 2017, and is expected to grow to USD 233.24 billion in 2022. Therefore, the telematics industry is expected to experience considerable growth.

However, performing multimedia streaming services is a crucial future field of study in the vehicular ad hoc networks (VANET) environment. Therefore, wireless streaming technology developed a real-time video streaming protocol to deliver video packets. With the improvement of video quality, it is vital for a real-time video packet to focus on delay time and packet loss in a wireless environment. The majority of researchers explored methods to increase quality of service (QoS) under a mobile network. Some studies showed that the round trip delay of DSRC was lower than LTE (long term evolution) [26-27]. Therefore, this study used IEEE 802.11p wireless network standards to build a telematics system and personalize safety services. The application of this technology is crucial in a multimedia streaming service. The packet routing path may be dynamically changed in VANETs, so the number of reconnections may be higher. Therefore, the HTTP-based streaming system may be not adaptable for VANET [28], so the main objective of this study was to provide smooth streaming service in the situation of road-side unit distribution. This study designed and implemented the system of “Vehicular

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Streaming and Seamless Handoff Mechanism Based on the Prediction Buffer Control." A global positioning system (GPS) was used to collect parameters of vehicle and road-side units, such as speed, current position, communication range, and forward direction, and these parameters were used to calculate their link expiration time. These results were used to predict dynamic buffer size and achieve seamless handoff control for R2V. This study also considered handoff of various distances of RSUs, and divided them into two cases for investigation. One case was overlapping handoff, and the other case was non-overlapping handoff. Finally, a simple formula was designed to calculate vehicular prediction download time and the timing of handoff in these two cases.

The remainder of the paper is organized as follows. Section 2 discusses the related work of multimedia streaming control, route action of mobile nodes, and mobile management of the telematics environment. The proposed system and processes are presented in Section 3, and the proposed seamless handoff decision models based on DSRC is illustrated in Section 4. Section 5 and Section 6 remark the proposed predictable dynamic buffer control mechanism and the proposed adaptive transmission mechanism for streaming over R2V network. Section 7 gives experimental results to evaluate the performance of the proposed system and methods. Finally, Section 8 concludes this paper and discusses suggestions for future work.

2 Related Work

The section discusses the techniques of multimedia streaming control, route action of mobile nodes, and mobile management of the telematics environment.

2.1 Multimedia Streaming Control

The video playback smoothness and quality of service are usually used for system adjustment in multimedia streaming control. However, each vehicle is a mobile node in a telematics environment. It is easy to create the situation of packet loss and delay in the transmission process. To solve this problem, Hahm et al. [29] and Hashmi et al. [30] proposed different buffer control algorithms to demonstrate a complete framework system, including a switch, first order delay, and second order delay [31]. The system based on threshold level defined three states, such as normal, low threshold, and high threshold. It was used for throw and copy of frame control in the buffer. To solve the problem of buffer overflow and underflow, [32-36] proposed the adaptive playback buffer (APB) method to calculate network transmission delay time. They adapted dynamic buffer size of scope to calculate the buffer change size. [37-40] used a Quality-Oriented Adaptation Scheme (QOAS) to test in a simulated local multi-service IP network with various types, sizes, and shapes of background traffic. They proposed that the adaptation of streaming video was based on end-user perceived quality information. Test results demonstrated excellent quality and high link utilization with low loss rates. Moreover, the performance of QOAS was close to that of an adaptive system in all traffic conditions. Although these methods can adapt dynamically buffer size in accordance with transmission delay for multimedia streaming control, the vehicle speed and transmission range in VANET are not considered. Therefore, this study will analyze the vehicle speed and transmission range to calculate more suitable buffer size for vehicular streaming communications.

2.2 Route Action of Mobile Nodes

For route action of mobile nodes, [41-42] proposed the prediction of link expiration time (LET) between two mobile nodes. The equipment proposed in this paper used GPS location information. Therefore, if the motion parameters of two neighbor nodes (e.g., speed, direction, and transmission range) are determined, this information would be able to predict future disconnection time between two neighbor nodes in motion. Based on this prediction, the goal of this study was to achieve a seamless handoff control by using this scheme. Namboodiri et al. [43-44] used the speed and location information of nodes to predict link lifetimes. They modified the algorithm (PRAOVD-M) to compute the maximal predicted life time among various route options. However, this algorithm includes a large time cost because it depends on the authenticity of node position and mobility. It does not consider that relative velocity problems lead to overrated or underrated lifetime. If the prediction model can provide more specific estimation, it can provide higher stable connection quality. A prediction-based routing method was applied to the route with the minimal predicted value among multiple routes as a metric, unlike the Inter-Vehicular Geocast (IVG) and (Distributed Robust Geocast (DRG) schemes, which use minimum hop count to provide efficient inter-vehicle communication. Although these methods can build a routing path in accordance with the vehicle speed and moving direction, the issues of overlapping handoff and non-overlapping handoff are not considered. Therefore, this study will analyze the communications in the cases of overlapping handoff and non-overlapping handoff according to predicted moving behaviors.

2.3 Mobile Management of the Telematics Environment

For mobile management of the telematics environment, the wave basic service set (WBSS) consisted of RSUs, which provide internet service for users in communication range. Because vehicles move at high speeds, users forward frequently to access WBSS area on-road. Therefore, IEEE 802.11p must support the fast handoff scheme to achieve an uninterrupted service. Under a mobile network, a scheme for buffer control was designed to reduce the situation of packet loss for mobile nodes in the handoff process. It set an agent router or any entity devices to the deploy buffer area, and forwarded the loss packets to the mobile node. The inter-access point protocol (IAPP) was proposed to define information exchange between APs [45-46]. In this approach, a proactive caching scheme effectively reduces the re-connection delay of a node. However, the current IEEE 802.11p draft did not define the handoff process between APs [47]. Pack et al. [48] defined the fast handoff control under IEEE 802.11. As shown in Figure 1, the proposed fast handoff control mechanism included probe, authentication, and re-association steps. The time spent during these steps is called handoff delay time. After these steps, mobile devices receive information from the physical layer. The probe delay results in a large delay time and interruption of service. This is crucial in real-time services, such as multimedia streaming. Therefore, the goal of most fast handoff schemes is to reduce probe delay. Therefore, this study will propose a predictable dynamic buffer control mechanism according to the cases of overlapping handoff and non-overlapping handoff and design an adaptive transmission mechanism for streaming over R2V networks.

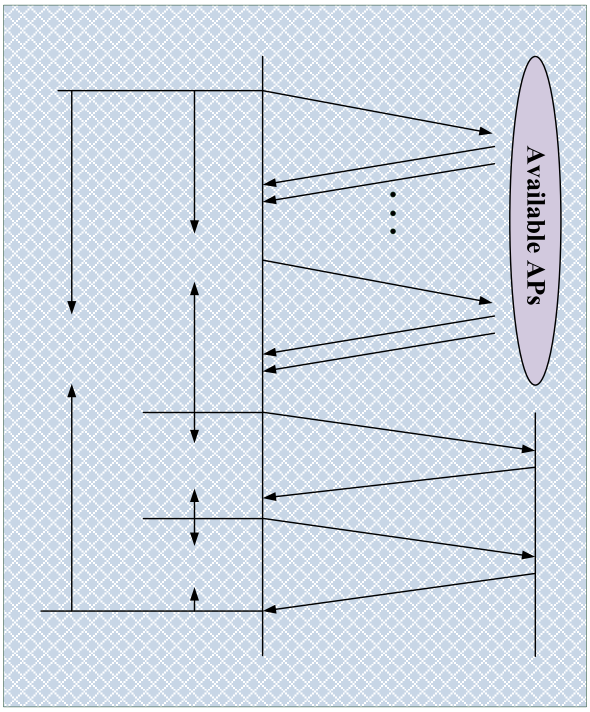


Figure 1. The handoff operation under IEEE 802.11 environment

3 Research Framework

3.1 The Explanation of System Function

This study was based on the R2V communication environment, and achieved a seamless handoff scheme of streaming service. As shown in Figure 2, to achieve the goal of multimedia streaming sharing, a motion vehicle may collect the parameter of motion action by GPS, which processes the prediction of connection time. However, the building of each RSU is almost unfixed on a real road. This study designed a scheme of dynamic buffer control, and used flow control of transmission to achieve seamless handoff control. The objective was to achieve un-interrupted playback of the streaming service and provide application services, such as driving safety, entertainment, and traffic monitoring. This study also used DSRC technology as the wireless network protocol. This protocol caused interference difficulty in high speed motion, and its communication range was up to 1000 m. This study designed six components for a seamless handoff control scheme.

(1) Information Collector: Uses a GPS device to collect parameter of location information for motion vehicles.

(2) Life-time Prediction: Based on link expiration time to predict buffer size and adaptive flow rate between two mobile nodes.

(3) Interruption Prediction: Uses a formula of tangent to predict interruption time and pre-buffer size.

(4) Event Analyzer: Estimates and analyzes the judgement of handoff using various calculation methods to predict the number of buffer sizes required for download.

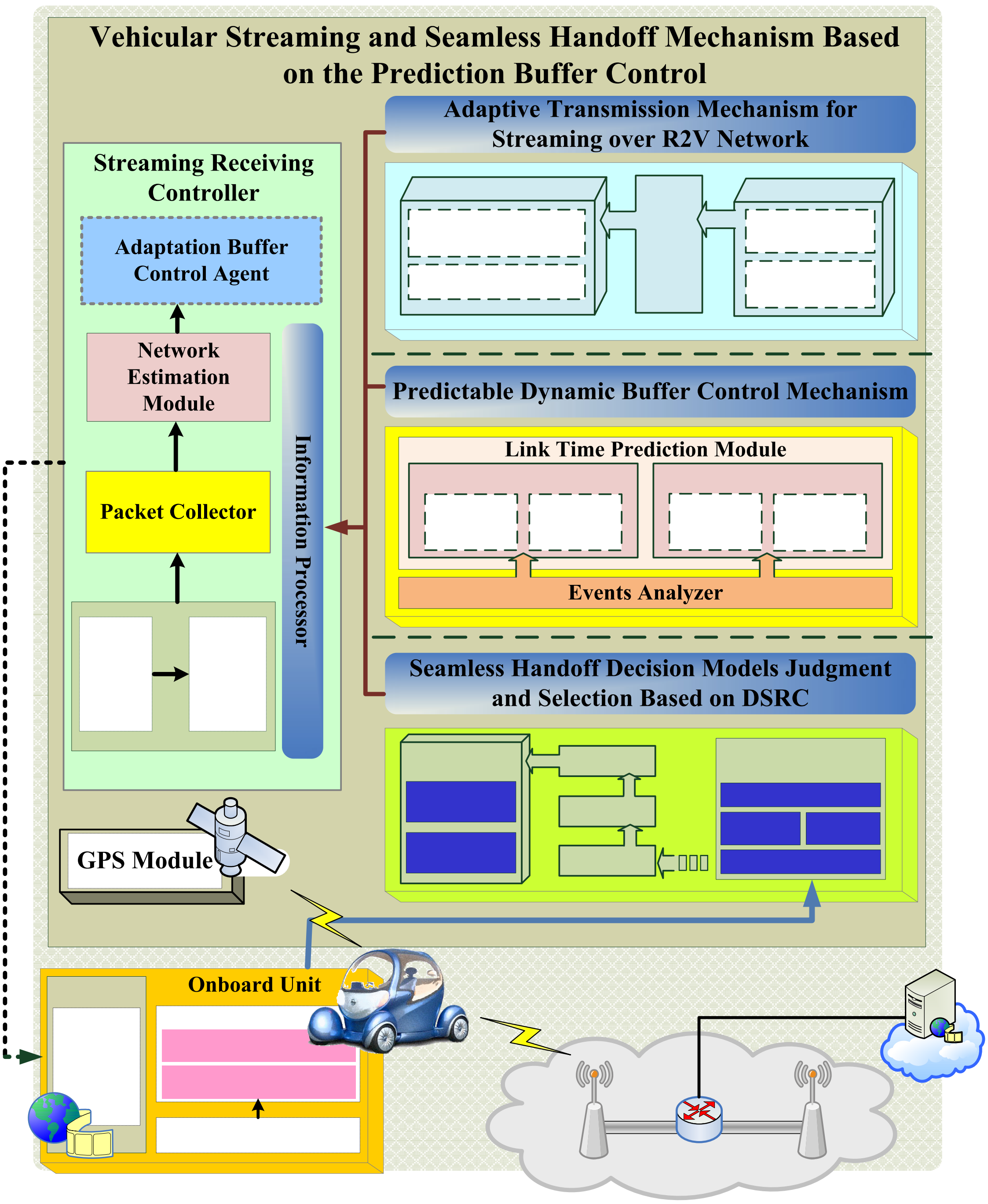


Figure 2. Research architecture

(5) Buffer Controller: Playback time of interruption of the network can carry the receiver buffer size adaptation strategies to achieve a seamless handoff scheme.

(6) Adaptive Handoff Module: For various distances of RSUs, GPS obtains the parameters for the calculation of the dynamic buffer size, and makes up the buffer size to accommodate the time of handoff delay before communication interruption.

3.2 The Operation Flow of Mechanism

Figure 3 shows the detailed operation steps of this scheme. The RSU continues to broadcast packets to allow vehicles to enter the communication range to receive these packet by adding WBSS. If the vehicle is determined within the communication range of the RSU, it would collect the driving information (e.g., speed, direction, and location), and exchange parameters by DSRC. First, a simple judgment of the handoff case was conducted, and the method of connection time and the concept of the tangent equation were used to develop link expiration time and network interruption time. This scheme is determined according to the network interruption time, and dynamically adjusts the transmission rate between the vehicle and the RSU.

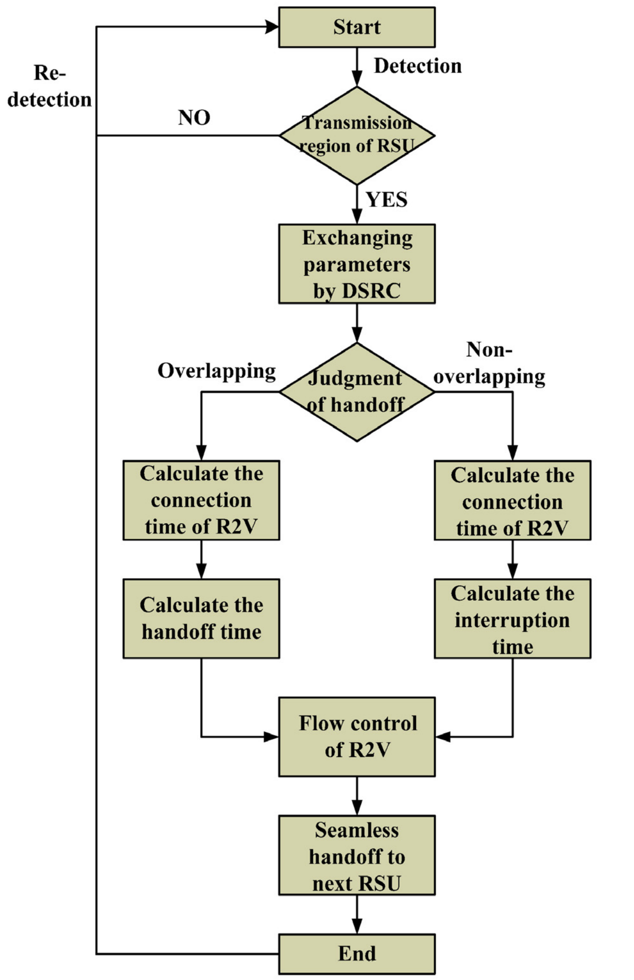


Figure 3. Operation flow chart of mechanism

4 Seamless Handoff Decision Models Based on DSRC

Because of the frequent change of topology, vehicles driving on the road exhibit several unexpected behaviors. This study explored the manner in which vehicles use transmission control by DSRC. This study also investigated the problems that vehicles encounter in the handoff process, and offers a brief description of the operation of the process as the method in search of RSUs. The establishment of RSUs is a vital part of the telematics environment. The manners by which to control a vehicle to obtain a source of stability and uninterrupted message on the road are crucial issues for research.

4.1 DSRC Handoff Operation Flow

VANET is a separate discipline, although it is a part of mobile ad hoc networks (MANET). VANET is one of the most challenging forms of MANET because of high and unpredictable dynamic topology, frequent disconnections, and life threatening issues. However, a node in the telematics network is usually in the high-speed mobile vehicle. Conversely, when the moving vehicle attempts to switch the RSU of access services, it may experience service interruption caused by an incomplete download. This is the handoff delay time of the switching of RSUs. Figure 4 shows the use of the acknowledgement (ACK) packet as the handoff start. This study used the transmission management layer of DSRC to determine the parameter of time-out and detection to perform the handoff timing of judgment. A number of the steps are presented in an example of multimedia streaming, as follows.

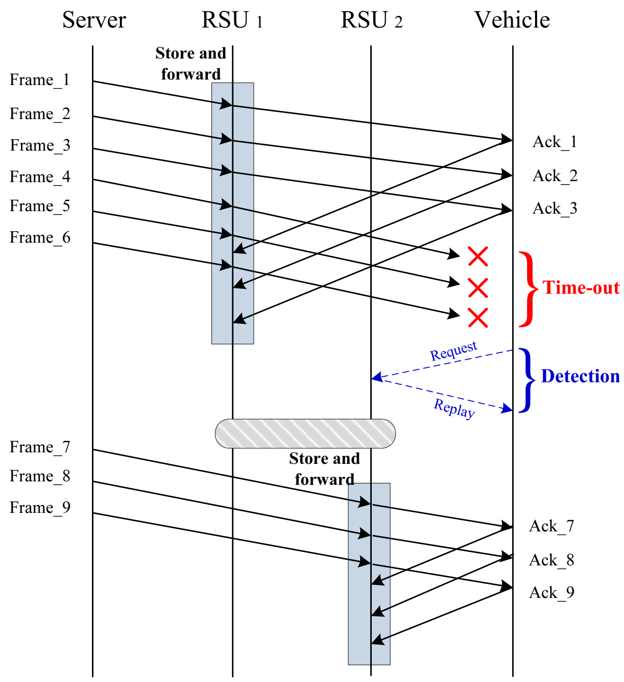


Figure 4. DSRC handoff flow

• Vehicle equipped with OBU continues to broadcast a request packet and detect whether it is in the RSU1 transmission range. If so, the vehicle begins to access the service with the RSU1.

• Accessing the service of multimedia streaming settings for persistent download from Frame_1 to Frame_9. When the vehicle downloads with no loss from Frame_1 to Frame_3, the vehicle and RSU1 have a persistent connection.

• It has an interruption in Frame_4. Interruption may be caused by network instability and other external factors that force interruption. However, RSU1 sends the stream of information to the vehicle.

• The viewing quality of the user is usually affected when the interruption occurs. However, it does not perform the processing for the packet loss from Frame_4 to Frame_6 in this case.

• If the OBU no longer receives an incoming stream of information flow from RSU1 for a specific period, the vehicle determines it is not in the transmission range of RSU1. This is a time-out mechanism. Subsequently, it proceeds to the detection of action. If the detected vehicles are in the transmission range of RSU2, it establishes a connection with the vehicle.

4.2 Link Expiration Time

This section presents the LET prediction method. When a vehicle is in the communication range of RSU, the time required for the vehicle to leave the communication range is referred to as link expiration time between RSU and the vehicle. First, assume that all vehicles and RSU use the same time parameters, that is, Greenwich Mean Time (GMT), which is the mechanism of the time synchronization standard. Figure 5 demonstrates that a vehicle can calculate the persistent communication time between OBU and RSU if it knows the speed, direction, and location of two nodes.

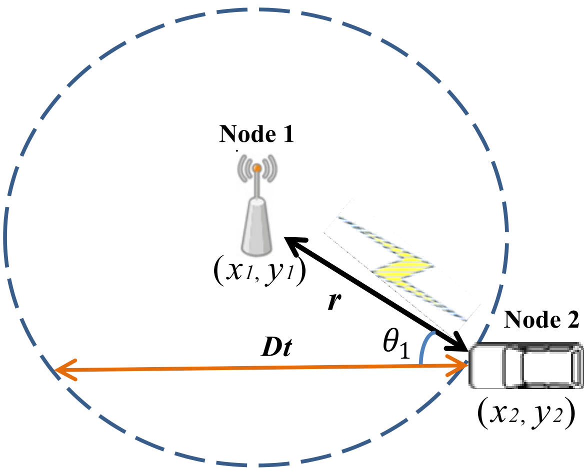


Figure 5. Link expiration time

Therefore, if the motion parameters of two neighbors are determined, the duration for which these two mobile nodes remain connected can be determined. Assume that two mobiles, 1 and 2, are within hearing range, and have equal transmission range, r. Let (x_1, y_1) and (x_2, y_2) be the position for mobiles 1 and 2, respectively. Let v_1 and v_2 be the speeds of mobiles 1 and 2, and θ_1 and θ_2 be the headings of mobiles 1 and 2, respectively. Subsequently, Dt is the duration for which they remain connected, denoted as Equation (1). To demonstrate the proposed method, the following parameters were adopted to estimate the duration: r = 100 m, v_1 = 10 m/s, v_2 = 5 m/s, θ_1 = 0 degree, θ_2 = 0 degree, b = 10 m (i.e., horizontal distance), and d = 10 m (i.e., vertical distance). The duration can be estimated as 17.90 s (shown in Equation (2)).

$$Dt = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

where

r = transmission range **(1)**

$a = v_1 \cos\theta_1 - v_2 \cos\theta_2$

$b = x_1 - x_2$

$c = v_1 \sin\theta_1 - v_2 \sin\theta_2$

$d = y_1 - y_2$

$$Dt = \frac{-(5\times10+0)+\sqrt{(5^2+0^2)\times100^2-(5\times10+0)^2}}{5^2+0^2} = \frac{-50+\sqrt{250000-2500}}{25} = \frac{-50+497.49}{25} = 17.90 \quad \textbf{(2)}$$

where

$a = 10\times\cos 0^\circ - 5\times\cos 0^\circ = 5$

$c = 10\times\sin 0^\circ - 5\times\sin 0^\circ = 0$

4.3 Judgment Method of Handoff

The general handoff algorithm usually requires a handoff determination mechanism to determine the time at which to start the handoff service. Subsection 4.2 described the time at which to start the handoff services. According to the IEEE 802.11p WAVE transmission environment, vehicular access communication is crucial to determine the manner in which to maintain vehicle and RSU communication to prevent interruption. Figure 6 shows the handoff service of R2V, in which one service is non-overlapping handoff and the other service is overlapping handoff.

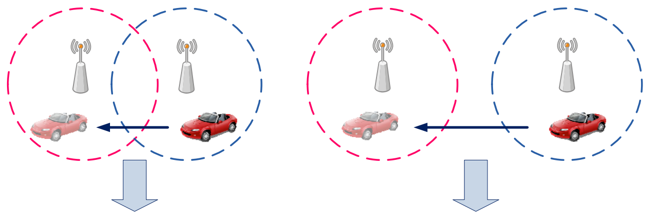


Figure 6. Handoff situation of R2V

Therefore, this study used a mechanism to select these two handoff cases, that is, through the position of the relationship between two circles. The circles represent the transmission range of RSU. This produced two cases. Figure 7 shows that the first case is a non-intersection of two circles.

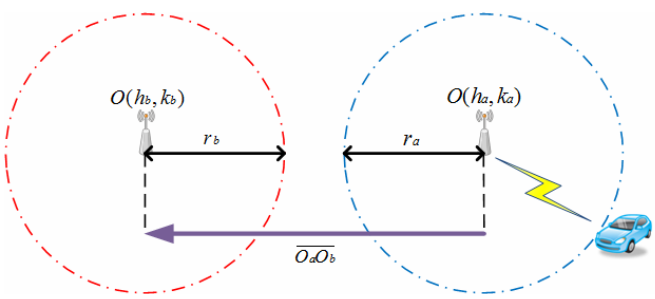


Figure 7. Situation of non-overlapping handoff

Assume that there are two centers, $O(h_a, k_a)$ and $O(h_b, k_b)$, of the communication area of the RSU. The radiuses were set as r_a and r_b, and the distance of two centers was $\overline{O_aO_b}$. Subsequently, this study obtained

Equation (3). To demonstrate the situation of non-overlapping handoff, the following parameters were adopted to estimate the duration: r_a = 100 m, r_b = 100 m, and $\overline{O_aO_b}$ = 250 m (shown in Equation (4)).

$$\overline{O_aO_b} \geq r_a + r_b \quad (3)$$

$$\overline{O_aO_b} \geq r_a + r_b \Rightarrow 250 \geq 100 + 100 \quad (4)$$

Figure 8 shows that the second case is an intersection of two circles. Equation (5) can calculate the time at which the vehicle is in the transmission range of the RSU and OBU will receive the parameters through the DSRC. To demonstrate the situation of overlapping handoff, the following parameters were adopted to estimate the duration: r_a = 100 m, r_b = 100 m, and $\overline{O_aO_b}$ = 150 m (shown in Equation (6)).

$$|r_a - r_b| < \overline{O_aO_b} < r_a + r_b \quad (5)$$

$$|r_a - r_b| < \overline{O_aO_b} < r_a + r_b \Rightarrow |100 - 100| < 150 < 100 + 100 \quad (6)$$

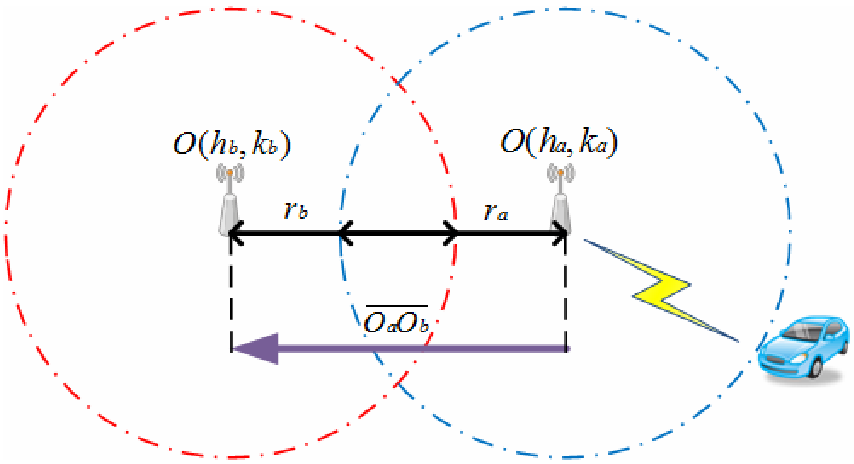


Figure 8. Situation of overlapping handoff

5 Predictable Dynamic Buffer Control Mechanism

By the base station or access point, the exchanging and sharing of traditional wireless networks carrying the message becomes the network architecture for mobile ad hoc networks. The main actions for the wireless network environment are node packet forwarding and packet delivery through multi-hop, which is not required by the infrastructure. However, this is only for single-hop exploration. This indicates that is does not require a relay node for packet forwarding. In the telemetics environment, vehicles are often in a high mobility environment. They usually require access to external networks by APs, which causes the handoff. If the handoff process to produce a higher delay time affects the quality of network transmission, real-time transmission of behavior is more obvious. To prevent this, multimedia streaming is downloaded to the client's buffer of any destabilizing factors, such as delay and jitter. Therefore, this section presents the detailed control of the client buffer. Communication between vehicles and RSUs can be maintained at a stable streaming download. Flow control along with the variation of the network environment can enable the client to obtain sufficient buffer data to the player for consumption after network disruption.

5.1 Non-overlapping Handoff

This study used the method of prediction buffer control to design seamless handoff mechanism. First, this study focused on non-overlapping handoff, which produced a situation of network interruption. If a vehicle is driven on this road, it would cause interruption in network transmission. Figure 9 shows that a gap of no network link occurs between two RSUs. The vehicles will receive the broadcast packets that are regularly issued by the RSU. If the vehicle joins this set of services, the vehicle would be issued with an agree packet triggering RSU to begin service access (PSID: 123). Simultaneously, the vehicle calculates the LET and the judgment of the handover situation. When a vehicle wants to leave the communication range of the RSU, it records the action and the amount of preload buffer. Finally, when the vehicle wants to enter the communication range of RSU2, it processes a handoff through the backbone. Finally, the vehicle begins to follow the last recorded multimedia frame and continues to play the video.

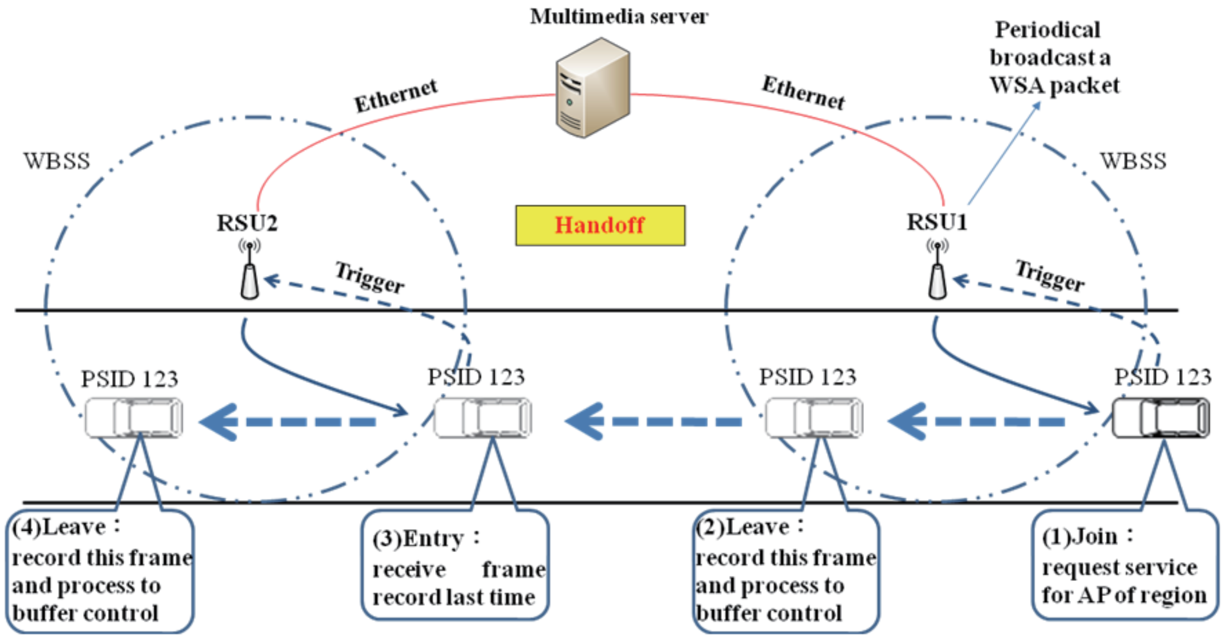


Figure 9. Non-overlapping handoff situation of R2V

When the vehicle enters the transmission range of the RSU_1, it predicts the amount of time required to leave this transmission range. The method is the subtraction of RSU_2's transmission range of the vehicle entering contact and RSU_1's transmission range of the vehicle leaving contact. This value of subtraction represents network interruption distance, as shown in Figure 10. The value is subsequently used to divide the speed of the vehicle and obtain the interruption time of $D't$. Finally, this study modified the connection time of Dt. Because RSU was fixed in this study, the speed of RSU was not considered. In addition, this study also removed the parameters of speed and direction of RSU, which is simply denoted as Equation (7). To demonstrate the proposed method, the following parameters were adopted to estimate the duration: r = 100 m, V = 10 m/s, x = 10 m (i.e., horizontal distance), and y = 10 m (i.e., vertical distance). The duration can be estimated as 10.95 s (shown in Equation (8)).

$$Dt = \frac{-(ax) + \sqrt{a^2 r^2 - (ay)^2}}{a^2} \tag{7}$$

where

r = transmission range

$a = -V \cos\theta$

$x = h - x_0$

$y = k - y_0$

$$Dt = \frac{-(-10 \times 10) + \sqrt{(-10)^2 \times 100^2 - ((-10) \times 10)^2}}{(-10)^2} = \frac{100 + \sqrt{1000000 - 10000}}{100} = \frac{100 + 994.99}{100} = 10.95 \tag{8}$$

where

$a = 10 \times \cos 0^\circ = -10$

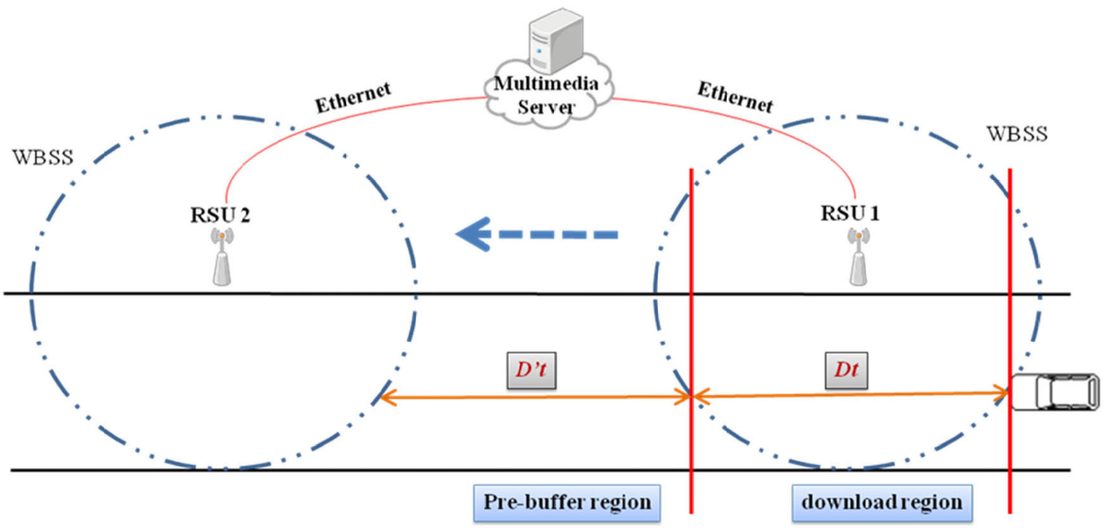
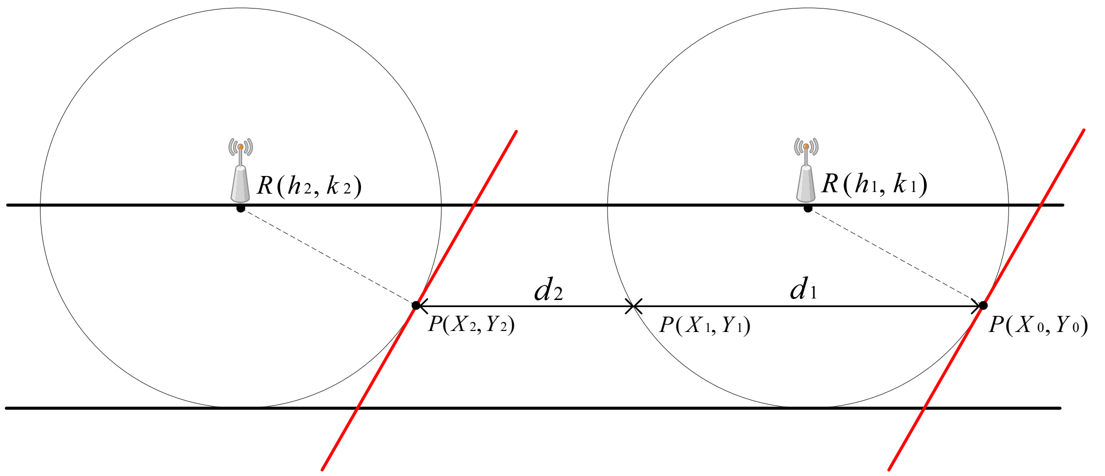


Figure 10. Situation of seamless handoff

Therefore, this study used Dt and $D't$ to determine the required bit rate of the vehicle to adjust when entering the RSU. This was used to process the buffer control to achieve smooth video playback services.

Therefore, this study determined the time of $D't$, and calculated the time required to reach the next RSU. Figure 11 shows the interruption distance of the tangent equation. This study used the coordinates of the tangent point as the point of vehicle entry. This study used tangent equation to calculate the next RSU communication range coordinate's point $P(X_2, Y_2)$. In addition, when the vehicle speed was fixed, this study estimated the coordinate's point $P(X_1, Y_1)$ because of the division of connection time and speed. Subsequently, this study used $P(X_2, Y_2)$-$P(X_1, Y_1)$ to obtain a distance of d_2, and determined the size of pre-buffer. This pre-buffer size is called $D't$, and is denoted as Equation (9). To demonstrate the proposed method, the following parameters were adopted to estimate the duration: $r = 100$ m, $V = 10$ m/s, $X_0 = 200$ m, $Y_0 = 0$ m, $X_2 = 10$ m, $Y_2 = 0$ m, $h_1 = 190$ m, $k_1 = 10$ m, $h_2 = 0$ m, and $k_2 = 10$ m. The duration can be estimated as 29.95 s (shown in Equation (10)).

$$D'_t = \frac{\left| \left[\frac{(X_0 - h_1)(Y_2 - k_2)}{Y_0 - k_1} + h_2 \right] - \left[X_0 + (D_t * V) \right] \right|}{V} \quad \textbf{(9)}$$



$$(X_2 - h_2)(x - h_2) + (Y_2 - k_2)(y - k_2) = r^2 \qquad (X_0 - h_1)(x - h_1) + (Y_0 - k_1)(y - k_1) = r^2$$

Figure 11. The interruption distance of tangent equation

$$D'_t = \frac{\left| \left[\frac{10 \times (-10)}{-10} + 0 \right] - \left[200 + (10.95 \times 10) \right] \right|}{10} = \frac{299.5}{10} = 29.95 \quad \textbf{(10)}$$

Equation (9) is in a one-dimensional environment. This is based on the same concept of the slope of the tangent equation. This study used $D't$ to determine the number of buffer sizes required for download in Dt. This study dynamically adjusted transmission rates between the vehicle and the RSU. Equation (9) was solved by tangent equation, as shown in Figure 11.

5.2 Overlapping Handoff

Mobile node handoff behavior is usually based on the network received signal strength indicator (RSSI) to determine the timing of the handoff in general. When the signal of the mobile node weakens, it will start the detection mechanism to search for another base station within the region. The method is registered to another base station with the original base station connected to the establishment of the channel. This channel is used to send the service to the new base station. Subsequently, the channel with the original base station ends to successfully complete the handoff procedure. However, the design did not consider the delay time of handoff. This study considered the worst-case scenario to the overlapping area of the two sides of RSUs. In other words, it was designed to satisfy the playback buffer of the client.

Figure 12 shows that a vehicle periodically receives the broadcast message from the RSU if it enters the RSU (R_1) transmission range. If the vehicle wants to join this WBSS, it sends a request trigger to the RSU to start the service. The vehicle simultaneously calculates the prediction of *Dt*. Subsequently, this study attempted to determine the *Qt*. This study expressed the vehicle entry point $P(X_0, Y_0)$ to (X_0), expressed the (R_2) contact of the vehicle entry point $P(X_1, Y_1)$ to (X_1), and expressed the (R_1) contact of the vehicle leaving point $P(X_2, Y_2)$ to (X_2). A calculation on only the X-axis was performed, as follows.

$$Qt = \frac{|X_0 - X_1|}{V}$$

where **(11)**

$$X_0 = (h_0 + \sqrt{r_0^2 - (Y - k_0)^2})$$
$$X_1 = (h_1 + \sqrt{r_1^2 - (Y - k_1)^2})$$

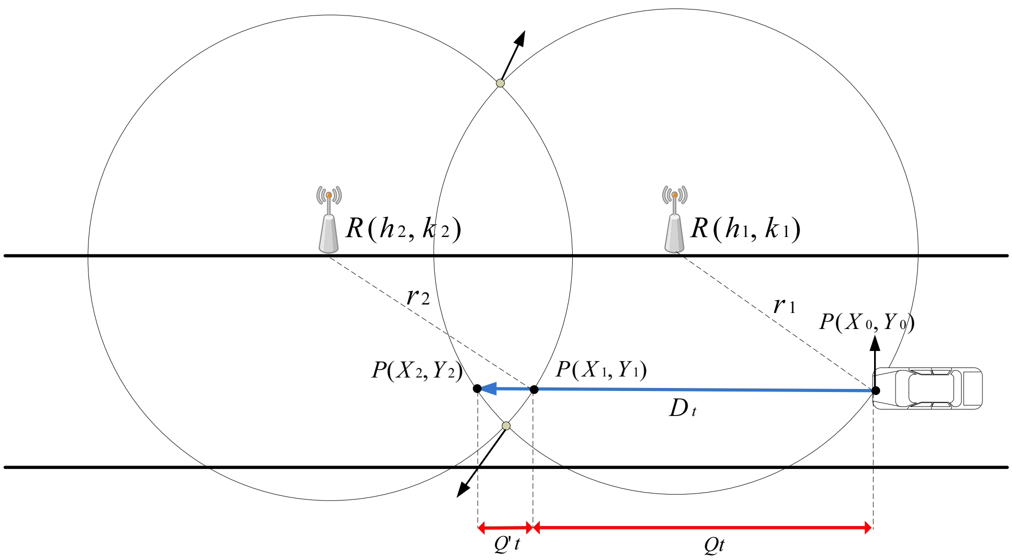


Figure 12. Situation of overlapping handoff

Equation (11) was used to calculate the coordinate location of X_0 and X_1, and the subsequent subtraction of these two locations. Finally, the distance of these two locations was used to divide the speed of the vehicle. Subsequently, it was easy to calculate $Q't$, as follows.

$$Q'_t = D_t - Q_t \quad \textbf{(12)}$$

6 Adaptive Transmission Mechanism for Streaming over R2V Network

The vehicle often encounters unexpected things when it is in motion. Various environmental factors influence the transmission quality, especially for real-time streaming service. A management mechanism is required for the transmission and buffer controller to achieve smooth video playback. This study used the pre-buffer to dynamically adjust transmission rate to provide seamless handoff of streaming service. This study also used the interruption time to determine buffer size of client. To dynamically adjust transmission rate to control buffer size, this study used the video playback time of interruption to determine transmission variation rate, which denoted as Equation (13). The definition of each parameter is presented in Table 1.

Adjusted Transmission Rate =
Playback Rate + Transmission Variation Rate
Playback Rate = FR × FS
Transmission Variation Rate =

$$\left[\frac{D't \times FR \times FS}{Dt - PB}\right] \times 8 \quad \textbf{(13)}$$

Table 1. Notations of transmission rate

Parameter	Meaning
D'_t	Network interruption time (sec)
FR	Frame rate (fps)
FS	Frame size (Kbyte)
PB	[original] Buffer time (sec)
TR	[original] Bit rate (Kbit)

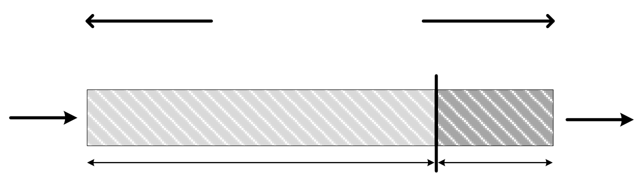


Figure 13. Variation of transmission rate

Figure 13 shows that total buffer size is the interruption buffer plus default buffer. Default buffer indicates that, when the vehicle enters the RSU communication range, it first suspends for PB second, and subsequently uses the time to download the amount of pre-buffer. When the vehicle waits until PB second, the buffer must download to low threshold. Subsequently, the vehicle follows the adjusting transmission rate, and downloads at interruption buffer sector until high threshold. The interruption buffer sector is based on interruption time. Therefore, the buffer is slowly filled, indicating that the communication will be interrupted. The vehicle subsequently consumes the buffer in network interruption. The rate of consumption is consistent with the time calculated by the network interruption. The vehicle will successfully complete handoff to the communication range of the next RSU.

7 Experiments and Performance Evaluation

This section proposes a scheme of LET and interruption time prediction for adjusted transmission rate in V2R communication. This study used the calculation of buffer size to achieve seamless handoff by transmission control. The experiment was conducted in a simulation of an actual environment.

The generated mobility trace was immediately used by NS-2 version 2.34 to simulate real world vehicle movements. Therefore, the simulation was based on a one-dimensional highway. This study used the parameter setting of IEEE 802.11p physical (PHY) and medium access control (MAC) Layer, as shown in Table 2. According to this simulation parameter setting, the link expiration time of V2R is shown as Figure 14.

Table 2. Notations of IEEE 802.11P

802.11p setup in NS2 configuration	Parameter	Value
Phy/WirelessPhyExt	freq_	5.9e+9 (5.9GHz)
Phy/WirelessPhyExt	noise_floor_	1.26e-13(10MHz bandwidth)
Phy/WirelessPhyExt	Pt_	0.001 (Transmission Power)
Phy/WirelessPhyExt	CSThresh_	3.162e-12
Phy/WirelessPhyExt	trace_dist_	1e6
Mac/802_11Ext	CWMin_	15
Mac/802_11Ext	CWMax_	1023
Mac/802_11Ext	SlotTime_	0.000013
Mac/802_11Ext	SIFS_	0.000032

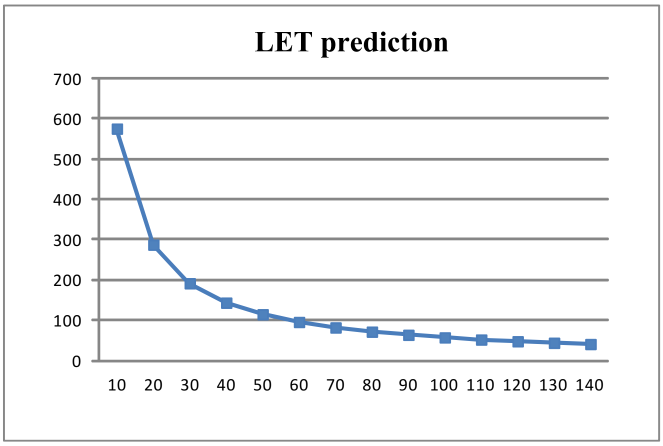


Figure 14. LET prediction of R2V communication

This paper presents the pre-buffer mechanism will limit the speed to fixed. The maximal transmission range was 1061 meters in an 80 km/h environment. Figure 15 shows the adjusted transmission rate and actual receive rate. This study limited the distance of RSUs from 1000 to 3000 meters. This study discovered that the circle become non-overlapping from 1600 meters, indicating that it begins to produce the situation of network interruption. Therefore, this study used (13) to determine the buffer sizes required for download, and the transmission rate that required adjustment.

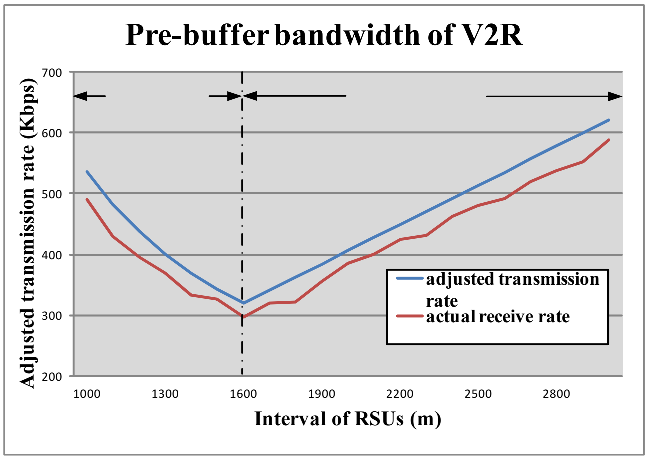


Figure 15. The analysis of pre-buffer bandwidth

Therefore, this study observed the situation of pre-buffer mechanism in actual buffer sectors. Table 3 shows the value of each parameter for pre-buffer mechanism in experiments. Vehicles must be based on the interruption time to play video and adjust the transmission rate. Figure 16 shows the buffer variation of client. When the vehicle starts to download, the buffer first pre-loads for approximately 5 s. The packets are slowly filled with the adjusted RSU transmission rate. The interruption time starts when the buffer area is filled. The client started to consume the buffer at 70 s. In the proposed scheme, the buffer area has sufficient amounts to consume at 100 s. Conversely, if not using the proposed scheme, the vehicle only allows the frame to play at 86.5 s. This produces an interruption time of approximately 13.5 s.

Table 3. Notations of pre-buffer bandwidth

Value	Setting	Value	Setting
Vehicle speed	80 km/h	Stream bit rate (initial)	384 Kbps
Connect type	CBR/UDP	Stream bit rate (adjusted)	467 Kbps
Frame rate	20 fps	Packet size	1024 bytes
Frame size	2048 byte	Data rate	6 Mbps

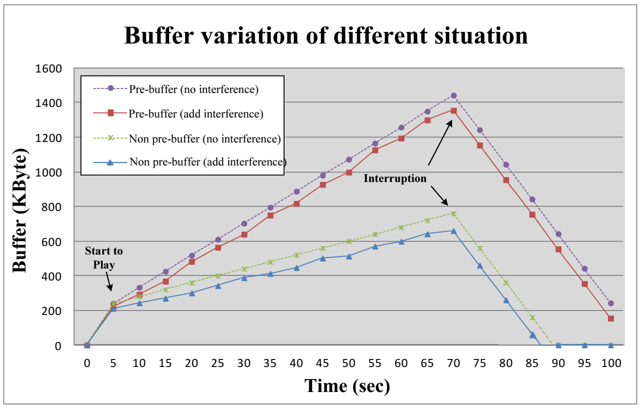


Figure 16. The buffer variation of different situation

Finally, this study observed the QoS accomplish rate of the vehicle speed as 60 km/h, 100 km/h, and 140 km/h. They represent the road of jam, medium, and smooth. The QoS accomplish rate is the total received amount divided by total traffic amount. The QoS accomplish rate is high at 60 km/h, as shown in Figure 17.

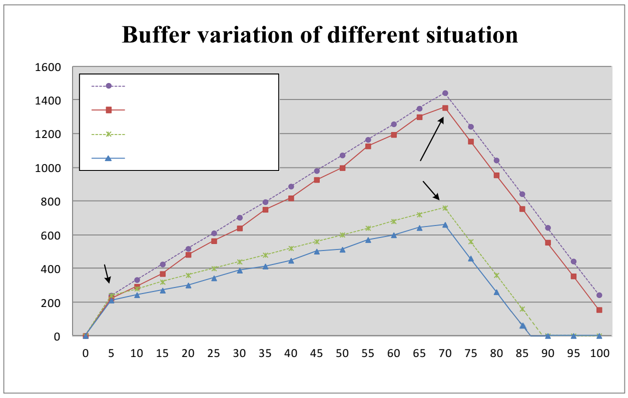


Figure 17. The buffer variation of different situation

Figure 18 shows the results of QoS accomplish rate of the vehicle speed.

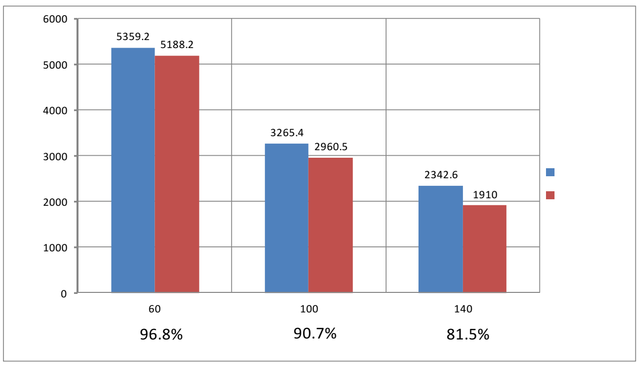


Figure 18. The QoS accomplish rate of the vehicle speed

8 Conclusions and Future Work

This study was conducted in response to the small number of RSUs in the R2V communication environment. This study proposes a pre-buffer scheme that uses the concept of LET to perform buffer and flow control. Thus, it can achieve seamless handoff to offer a smooth video for clients. The NS2 simulation demonstrated that the scheme is feasible in a one-dimensional environment on the road. Although the RSU distribution is variable, this study can predict the time to control the rate of transmission to download. Future studies will address the link time prediction in a two-dimensional urban city, and vehicle acceleration change for streaming service.

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