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Handover Algorithm for Video Communications by Sharing Communication Quality Information of Access Points between Terminals

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Abstract

In recent years, the demand for multimedia services that can handle voice and/or videos on mobile terminals has increased. Many handover algorithms have been proposed for switching the connection between different networks while maintaining QoE (Quality of Experience), which is a metric that is a measure of users' satisfaction when using a certain service or application. The QoE-driven VHO algorithm is one of such algorithms using a prediction model of QoE for movies streamed over wireless networks. Since the algorithm may not provide an acceptable level of quality when network performance temporarily decreases, the authors also proposed an algorithm (hereinafter referred to as the "previous algorithm") to improve the problem. However, since these algorithms cannot predict QoE of candidate networks before switching, the connection may be switched to a network with much lower QoE. In order to solve the problem, this paper proposes a new handover algorithm for video communications by sharing communication quality information of access points between terminals. In this algorithm, each mobile terminal creates a list specifying the communication quality of the connected access point and shares it with other terminals. The simulation results show that terminals in the proposed method can connect to the access points with better QoE for longer durations than the QoE-driven VHO algorithm and the previous algorithm.

Keywords: Sharing Communication Quality Information Handover Algorithm, QoE, Video Communication, Wi-Fi

1 Introduction

As the performance of mobile terminals such as smartphones, tablets, and note PCs has increased recently, these terminals can easily handle multimedia content such as voice and videos. Since various applications are provided on the terminals through wireless networks, there is an ever-increasing demand for multimedia services. Recently, since many wireless connection services such as 3G, LTE, Wi-Fi, WiMAX, etc. are offered at a low price, a typical mobile terminal can use multiple heterogeneous communication links, where such communication links are just called networks in this paper, at the same time. However, it is too difficult for general users to choose the most appropriate network from among these candidate networks when making a connection.

To solve this problem, many handover algorithms have been proposed for seamlessly switching connections between different networks to maintain QoS (Quality of Service). For example, Huang et al. proposed a context-aware handoff algorithm where a user's moving path has been planned by a context server. The algorithm adopted AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order reference by Similarity to Ideal) to solve AP (Access Point) selection [1]. TalebiFard et al. proposed a dynamic context-aware handoff algorithm method based on a modified WPM (Weighted Product Method) to continue sessions with the users' existing context. In this algorithm, Quality of Context is used to penalize alternatives with poor communication quality [2]. Bathich et al. proposed a QoS-driven vertical handover mechanism on a maximum achievable data rate calculated by SINR (Signal to Interference and Noise Ratio) obtained from the connectable APs of Wi-Fi and BSes (Base Stations) of WiMAX from IEEE 802.21 [3]. Hourai et al. proposed a vertical handover control system that is based on a communication priority and end-to-end network performance [4]. Ohishi et al. investigated two kinds of network selection criteria, i.e., the real-time network status and stored statistical information, and compared them by some field experiments [5].

Although QoS is the objective quality of the network, it does not always correspond to the quality that users actually experience in relation to the service. Therefore, in recent years, it has become important to consider QoE (Quality of Experience) which corresponds to the users' perception of the quality they experience.

Based on this background, Li et al. proposed a QoE-driven Vertical Handover (VHO) algorithm [6] using the QoE prediction model for videos [7, 8]. In this algorithm, when the Mean Opinion Score (MOS), which is a numerical measure of QoE, falls below a certain threshold, this algorithm switches the connection if another connectable network can be found. But this method had a problem that the handover is executed instantly even when the deterioration in network performance is only temporary. The authors have improved this algorithm [9]. This algorithm is referred to as the "previous method" in the rest of paper. The algorithm monitors the communication environment periodically and predicts the average MOS from a fixed number of observed data to determine if a temporary change in QoE is about to occur. However, since neither algorithm can predict the QoE of candidate networks before switching, the connection may be switched to a network with much lower QoE.

In order to solve the problem, this paper proposes a new handover algorithm for video communications by sharing communication quality information of the connected access points between terminals. In this algorithm, each mobile terminal creates a list of the communication quality of the connected access point and shares it with other terminals. The simulation results show that terminals in the proposed method can connect to the access points with better QoE for a longer period than the QoE-driven VHO algorithm and the previous algorithm.

The rest of the paper is organized as follows: Section 2 explains the handover algorithm and QoE. Section 3 describes the QoE prediction model [7, 8] for video streamed on a wireless network. Then, it explains the QoE-driven VHO algorithm [6] and the previous method [9], and elucidates the problems associated with these handover algorithms. In Section 4, we propose our new algorithm whereby communication quality information of access points is shared between terminals. Section 5 executes the simulations in the NS3 simulator and compares the proposed algorithm with the QoE-driven VHO algorithm and the previous algorithm. Section 6 concludes the paper and describes future work.

2 Handover Algorithm and QoE

This section explains the handover algorithm and QoE that is the main focus of the paper.

2.1 Handover Algorithm

A handover is an operation that involves switching a base station or an access point as a wireless connection end point, when a mobile terminal is moving while communicating.

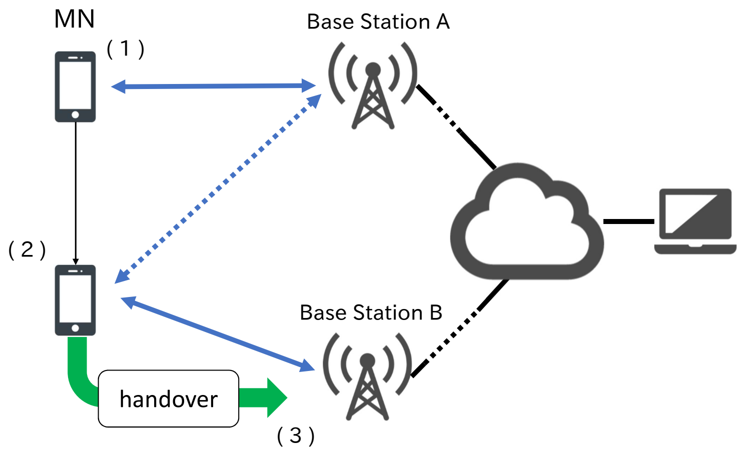

Figure 1: Handover

In Figure 1, (1) a terminal is connected to Base Station A, and communicates with the PC through this station. (2) When the terminal moves downward, the quality of communication with Base Station A gets worse. When the terminal reaches an area where the quality of communication with Base Station B becomes better than that with Base Station A, the terminal performs the handover process as follows. (3) The terminal disconnects the connection with Base Station A, and then connects with Base Station B. If this process takes a long time, the communication is temporarily interrupted. In particular, when the terminal performs real-time communication such as voice and video, the quality the user experiences will become worse due to the interruption. Thus, the handover algorithm is very important for switching the connection smoothly.

2.2 Quality of Experience

In recent years, the user's experience referred to as Quality of Experience (QoE), rather than QoS, needs to be considered during handover. QoE is a subjective measure of QoS and is based on the user's perception of the overall quality of the service provided. For example, video viewers have a low QoE when the video is frequently affected by blocking noises and/or lack of synchronization between sounds and images.

QoE is often represented by a numerical measure called the Mean Opinion Score (MOS). The MOS is the average score assigned by multiple users when evaluating the quality of a service and is expressed as an integer between 1 and 5 as shown in Table 1. For example, the previous handover algorithm described in Section 3.3 specified that the MOS over the current access point should be 3.5 or more. Otherwise, mobile terminals connecting to the access point would consider performing handover to another access point if one could be found.

Table 1: Meaning of MOS

MOS	Meaning
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

3 QoE Prediction Model and Handover Algorithm for Video Streams on Wireless Networks

This section describes the QoE prediction model [7, 8] for video streams on wireless networks. Based on the prediction model, the QoE-Driven VHO algorithm [6] and its improved version, referred to in this paper as the previous algorithm [9], are also explained.

3.1 QoE Prediction Model for Video Streams on Wireless Networks

As Section 2.2 mentioned, when users watch a video stream, they can subjectively evaluate the quality of the video on the wireless network. Khan et al. proposed the prediction model [7, 8] from the following application level parameters:

- Sender Bit Rate (SBR)
- Frame Rate (FR)
- Content Type (CT)

and the following network level parameter that can be objectively measured:

- Packet Error Rate (PER)

The model calculates the MOS from these values. The calculation depends on the class of the video that is classified into three Content Types (CTs) as follows.

- Slight Movement (SM)
  An SM video has little movement of either the object or the background so that the changes in the entire screen are small. An example of this type would be a video showing a newscaster reading the news.
- Gentle Walking (GW)
  A GW video has significant motion of either the object or the background but not of both. An example of this type would be a video taken from inside a moving car against so that the background appears to move.
- Rapid Movement (RM)
  An RM video has significant motion of both the object and the background so that the entire screen changes rapidly. An example of this type would be a videos showing a sports event such as a football game.

In the model, the MOS is predicted for a video from Equation (1) whose coefficients from a_1 to a_5 depend on the CT of the video as shown in Table 2.

$$\mathrm{MOS} = \frac{a_1 + a_2\mathrm{FR} + a_3 \ln(\mathrm{SBR})}{1 + a_4\mathrm{PER} + a_5(\mathrm{PER})^2} \tag{1}$$

Table 2: Value of Coefficients for Content Type

Coefficient	SM	GW	RM
a_1	2.707	2.273	-0.0228
a_2	-0.0065	-00022	-0.0065
a_3	0.2498	0.3322	0.6582
a_4	2.2073	2.4984	10.0437
a_5	7.1773	-3.7433	0.6865

3.2 QoE-Driven Vertical Handover Algorithm

Li et al. proposed the QoE-Driven VHO algorithm [6] which makes it possible to avoid unnecessary handover and maintain QoE of videos based on the QoE prediction model described in the previous subsection. In this algorithm, each mobile terminal periodically estimates the MOS of the currently connected network from Equation (1). When the predicted MOS is lower than the threshold value of 3.5, the terminal executes handover to another connectable network. Note that when a video is evaluated by the ACR (Absolute Category Rating) method recommended by ITU-T P.910, if the MOS of the video is 3.5 then about 90% of the evaluators feel that the video's score is 3 (Fair) or more in general [10]. After completing the handover, the previously connected network is recorded in the block list as an ineligible candidate as it cannot provide the user with an acceptable QoE. Next, the registered candidates are excluded from the destination candidates for the handover to maintain the QoE.

3.3 A Handover Algorithm Considering Temporary QoE Variation for Video Communication

Although the QoE-Driven VHO algorithm can detect the degradation of QoE and start handover based on the prediction model, it also has some problems. When a certain MOS prediction temporarily falls below the threshold for some reason, such as where many terminals are connected to the network within a short time, the terminal executes the handover to another network and registers the previously connected network in the block list. In order to solve this problem, the authors proposed an improved handover algorithm. In the algorithm, each terminal estimates the MOS periodically and calculates the average MOS from a fixed number of the estimated MOSes to take into account a temporary change in QoE [9].

When the average MOS is 3.5 or more, the terminal continues predicting the MOS and updating its average value. Otherwise, the terminal executes handover if it has received a beacon packet from another network. In addition, the terminal registers the previous connected network in the block list. However, after a certain period, the network is removed from the list. From this procedure, the terminal can connect again to the network, if the MOS of the network recovers to an acceptable level.

3.4 Problems of Handover Algorithms

Both algorithms described in this section execute handover based on the MOS of the currently connected network, while it cannot predict the MOS of any destination candidates. Therefore, if the MOS of the destination network is lower than that of the previously connected network, the QoE becomes worse as a result of the handover.

Since many mobile terminals are moving while communicating, each terminal can share its estimated MOS with other terminals so that it can select a destination candidate with a better MOS than that of the currently connected network.

4 Proposed Handover Algorithm

In order to solve the problem mentioned in the previous section, this section proposes a new handover algorithm that allows sharing of communication quality information between terminals to evaluate the MOS of connectable access points around the current position as handover candidate destinations before connecting [11]. This algorithm assumes that each terminal has a radio interface to facilitate direct communication between terminals in addition to another radio interface for connecting to an access point. Since typical terminals often have multiple wireless interfaces such as wireless LAN and Bluetooth, this assumption should not cause any problems.

In the proposed algorithm, each terminal basically works as in the previous algorithm described in Section 3.3. Moreover, each terminal creates a network status list comprising network ID, PER, and record time of the connected networks in order to share the list among connectable terminals around the current position. Such PER may depend on the situation of each terminal, because each terminal sends in different bit rate or different communication environment. Each terminal such as a smartphone adopts the same communication standards such as IEEE 802.11 and WiMAX, and has only one or two antennas within its compact body. Under similar communication environment, the bit rate should also be similar, since each terminal typically selects the highest bit rate. Thus, if it does not take for a long time from the record time, then the communication environment is expected to be same at the record time, and the received PER should be adoptable.

This sharing operation is periodically performed by ad hoc communication in which the terminals directly communicate with each other. Then each terminal exchanges its network information comprising network ID, PER, and record time of the connected networks, and adds the received network information into its own list if the network ID is not already listed or updates the information if the record time of the network ID is newer. Since the proposed algorithm is dedicated for video communications, the proposed sharing operation may be installed on video applications. In this case, these applications typically monitor statistical information such as PER, and then there is less cost to share a network status list if the applications agree with some sharing protocol standard such as Wi-Fi Direct and FTP (File Transfer Profile) for Bluetooth. When the video applications are restricted on a specific service, the service may also provide the sharing mechanism like Dynamic DNS for terminals with a single wireless interface.

When the average MOS of the currently connected access point is lower than 3.5 and the beacon from the new access point is received, the terminal searches for the network ID in the beacon from the list. If it is found, the terminal predicts the MOS from PER in the list. Then, if the predicted MOS is lower than that of the currently connected access point, the terminal remains connected to the current access point. Otherwise, the terminal executes handover to the new access point that sent the beacon as in the previous algorithm.

5 Performance Evaluations

This section describes three evaluations of the proposed algorithm, which use Network Simulator 3 (NS3) [12], and the first scenario compares them with the two handover algorithms described in Section 3 and the conventional received signal strength reference algorithm that is the closed handover algorithm used by most mobile terminals and maintains a connection as long as the currently connected access point is connectable. The second and third scenarios also compare with the QoS-driven Bathich's method [3]. In the previous and proposed algorithms, the expiration time of a record in the block list is 100 seconds. In the proposed algorithm and previous algorithm, each mobile node (MN) measures PER of the currently connected AP every 100ms to estimate MOS. The average MOS calculation period is 3 minutes.

5.1 Predetermined Mobility Scenario

In the first scenario, the MN moves along the predetermined route and executes handover according to each algorithm.

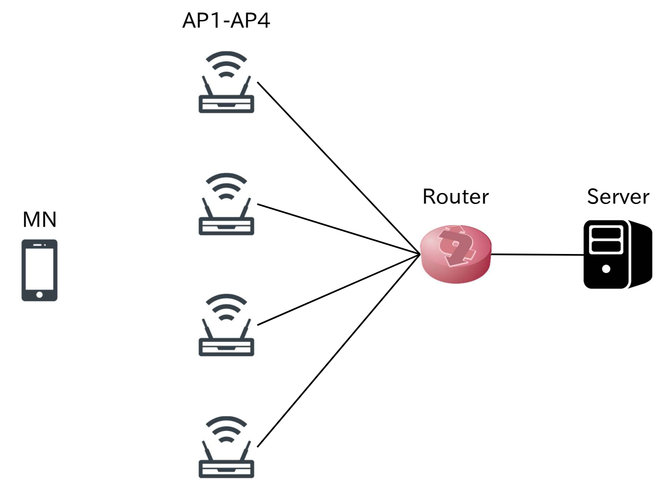

Figure 2: Network Topology (Predetermined Mobility Scenario)

Figure 2 shows the network topology in the first scenario where the server transmits packets to the MN, and the router forwards packets between the server and one of the access points (APs) denoted as AP1–AP4. The MN connects to one of the four APs (AP1–AP4) selected by the adopted handover algorithm. Figure 3 shows the simulation scenario. In the figure, the unit of coordinates is meters (m). The server sends UDP packets containing movie data over UDP toward the MN, the router forwards these packets to the AP to which the MN is connected, and the AP sends them to the MN. When the simulation starts, the MN stays at (0, 0) and is connected to AP1. During the simulation, the MN always moves along the dotted line shown in Figure 3. Therefore, the MN goes straight from the starting point (0, 0), turns right at AP2, AP3, AP4 and returns to the point (0, 0) at AP1 again. Since the MN's speed is 1 m/s, the simulation time is 150 seconds.

For the proposed algorithm, the terminals FN1 and FN2 are fixed at (37.5, 27.5) and (10.0, 37.5) and connected to AP3 and AP4, respectively. These terminals have a list containing information such as the PER of the AP to which each is connected. When the MN enters the communication range of each AP, which is indicated by a large circle in Figure 3, the AP's PER is observed immediately. When the MN enters the ad hoc communication range of the fixed node, which is indicated by a small circle with a radius of 10 m (Figure 3), it immediately starts ad hoc communication to share the list of the AP's information with other MNs.

Table 3 shows the simulation parameters. AP1–AP4 support the IEEE802.11g standard. Their communication radius is 25 m and bandwidth is 11 Mbps. Although the maximum bandwidth of the IEEE 802.11g standard is 54Mbps, this paper selected 11 Mbps as the effective bandwidth on outdoor fields. Since their PER is 10 %, 0.0 %, 3.0 %, and 5.5 %, their predicted MOS is 2.0, 4.0, 3.0, and 2.5, respectively. The content type of the transmitted video is RM with a sender bit rate of 4 Mbps and a frame rate of 60 fps. The server sends these packets at a constant bit rate over UDP to the MN.

Figure 4, Figure 5, and Figure 6 show the changes in the predicted MOS. The horizontal axis of the figures shows the elapsed time from the beginning of the simulation and the vertical axis shows the predicted MOS values in the simulation scenarios for each algorithm. Since these values overlap to a significant degree to facilitate comparison, Figure 4 shows the predicted MOS values of only the received signal reference and QoE-Driven VHO algorithms. For the same reasons, Figure 5

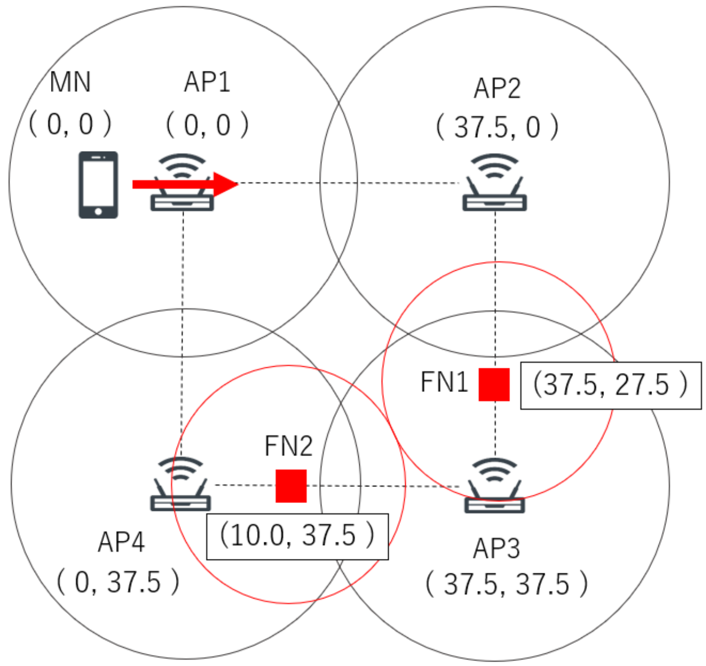

Figure 3: Simulation Scenario (Predetermined Mobility Scenario)

Table 3: Simulation Parameters (Predetermined Mobility Scenario)

parameters	**Wireless Technology (802.11g)**			
	AP1	**AP2**	**AP3**	**AP4**
Coverage Area	25 m			
Bandwidth	11 Mbps			
Packet Error Rate	10.0 %	0.0 %	3.0 %	5.5 %
MOS	2.0	4.0	3.0	2.5
parameters	**Video**			
Types of Video	RM			
Frame Rate	60 fps			
Sender Bit Rate	4 Mbps (CBR UDP)			
Packet Size	128 byte			
parameters	**MN**			
Speed	1 m/s			
Timetable at AP's coverage area	0–25 s, 125–150 s	12.5–62.6 s	50–100 s	87.5–127.5 s
parameters	**FN**			
Coverage Area	10 m			

compares the QoE-Driven VHO algorithm with the previous algorithm and Figure 6 compares the previous algorithm with the proposed algorithm.

From Figure 4, in the received signal reference algorithm, since the MN continued connecting to the same AP until it moved out from the communication area, the MN could not execute handover from AP1 to AP2 between 12.5 and 25.0 seconds. In the QoE-Driven VHO algorithm, since the MN detected that the predicted MOS of AP1 was lower than the threshold value of 3.5, it executed handover to AP2 at 12.5 seconds so that it could provide a higher MOS more quickly than the received signal reference algorithm. However, in the communication area of AP3, whose predicted MOS is lower than the threshold, the MN executed handover to AP4 at 87.5 seconds even though it could continue to connect to AP3 even after 100.0 seconds have elapsed, and then the predicted MOS dropped to 2.5. Furthermore, since AP1 was still registered in the block list at the time the first handover was executed, there was no connectable AP after the MN moved out from the communication range of AP4, and then the MOS was dropped to 0.0. On the other hand, as shown in Figure 5, in the previous method, since AP1 was removed from the block list at 100.0 seconds, the MN executed handover from AP4 to AP1. But the previous algorithm also dropped the predicted MOS to 2.5 between 87.5 and 100.0 seconds just as the QoE-Driven VHO algorithm did.

In contrast, as shown Figure 6, the proposed algorithm postponed executing handover until 100.0 seconds when the MN moved out from the communication area of AP3. This is because, when the MN moved inside the communication area of AP3, the MN performed ad hoc communication with FN2 to obtain the information list of AP4. As a result, the MN found that the predicted MOS of AP4 was lower than that of the currently connected AP3, and then it could delay the execution of handover from AP3 to AP4.

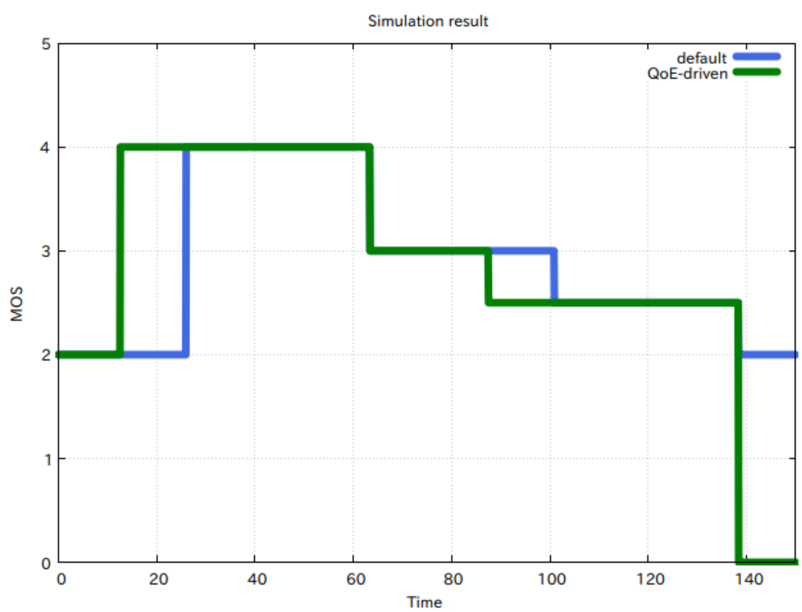

Figure 4: Predicted MOS of Received Signal Reference Handover and QoE-Driven Vertical Handover Algorithms (Predetermined Mobility Scenario)

5.2 Random Waypoint Mobility Scenario

In the second scenario, the MN randomly moves within the topology range using the random waypoint mobility model RandomWalk2dMobilityModel of NS3. To compared with a QoS-driven method, this scenario added the Bathich's method [3] to the methods in the first scenario, since the method can obtain SINR (Signal to Interference and Noise Ratio) from the connectable APs

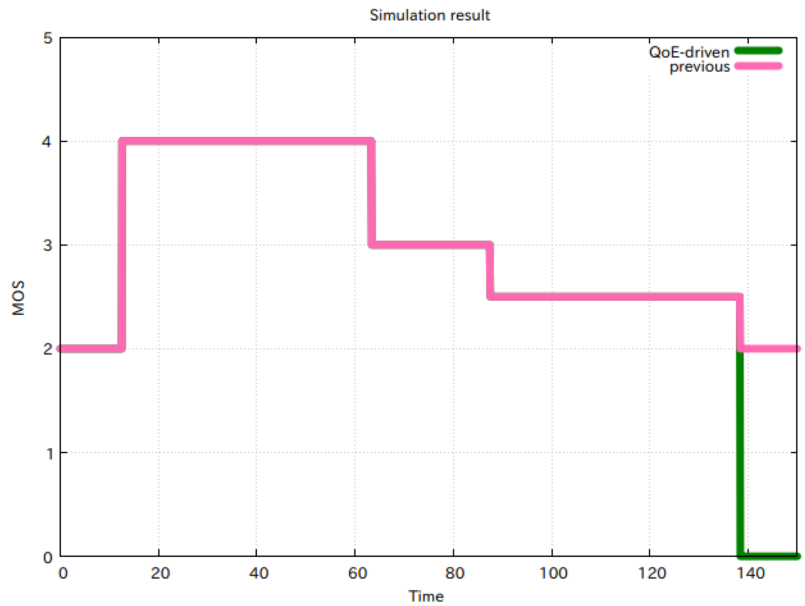

Figure 5: Predicted MOS of QoE-Driven Vertical Handover and Previous Handover Algorithms (Predetermined Mobility Scenario)

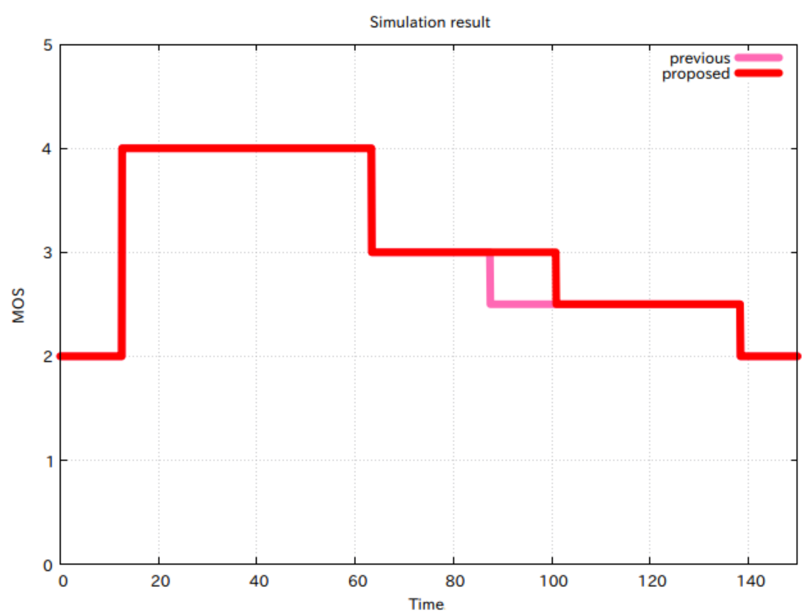

Figure 6: Predicted MOS of Previous and Proposed Handover Algorithms (Predetermined Mobility Scenario)

by IEEE 802.21, and SINR is related to PER (Packet Error Rate) that is used to predict MOS in the proposed method. Furthermore, in the proposed method, in addition to the MN, other mobile terminals are also implemented the proposed method and randomly move in the topology range. The number of the mobile terminals is changed for each simulation.

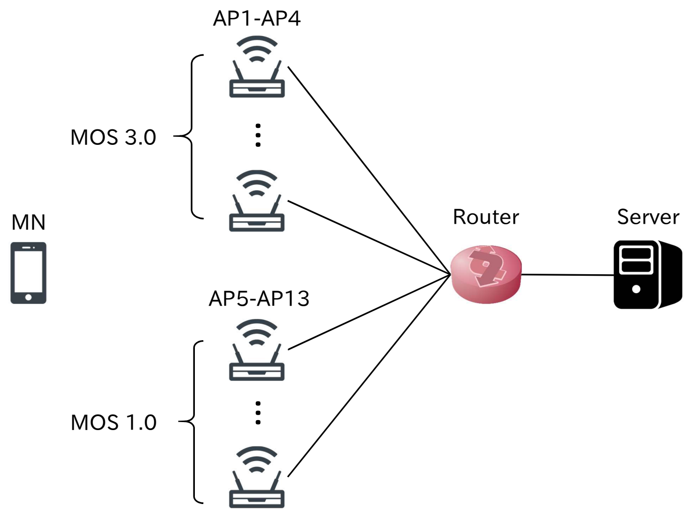

Figure 7: Network Topology (Random Waypoint Mobility Scenario)

Figure 7 shows the network topology in the second scenario and Figure 8 shows the position of all APs. The unit of coordinates is meters (m). This network consists of the server, the router, the APs (AP1–AP13) and the MN. The packet error rate of each wired link is 0%. The MOS of AP1–AP4 is 3.0 and the one of AP5–AP13 is 1.0. In the Figure 8, the squares and triangles represent AP1–AP4 and AP5–AP13, respectively. The dotted square shows the topology range. The dotted circles are the communication range of each AP. In the topology range, there is at least one AP that the MN can connect to.

When the simulation starts, the MN stays at (50, 50) and is connected to AP9. During the simulations, the MN always moves at 1.5 m/s according to the random waypoint mobility model of NS3, i.e., the MN first randomly determines the moving direction, randomly selects the duration time between 2.0 seconds and 10.0 seconds, and then moves to the determined direction. When it elapses the duration time or the MN reaches the boundary of the topology range, the MN determines the next direction and the duration time.

In the proposed algorithm, mobile terminals RNs with the proposed method also move randomly according to the same random waypoint mobility model. When the simulation starts, the RNs are randomly placed within the circle whose center coordinate is (50, 50) and radius is 50 m, and connect to the nearest AP. If there are two or more such APs, then the one with the smallest number is selected. When the MN enters the RNs' ad hoc communication range, it immediately shares each network status list with the RNs. In the simulation of the proposed method, the number of the RNs is selected from 0, 2, or 4.

Table 4 shows the simulation parameters. All the APs support IEEE802.11g standard. Their communication radius is 25 m and bandwidth is 11 Mbps. Since the PER of AP1–AP4 is 3.0% and the one of AP5–AP13 is 17.5%, their predicted MOSes are 3.0 and 1.0, respectively. The content type of the transmitted video is RM with a sender bit rate of 4 Mbps and a frame rate of 60 fps. The MN starts moving from the starting point (50, 50) for 600 seconds and executes handover according

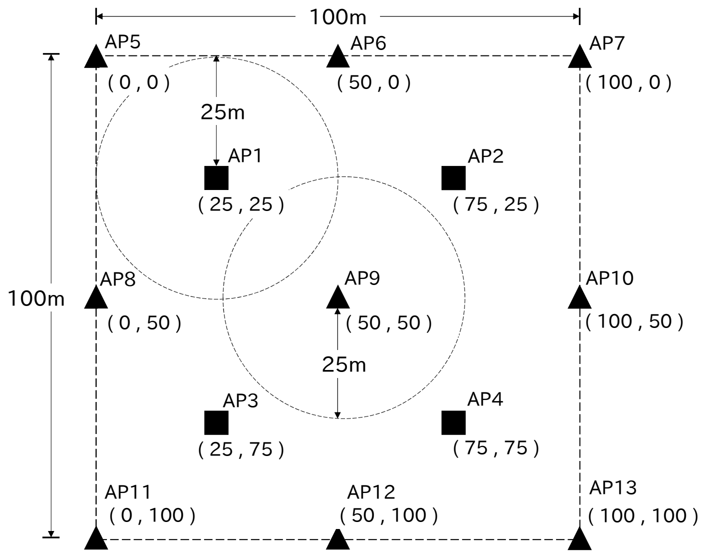

Figure 8: Simulation Scenario (Random Waypoint Mobility Scenario)

to each algorithm.

Table 4: Simulation Parameters (Random Waypoint Mobility Scenario)

parameters	**Wireless Technology (802.11g)**	
	AP1-AP4	**AP5-AP13**
Coverage Area	25 m	
Bandwidth	11 Mbps	
Packet Error Rate	3.0 %	17.5 %
MOS	3.0	1.0
parameters	**Video**	
Types of Video	RM	
Frame Rate	60 fps	
Sender Bit Rate	4 Mbps (CBR UDP)	
Packet Size	128 byte	
parameters	**MN**	
Speed	1 m/s	
parameters	**RN**	
Coverage Area	10 m	

Figure 9 shows the average MOS and its 95% confidential interval of 10 simulations for each handover algorithms. In the received signal reference based algorithm (RSS-based), since the MN continued connecting to the same AP until it moved out from the communication area, it connected to the AP whose predicted MOS is 1.0 for a long time and the average MOS became 1.84. In the Bathich's method, since the MN sometimes succeeded to select a better AP from its QoS-driven handover decision, the average MOS of 1.93 is a little larger than that of the RSS-based, but its confidential interval is covered by that of the RSS-based. In the QoE-driven VHO algorithm (QoE-driven), when the MN received a beacon from other APs, it executed handover immediately and switched the connection to an AP with the lower MOS, because all AP's MOSes were lower than the threshold. Furthermore, since the MN recorded every connected AP into the block list, it could not connect to any AP for a long time. As the result, the average MOS is 0.39, which is the worst result of all the algorithms. On the other hand, in the previous method (previous), which improved the QoE-driven VHO algorithm, the MN removed networks from the block list if a predefined time passed after they were registered. Since the MN was able to use again the APs to which it had already connected, the average MOS is 0.66 that is slightly higher than that of the QoE-driven VHO algorithm. However, since the MN could not use such APs until they were removed from the block list, there were periods when the MOS became 0.0, the average MOS is second-worst result of all the algorithms.

In contrast, in the proposed method with no RNs (proposed-RN0), the MN recorded the networks to which had been already connected and their parameters into the network status list. Thus, when such networks in the status list became the candidates for handover, the MN compared the predicted MOS of the candidates with that of the current network, and then it could execute handover to the network with higher MOS. It connected to APs whose MOS was 3.0 for a long time. As the result, the average MOS is 2.30, which is the highest among the four methods. When the number of the RNs are two or four (proposed-RN2/RN4), the average MOSes are 2.33 and 2.32, which are almost same as that of the proposed-RN0. This is because that as the simulation progressed, the unknown APs for the MN decreased and the MN had gathered all the information of all APs except for a short period after the scenarios started. Since MOS is always changing in a real environment, the MN needs to obtain the latest information of each AP from RNs. In addition, when the topology range of the MN is wider and the shape is complex like an urban area, sharing the network status list with RNs should be effective to maintain higher QoE.

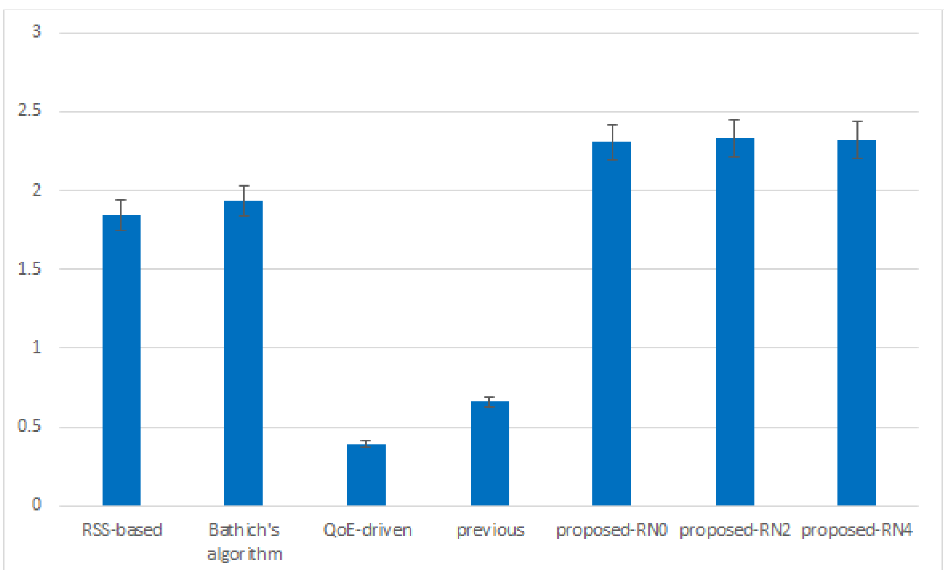

Figure 9: Average MOS of each method (Random Waypoint Mobility Scenario)

In the second scenario, all MOSes are lower than the threshold value of 3.5. This situation is typically considered as an urban area where there are many APs in some narrow region and so many people access to these APs. In the third scenario, in contrast, some MOSes are equal to or greater than 3.5 as shown in Table 5. This condition is considered as a suburban area where there are some APs and not so many people access to these APs. The other parameters such as the network topology, the start point of the MN, and the simulation time are the same as in the second scenario and Table 4. Note that the third scenario increased the MN's speed from 1 m/s to 1.5 m/s to occur more handover. In the scenario, since there are five APs whose MOS is equal to or greater than the threshold, the MN may maintain connecting to the same AP for long time, if the MN's speed is too slow.

Table 5: Simulation Parameters (Random Waypoint Mobility Scenario II)

parameters	**Wireless Technology (802.11g)**			
	AP1-AP4	**AP5-AP8**	**AP9**	**AP10-AP13**
Packet Error Rate	1.0 %	3.0 %	0.0 %	3.0 %
MOS	3.5	3.0	4.0	3.0
parameters	**MN**			
Speed	1.5 m/s			

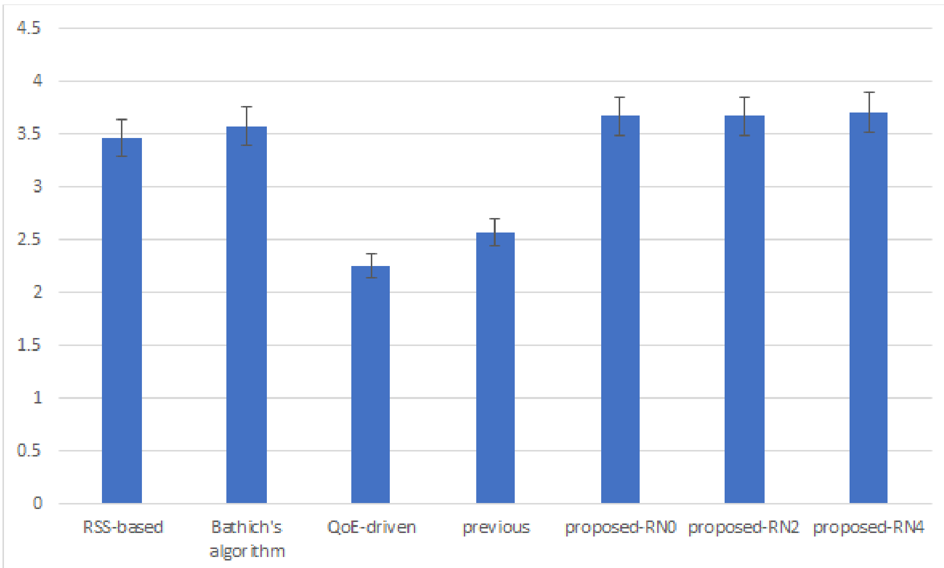

Figure 10: Average MOS of each method (Random Waypoint Mobility Scenario II)

Figure 10 shows the average MOS and its 95 % confidential interval for each handover algorithms. In the received signal reference based algorithm, since the MN continued connecting to the same AP whose predicted MOS is 3 or more, the average MOS became 3.46. In the Bathich's method, the MN selected a better AP from its QoS-driven handover decision like in the second scenario and the average MOS became 3.57. Since the Bathich's method often attempted to connect to the best AP, the MN switched the connection frequently. In the QoE-driven VHO algorithm and the previous method, if the currently connected AP's MOS is equal to or higher than the threshold value, then the MN continued connecting to the same AP and ignored the beacons from other APs to prevent from switching the connection frequently. Otherwise, however, since the MN delayed to find better APs, the average MOSes of these algorithms stayed at 2.25 and 2.56, respectively. In the proposed method, since the MN properly used the network status list, it could compare the currently connected AP with the predicted ones to connect to a better AP. When the number of the RNs are zero, two, and four, the average MOSes became 3.67, 3.67 and 3.7, respectively. Since the topology range and the number of APs are the same as in the second scenario, sharing list function could not work well and the average MOSes had slight difference each other.

The difference in the average MOSes between the RSS-based, Bathich's method, and the proposed one shown in Figures 9 and 10 is not so large. However, the difference in Figure 9 is larger than that in Figure 10. As mentioned that the second scenario is considered for an urban area, the former figure is more important than the latter figure, since the result can be applied for many users.

However, Figure 10 evaluated only the average MOS. To evaluate how long the MN connected to APs classified by MOS values, Table 6 shows the total and average connecting durations to the APs and the average number of handover in the third scenario, where the proposed-RN2 and the proposed-RN4 are omitted, since their average MOSes were almost same as the proposed-RN0. All results of connecting duration to each AP are shown in Table 7 in Appendix A. In the RSS-based algorithm, the average number of handover was 2.8 less than the proposed one's. However, the total duration at APs whose MOS is the lowest value of 3.0 was 113.5 s longer, and then the duration at AP9 whose MOS is the highest value of 4.0 was reduced by 50.7 s. In Bathich's method, the average number of handover was 0.9 greater than the proposed one. The total duration at APs with the lowest MOS was 68.7 s longer, but the duration at AP9 was reduced by 104.0 s. From these results, the RSS-based algorithm and Bathich's method connected APs with lowest MOS for longer time. Since these methods had no disconnection time, their average MOSes were only a little smaller than the proposed one's. In the QoE-driven VHO algorithm and the previous method, most APs are registered in the block list. Since the MN could not connect to any AP for longer time, the disconnection time also became 334.7 s and 96.6 s, respectively, and then their average MOSes were also reduced. In contrast, in the proposed method, even if the MN cannot find any RNs, the MN recorded APs with lower MOS and avoided connecting to them again. As a result, the MN maintained to connect with APs with higher MOS.

From the above comparisons, the simulation results show that the proposed algorithm can select appropriate APs to maintain higher predicted MOS than other handover algorithms including a QoS-driven one, even if each terminal under the QoS-driven Bathich's method can obtain SINR of connectable APs by IEEE 802.21. This is because PER on each terminal, which is one of basic criteria for QoE-driven handover decision algorithms, can be obtained only after the terminal exchanged several packets with the currently connected AP. Thus, the result shows that PER is sometimes different from QoS information such as RSS and SINR.

Table 6: The Number of Handover and Connecting Duration to APs Classified by MOS Values (Random Waypoint Mobility Scenario II)

	RSS-based	**Bathich's**	**QoE-driven**	**previous**	**proposed-RN0**
disconnection	0.0 s	0.0 s	334.7 s	96.6 s	0.0 s
MOS 4.0 (AP9 only)	203.3 s	150.0 s	128.6 s	226.6 s	254.0 s
Total at MOS 3.5	234.5 s	333.6 s	109.3 s	210.4 s	298.2 s
Average of MOS 3.5	58.6 s	83.4 s	27.3 s	52.6 s	74.6 s
Total at MOS 3.0	164.4 s	119.6 s	30.6 s	49.5 s	50.9 s
Average of MOS 3.0	20.6 s	15.0 s	3.8 s	6.2 s	6.4 s
Number of Handover	9.5	13.2	15.8	14.4	12.3

6 Conclusion

This paper proposed a new handover algorithm for video communications by sharing information on network communication quality with mobile terminals by ad hoc communication. In order to estimate the performance of the proposed algorithm, a simulation was carried out. The results of the simulation showed that the proposed method can execute handover appropriately and maintain higher QoE than other handover algorithms.

In future work, the proposed algorithm will be evaluated in more complicated and practical network environments such as those where many MNs move randomly meaning that the predicted MOS will change over time. In the simulation results, even when two or four RNs exist in the proposed method, their average MOSes do not so increase from that when no RNs exist. Thus, the qualitative evaluation must be required to show what kind of complicated and practical network environments requires the latest information of each AP from RNs. Since the proposed algorithm requires two network interfaces to introduce RNs, it also needs to suppress the power consumption. For example, the beacon interval for the ad hoc communication may become longer to suppress the frequency for sharing the network status list. However, longer beacon interval may also decrease MOS, since the network status list is out of date when the handover decision occurs in each terminal. In Table 4, the coverage area of APs is 25 m and the MN's speed is always 1 m/s. Then, each MN may stay 25 s in the same coverage area in the average. In this situation, it may be considered as the interval should be at most 12.5 s, a half of the average duration time. In this manner, the interval should be determined as considering the trade-off relationship between the power consumption and the sensitiveness to the fluctuation in network conditions.

The proposed algorithm should also be compared with various handover algorithms based on QoS and investigated the effects of its overhead.

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A All Results of the Number of Handover and Connecting Duration to Each AP (Random Waypoint Mobility Scenario II)

Table 7: The Number of Handover and Connecting Duration to Each AP (Random Waypoint Mobility Scenario II)

	RSS-based	**Bathich's**	**QoE-driven**	**previous**	**proposed-RN0**
disconnection	0.0 s	0.0 s	334.7 s	96.6 s	0.0 s
AP1 (MOS 3.5)	43.0 s	25.5 s	18.6 s	9.8 s	121.0 s
AP2 (MOS 3.5)	72.9 s	76.7 s	61.1 s	61.3 s	36.4 s
AP3 (MOS 3.5)	62.2 s	144.2 s	13.3 s	41.7 s	62.7 s
AP4 (MOS 3.5)	56.4 s	87.2 s	16.3 s	97.6 s	78.1 s
AP5 (MOS 3.0)	0.0 s	22.6 s	1.9 s	0.0 s	1.6 s
AP6 (MOS 3.0)	25.7 s	9.2 s	1.1 s	2.0 s	9.1 s
AP7 (MOS 3.0)	0.0 s	0.0 s	2.2 s	0.0 s	0.0 s
AP8 (MOS 3.0)	35.2 s	25.0 s	11.0 s	21.1 s	18.1 s
AP9 (MOS 4.0)	203.3 s	150.0 s	128.6 s	226.6 s	254.0 s
AP10 (MOS 3.0)	55.7 s	44.6 s	1.9 s	7.1 s	1.8 s
AP11 (MOS 3.0)	4.8 s	4.8 s	0.3 s	0.1 s	20.1 s
AP12 (MOS 3.0)	42.9 s	13.4 s	9.0 s	8.9 s	0.2 s
AP13 (MOS 3.0)	0.1 s	0.0 s	3.2 s	10.3 s	0.0 s
MOS 4.0 (AP9 only)	203.3 s	150.0 s	128.6 s	226.6 s	254.0 s
Total at MOS 3.5	234.5 s	333.6 s	109.3 s	210.4 s	298.2 s
Average of MOS 3.5	58.6 s	83.4 s	27.3 s	52.6 s	74.6 s
Total at MOS 3.0	164.4 s	119.6 s	30.6 s	49.5 s	50.9 s
Average of MOS 3.0	20.6 s	15.0 s	3.8 s	6.2 s	6.4 s
Number of Handover	9.5	13.2	15.8	14.4	12.3