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AP Selection Algorithm for Real-Time Communications through Mixed WLAN Environments

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SUMMARY Recent rapid development of high-speed wireless access technologies has created mixed WLAN (Wireless LAN) environments where QoS capable APs coexist with legacy APs. To provide QoS guarantee in this mixed WLAN environment, this paper proposes a new AP selection algorithm. The proposed algorithm assigns an STA (Station) to an AP in the overall WLAN service area. Simulation results show improvement in the VoIP performance in terms of an eMOS (estimated Mean Opinion Score) value and the FTP throughput compared to conventional algorithms.

key words: AP selection, IEEE802.11e, load balancing, eMOS, QoS

1. Introduction

Nowadays, WLANs (Wireless LANs) are prevalent in airports, stations, and many public or private spaces. These networks have many APs (Access Points) and they can provide wireless internet connection to many STAs (Stations). Since current WLAN standards such as IEEE802.11a, g and n can provide high-speed internet accesses, it can realize real-time multimedia services such as VoIP (Voice over Internet Protocol) service as well as text-based services such as WWW (World Wide Web) and e-mail services. The real-time services require QoS (Quality of Services) guarantee, such as low-delay and low PLR (Packet Loss Rate). In order to provide QoS supports in WLAN, IEEE802.11e was standardized in 2005. In large-scale WLANs, however, a mixed environment where QAPs (QoS supported APs) coexist with legacy APs. In a mixed WLAN environment, considering AP's QoS support is required to provide QoS for real-time services. In addition, these large-scale WLANs require appropriate load balancing because a non-uniform distribution of STAs causes access concentration to an AP.

To provide QoS for the real-time services and load balancing, many AP selection schemes and algorithms have been proposed [1]–[6]. RSSI (Receive Signal Strength Indicator) based AP selection is a well known algorithm. This algorithm select AP which has highest RSSI. But this algorithm causes an access concentration. If STAs are placed with non-uniform distribution, access concentration is likely to be happen. To solve this problem, there are some solution against non-uniform distribution [1]–[3]. Network trig-

gered APs hand-over [1] is one of the challenges, which provides the load balancing among APs and realizes effective frequency utilization. Signaling server in [1] monitors the traffic load of each AP and then it orders to STA to switch associated AP. There are similar challenges with distributed approach [2], [3]. In these challenges, STA uses the “extended beacon frames” of IEEE802.11 to select APs. The beacon frames contain the number of STAs associated with AP. Since these challenges don't consider a kind of transmission priority of applications, they can't provide QoS for real-time application traffic, especially.

Other AP selection considering load conditions in APs and transmission priorities of applications, HRFA (High Rate First Association) [4] has been proposed. HRFA assigns an STA to an AP based on present load conditions of both RT (Real-Time) and NRT (Non Real-Time) traffic which are processing in QAPs. But HRFA get the information from IEEE802.11e beacon frames only, thus HRFA is not available in the mixed WLAN environment.

For the mixed WLAN environment, QoS guarantee AP selection methods for VoIP traffic, video streaming and CBR data traffic are proposed [5], [6]. In these methods, a QoS information server manages that every AP supports QoS or not and load conditions of RT and NRT traffic processing in all APs. Previously proposed algorithms [4]–[6] considers only UDP data traffic. In generally, however, data traffic is on the TCP, such as HTTP or FTP. Since TCP traffic goes to fill the load capacity based on the best-effort principle, beacon frame informs there is no more channel capacity whenever a TCP traffic exists. So these algorithms don't work correctly under the mixed traffic situation with TCP and UDP traffic.

This paper proposes a new AP selection algorithm, which can select appropriate AP in the mixed WLAN environment and also under the mixed traffic situation. In order to assign an appropriate AP, the proposed algorithm uses the number of STAs associated with each AP and the load condition of AP. The proposed algorithm make efforts to guarantee QoS for a real-time service even when TCP traffic coexists with UDP traffic. In this paper, the performance is evaluated in terms of an eMOS (estimated Mean Opinion Score) [10] value of VoIP traffic. The eMOS value is the index of the QoE (Quality of Experience) which is a subjective value of voice communications. The eMOS value is strongly related with PLR and delay time. The eMOS value and FTP throughput of data traffic are evaluated by computer simulation with QualNet [7]. The rest of paper is

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organized as follows. Section 2 describes the proposed algorithm and Sect. 3 describes the performance evaluation of the proposed algorithm. Finally, Sect. 4 describes the conclusion.

2. AP Selection Algorithm

2.1 Problems of AP Selection

2.1.1 Load Balancing Problems

There are 4 problems to select an AP in WLANs.

Figure 1(a) shows the distance problem. The AP1 is located near the STA who has two candidates to associate. The assignment based on RSSI tries to get highest throughput between two candidates. Thus, the spatial non-uniformity causes a convergence of traffic to an AP1.

Figure 1(b) shows the access concentration problem. 4 STAs are associated with AP1, while 2 STAs are associated with AP2. The load condition in AP1 is more congested than in AP2. The algorithms in [2], [3] solve this access concentration by balancing the number of connected STAs among APs.

Figure 1(c) shows the load balancing problem. It is impossible to balance the load among APs using the number of connected STAs to AP because the required data rate of traffic is different. More the number of STAs are associated with AP1 than AP2 in the figure. But the load condition in AP1 is lighter than in AP2, because the required data rate

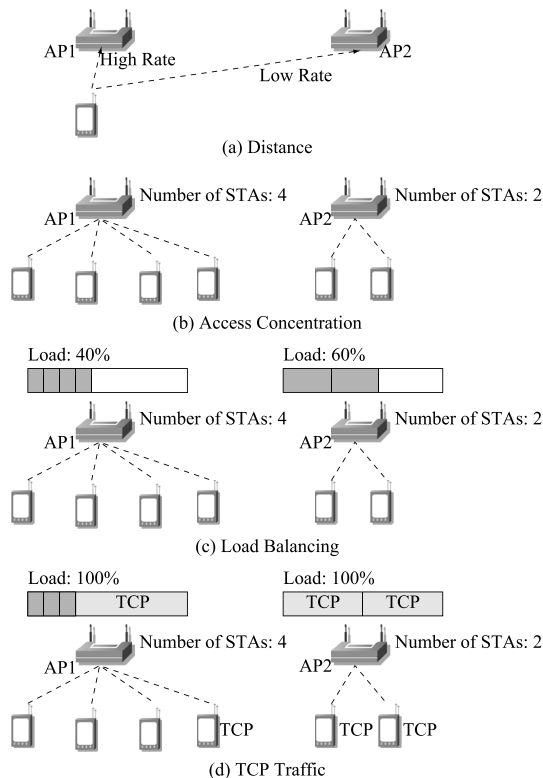


Fig. 1 Load balancing problems.

of traffic in STAs associated with AP1 is smaller than that with AP2. The algorithms in [4]–[6] solve load balancing problem.

Figure 1(d) shows the presence of TCP traffic. If there is TCP application. The TCP traffic goes to fill the load capacity due to their best-effort principle. Then the load condition in AP1 and AP2 are busy whenever a TCP traffic exists. Under the presence of TCP traffic, it is impossible to select an AP using the algorithm in [4]–[6], because these algorithm [4]–[6] can't handle the TCP traffic.

2.1.2 Problems in Mixed WLAN Environment

There are 2 differences between AP and QAP.

Figure 2(a) shows the difference of the priority control. A QAP has multiple queue [9] to perform a priority control. A VoIP traffic is treated as the highest priority, while other best-effort traffics are treated as the best-effort priority. But a legacy AP has no priority control. All traffics are treated as best-effort priority.

Figure 2(b) shows the difference of the notification items in beacon frames between AP and QAP. An STA can get a present load condition of both RT and NRT traffic load in a QAP, while STA can get only the total amount of the traffic load in a legacy AP.

The HRFA [4] correctly works under the condition in a WLAN which consists of QAPs only. Thus, new selection algorithm is needed which can treat criteria from not only QAPs but also legacy APs.

2.2 Selection Criteria

The proposed algorithm considers the criteria, as follows,

- The number of connected STAs with AP,
- The channel busy rate,
- The available admission capacity,
- The distance between STA and AP.

The number of STAs is announced from AP and QAP. AP can announce the number of associated STAs with extended beacon frame [2], [3] or SIP protocol [5],

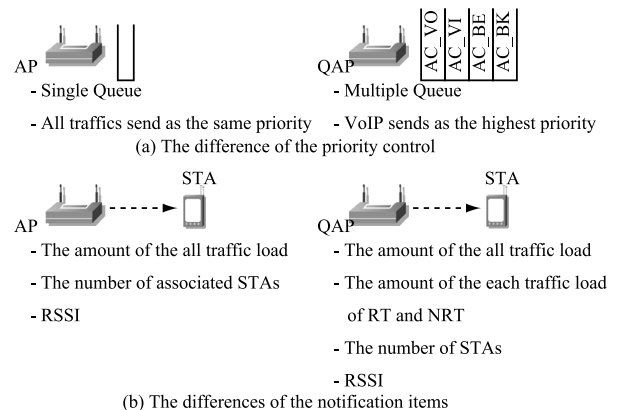


Fig. 2 Problems of AP and QAP mixed environment.

[6]. QAP can announce the information with Station Count field of IEEE802.11e beacon frame which is regulated in IEEE802.11e standard [9]. Then STA can obtain the information about the number of STAs associated with an AP or a QAP.

The channel busy rate is defined as CUR (Channel Utilization Rate) in this paper. The CUR of legacy AP is measured with carrier sense (CS) mechanism at wireless access devices on STA, which indicates present load condition in AP. While the CUR of QAP is announced with the IEEE802.11e beacon frame. The Channel Utilization (CU) field indicates the CUR of QAP. Thus, STA can obtain the present load condition of each legacy AP and each QAP.

The STA obtains the available admission capacity (AAC) from QAP only. The AAC Field in IEEE802.11e beacon indicates remaining time for RT traffic admission per second, in units of $32 \mu\text{s/s}$. The surplus amount of the TCP traffic is calculated from AAC. The less AAC value is the more capacity of the TCP traffic. But the STA can't obtain the AAC from the legacy AP because the legacy AP can't distinguish the TCP traffic and other traffic.

The STA estimates the distance between STA and AP from the RSSI. The less RSSI is the farther distance. And the farther distance is the less transmission mode of WLAN.

2.3 Proposed Algorithm

Figure 3 shows the flowchart of the proposed algorithm.

The Proposed algorithm firstly refers to the number of STAs associated to each AP and reduces the number of the candidate of APs. Under the TCP traffic coexists with real-time UDP traffic, the AP with a few STA is more likely to be sparse. Then, this algorithm calculates available transmission capacity (ATC) of each AP. ATC is calculated from CUR and AAC. The range of ATC is 0 to 100. $ATC = 100$ means that the AP has maximum transmission capacity,

while $ATC = 0$ means busy state. ATC_i of i -th AP, AP_i , is calculated as,

For legacy AP :

$$ATC_i = \left(1 - \frac{CUR_i}{100}\right) \cdot w_i, \quad (1)$$

For QAP :

$$ATC_i = \frac{AAC_i \cdot 32}{10^6} \cdot w_i, \quad (2)$$

where w_i is the weight of transmission rate. w_i is defined as follows,

$$w_i = \frac{1}{t_i}, \quad (3)$$

where t_i is the required transmission time of a packet which is calculated from the frame size, the header size, average DIFS and so on. If AP_i has higher rate, STA calculates less t_i and more w_i . And if AP_i is QAP, the average DIFS is smaller than the legacy AP. Then STA gets more w_i .

If can't determine the AP from the number of STAs and the ATC, this algorithm selects an AP having maximum transmission power based on RSSI.

3. Performance Evaluation

3.1 Simulation Model

Figure 4 shows the area model in the simulation. The area is 70 meters square. IEEE802.11g is used as wireless access system and IEEE802.11e on QAP as QoS management protocol. The parameters of IEEE802.11g and IEEE802.11e are shown in Tables 1 and 2, respectively. These parameters except radio frequencies are default values defined in IEEE802.11g [8] and IEEE802.11e standards [9]. The radio frequencies don't interfere among channels.

We assumed that there are 3 APs including APs and QAPs in this area. The data rate of all APs are fixed at 54 Mbps. These APs are placed randomly according to a uniform distribution. In this paper, 3 different situations are assumed for the number of APs, whose configuration is shown in Table 3; 2 legacy AP and 1 QAP (QAP 1/3),

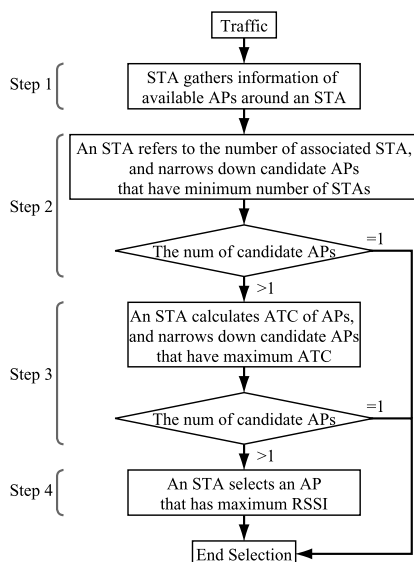


Fig. 3 Flowchart of the proposed algorithm.

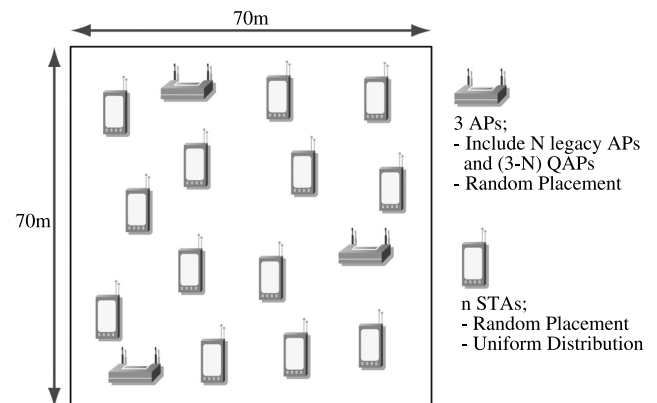


Fig. 4 Simulation area model.

Table 1 IEEE802.11g simulation parameters.

Frequency	2.412 GHz, 2.437 GHz 2.462 GHz
PLCP Preamble	16 μ sec
PLCP Header (Signal)	1 Symbol
PLCP Header (Service)	16 bit
MAC Header	24 Octet
LLC Header	8 Octet
FCS	4 Octet
PLCP Tail	6 bit
Symbol Length	4 μ sec
MAC ACK Length	10 Octet
Slot Time	9 μ sec
SIFS	16 μ sec
DIFS	34 μ sec
CWmin	15
CWmax	1023

Table 2 IEEE802.11e simulation parameters.

Access Category	CWmin	CWmax	AIFS
Background (BG)	31	1023	7
Best Effort (BE)	31	1023	3
Video (VI)	15	31	2
Voice (VO)	7	15	2

Table 3 The number of AP configurations of each situation.

Situation	legacy AP	QAP
QAP 1/3	2	1
QAP 2/3	1	2
QAP 3/3	0	3

Table 4 Parameters of each traffic.

Application	VoIP	FTP
Transport layer Protocol	UDP	TCP
Payload Size	160 byte	1460 byte
Interval	20 ms	
Required Data Rate	64 kbps	Best-Effort
Direction	UP DOWN	DOWN

1 legacy AP and 2 QAPs (QAP 2/3), no legacy AP and 3 QAPs (QAP 3/3).

In addition, 2 kinds of flows in this simulation, voice flow and data flow. Table 4 shows parameters of these flows. A Voice flow is assumed as a VoIP application whose transport layer protocol is UDP, payload size sets 160 bytes, interval sets 20 ms and AC (Access Category) of IEEE802.11e sets as Voice (AC_VO) in MAC layer. This is typical values of VoIP with G.711 codec [11]. A Data flow is a FTP application whose transport layer protocol is TCP, payload size is 1460 bytes, which is maximum payload size through Ethernet [12], and AC is set as Background (AC_BK) in MAC layer.

Table 5 shows 3 cases of generated traffics. Case 1 is the ratio 1:1 between voice and data. Case 2 is 3:1, and Case 3 is 1:3, respectively.

The performance of the proposed algorithm (Proposed) have been compared with the conventional algorithms, based on RSSI (RSSI), the number of associated STA (Num-

Table 5 Traffic rate configurations of each case.

	VoIP	FTP
Case 1	1	1
Case 2	3	1
Case 3	1	3

STA) [2], [3] and the algorithm like HRFA [4] (APP). APP assigns an AP according to AAC for RT traffic and CU field for NRT traffic, respectively. APP is assumed to get AAC and CU from QAP only. If all QAP's CU fields indicate maximum utilization, APP select AP based on RSSI for NRT traffic. And if there are no QAP, APP assigns AP based on RSSI.

The number of STAs is increased from 50 to 120. As a theoretical calculation of IEEE802.11g, the capacity for VoIP traffic is 17.18 Mbps approximately if there are 3 APs with 54Mbps data rate. If there are 67 VoIP flows are generated, a half of the capacity is filled. On the other hand, as a basic simulation result of IEEE802.11e, when a half of the capacity is filled, 30% packet loss is occurred. The up-link collision is dominant in the packet loss. Since AC_VO has the smallest CWmin and CWmax, the more uplink STAs are generated, the more collision is occurred. Thus, the upper bound of the number of STAs is up to a half of the capacity, 60 VoIP flows. 60 VoIP flows is equivalent to 120 STAs in Case 1.

We evaluate 3000 times for each evaluate point.

3.2 Evaluation Item

We have evaluated 2 items; average eMOS of VoIP flow, and average throughput of FTP flow.

The eMOS value is the value of the index of user's QoE (Quality of Experience), which is defined in ITU-T G.107 recommendation [10]. And the eMOS value can treat the PLR and the delay at the same time. In the VoIP communications, the value of $eMOS > 4.0$ is defined as "Class A" which is the same quality of the wired communications and $eMOS > 3.6$ as "Class B" which is the same quality of the wireless communications [13]. The eMOS value is calculated from the R-value [10]. The R-value is the index of the QoS of the voice communications, which is calculated from the average PLR and the average delay of each flow. In order to convert the QoS into the index of the QoE, we calculate the eMOS value from R-value, as in the Ref. [10]. In addition, in order to view the eMOS improvement from other side, the packet loss rate and the delay time in situation of QAP3/3 in Case 2 are evaluated.

3.3 Estimated MOS Evaluation

3.3.1 Case 1

Figures 5–7 show average eMOS values for each mixed WLAN environment of Case 1. Figure 5 and Fig. 6 show situations of QAP 1/3 and QAP 2/3, respectively. In these situations, Proposed and NumSTA keep the eMOS value of

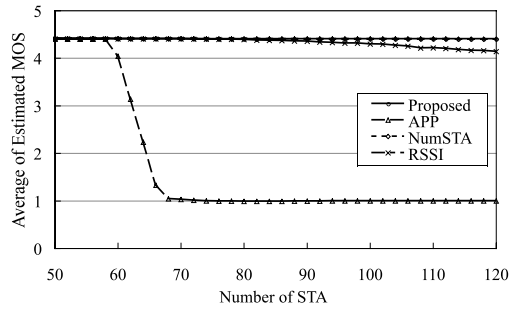


Fig. 5 Average VoIP eMOS in Case1, QAP 1/3.

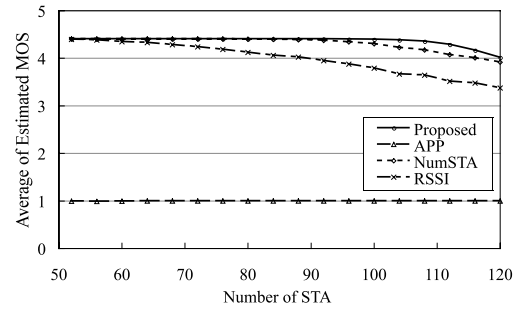


Fig. 8 Average VoIP eMOS in Case2, QAP 1/3.

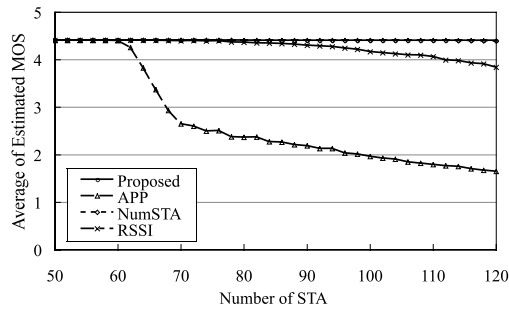


Fig. 6 Average VoIP eMOS in Case1, QAP 2/3.

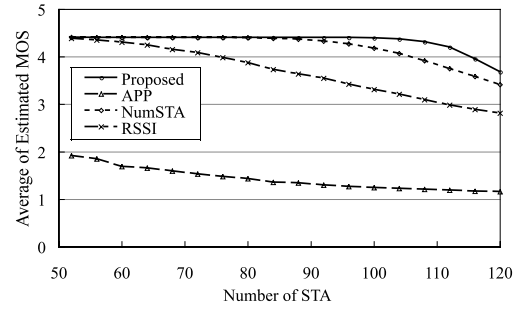


Fig. 9 Average VoIP eMOS in Case2, QAP 2/3.

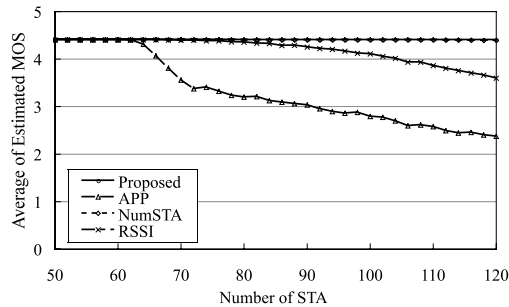


Fig. 7 Average VoIP eMOS in Case1, QAP 3/3.

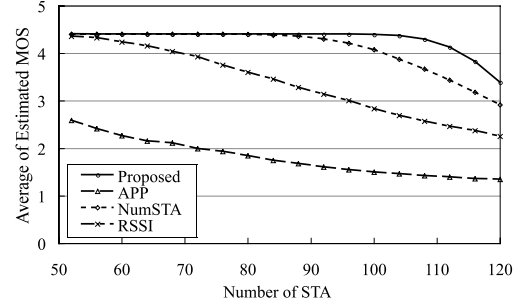


Fig. 10 Average VoIP eMOS in Case2, QAP 3/3.

4.5 for the all range, but APP and RSSI degrade the eMOS value. RSSI degrades the eMOS slightly toward 120 STAs, but RSSI keeps Class A quality when there are 120 STAs. APP degrades the eMOS significantly when the number of STAs are more than 60. While in the situation QAP 3/3 as shown in Fig. 7, Proposed and NumSTA keep the eMOS value of 4.5, but APP and RSSI degrade the eMOS value. RSSI keeps the Class A quality up to 102 STAs, and the Class B up to 120 STAs. While APP keeps the Class A quality up to 66 STAs, and the Class B up to 70 STAs.

This is because the proposal algorithm preferentially assigns a QAP than a legacy AP for VoIP traffic. Since APP doesn't consider FTP traffic effect for VoIP traffic, it makes VoIP traffic miss assignment to congested AP. Proposed has no degradation of eMOS.

3.3.2 Case 2

Figures 8–10 show eMOS value for each mixed WLAN en-

vironment of Case 2. Figure 8 shows situation of QAP 1/3, Proposed keeps the Class A quality. NumSTA keeps the Class A quality up to 112 STAs, but degrades the quality to Class B at 116 STAs and 120 STAs. RSSI keeps the Class B up to 108 STAs. APP keeps the eMOS value of 1, which means "all user dissatisfied." Proposed improves the capacity of Class A by 7% compared to the NumSTA. Figure 9 and Fig. 10 show the eMOS of QAP 2/3 and QAP 3/3 situation, respectively. In these situations, all algorithms degrade eMOS, but when there are 120 STAs, Proposed keeps higher eMOS value than other algorithms. In Figs. 9 and 10, Proposed improves the capacity of Class A by 10% and 14% compared to the NumSTA, respectively. The Proposed solves the TCP Application Problem described in Fig. 1(d). So, the proposed algorithm can guarantee the better eMOS performance than other algorithms when there are many VoIP traffic flows.

Table 6 Maximum confidential interval of eMOS Case1.

	QAP 1/3	QAP 2/3	QAP 3/3
Proposal	$\pm 3.86 \times 10^{-5}$	$\pm 1.38 \times 10^{-4}$	$\pm 4.94 \times 10^{-4}$
APP	$\pm 1.05 \times 10^{-3}$	$\pm 5.97 \times 10^{-2}$	$\pm 5.18 \times 10^{-2}$
NumSTA	$\pm 2.79 \times 10^{-3}$	$\pm 4.29 \times 10^{-3}$	$\pm 4.65 \times 10^{-3}$
RSSI	$\pm 2.29 \times 10^{-2}$	$\pm 3.30 \times 10^{-2}$	$\pm 3.86 \times 10^{-2}$

Table 7 Maximum confidential interval of eMOS Case2.

	QAP 1/3	QAP 2/3	QAP 3/3
Proposal	$\pm 2.95 \times 10^{-2}$	$\pm 3.71 \times 10^{-2}$	$\pm 3.99 \times 10^{-2}$
APP	$\pm 3.15 \times 10^{-6}$	$\pm 6.05 \times 10^{-2}$	$\pm 5.93 \times 10^{-2}$
NumSTA	$\pm 3.66 \times 10^{-2}$	$\pm 4.78 \times 10^{-2}$	$\pm 5.26 \times 10^{-2}$
RSSI	$\pm 4.58 \times 10^{-2}$	$\pm 5.46 \times 10^{-2}$	$\pm 5.85 \times 10^{-2}$

Table 8 Maximum confidential interval of eMOS Case3.

	QAP 1/3	QAP 2/3	QAP 3/3
Proposal	$\pm 2.33 \times 10^{-5}$	$\pm 2.60 \times 10^{-5}$	$\pm 2.84 \times 10^{-5}$
APP	$\pm 9.93 \times 10^{-4}$	$\pm 5.81 \times 10^{-4}$	$\pm 8.16 \times 10^{-5}$
NumSTA	$\pm 2.77 \times 10^{-5}$	$\pm 3.04 \times 10^{-5}$	$\pm 3.31 \times 10^{-5}$
RSSI	$\pm 5.17 \times 10^{-5}$	$\pm 5.53 \times 10^{-5}$	$\pm 5.95 \times 10^{-5}$

3.3.3 Case 3

In each situation of Case 3, the eMOS performances of all algorithms are all 4.5 at the number of STAs of between 50 to 120 except APP at 120 STAs in the situation of QAP 1/3. But it keeps the Class A quality.

3.3.4 Confidential Interval of eMOS Evaluation

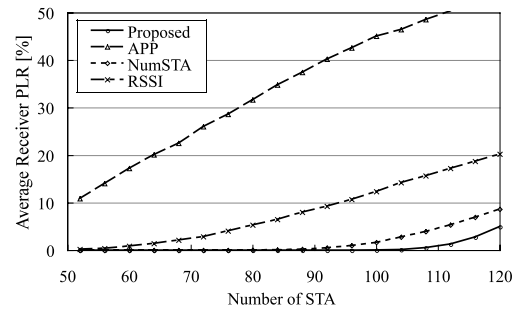
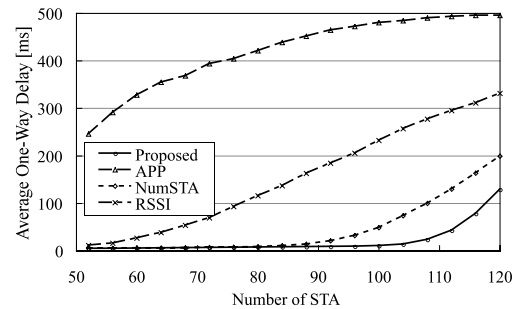
Tables 6 through 8 show the maximum two-sided 95% confidential intervals of t-distribution.

A comparison shows the eMOS value is convergent enough and there are significant differences between the proposed algorithm and other 3 algorithms in all cases and all situations.

3.3.5 Packet Loss Rate and Delay Evaluation

In order to clarify the eMOS improvement from other side, Fig. 11 and Fig. 12 show the PLR and the delay time in situation QAP 3/3 in Case 2. As shown in Figs. 11 and 12, Proposed reduces the PLR and the delay time drastically compared to other 3 algorithms, respectively.

In Fig. 10 at 84 STAs, Proposed improves the eMOS score by 1 compared to RSSI. From the view of PLR and delay time shown in Figs. 11 and 12, Proposed improves the PLR by 7% and 130 ms compared to RSSI at 84 STAs, respectively.

**Fig. 11** Average VoIP PLR in Case2, QAP 3/3.**Fig. 12** Average VoIP one-way delay in Case2, QAP 3/3.

3.4 FTP Throughput Evaluation

3.4.1 Case 1

In each situation of Case 1, APP slightly degrades throughput compared to other 3 algorithms when there are less than 90 STAs. While there are more than 90 STAs, APP achieves 100 kbps higher throughput than other 3 algorithms. These 3 algorithms achieve almost the same throughput through all range.

Thus, the proposed algorithm doesn't degrade the FTP throughput compared with other 3 algorithms while the proposed algorithm improves the VoIP eMOS described in 3.3.

3.4.2 Case 2

Figures 13–15 show the average receiver throughput of Case 2. In the situations of QAP 1/3 and 2/3 are shown in Fig. 13 and Fig. 14, respectively, APP achieves higher throughput in these 4 algorithms when there are more than 64 STAs and 60 STAs, respectively. This is because the same reason of Case 1. When there are less FTP flows, APP has more channel capacity for FTP traffic than other 3 algorithms. In the situation QAP 3/3, shown in Fig. 15, APP achieves highest throughput in the 4 algorithms. But referring to the average eMOS value in Fig. 10, APP lost more VoIP packets than other 3 algorithms. So, APP buys FTP throughput at the sacrifice of VoIP eMOS.

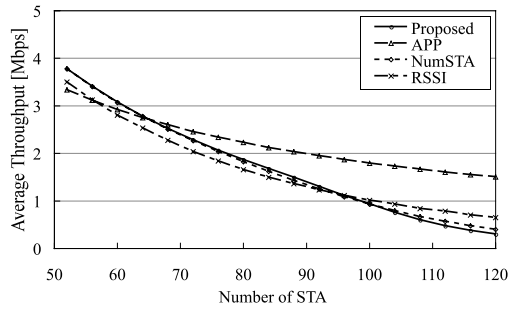


Fig. 13 Average receiver throughput in Case2, QAP 1/3.

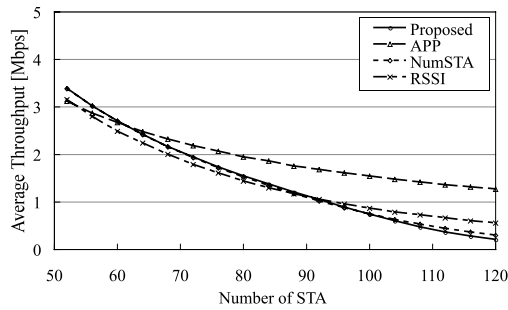


Fig. 14 Average receiver throughput in Case2, QAP 2/3.

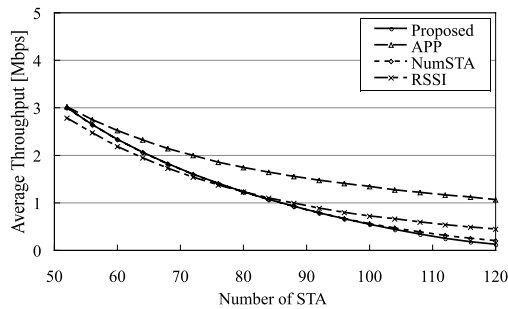


Fig. 15 Average receiver throughput in Case2, QAP 3/3.

3.4.3 Case 3

In each situation of Case 3, APP achieves higher throughput up to 80 kbps than other 3 algorithms, Proposed, NumSTA and RSSI. Among the 3 algorithms, Proposed, NumSTA and RSSI, there are no difference of throughput. The Proposed doesn't degrade the FTP throughput compared to other 3 algorithms.

3.4.4 Confidential Interval of Throughput Evaluation

Tables 9 through 11 show the maximum confidential two-sided 95% confidential intervals of t-distribution.

In Case 1, significant differences between Proposed and APP are detected in the STA range of 50 to 76 at the situation QAP 1/3, 50 to 68 and 110 to 120 at QAP 2/3, 102 to 120 at QAP 3/3, respectively. Otherwise, there is no significant differences. In Case 2, a comparison shows significant

Table 9 Maximum confidential interval of throughput Case1.

	QAP 1/3	QAP 2/3	QAP 3/3
Proposal	$\pm 1.92 \times 10^{-2}$	$\pm 1.90 \times 10^{-2}$	$\pm 1.30 \times 10^{-2}$
APP	$\pm 1.28 \times 10^{-1}$	$\pm 1.08 \times 10^{-1}$	$\pm 9.32 \times 10^{-2}$
NumSTA	$\pm 2.74 \times 10^{-2}$	$\pm 2.53 \times 10^{-2}$	$\pm 2.29 \times 10^{-2}$
RSSI	$\pm 1.29 \times 10^{-1}$	$\pm 1.26 \times 10^{-1}$	$\pm 1.24 \times 10^{-1}$

Table 10 Maximum confidential interval of throughput Case2.

	QAP 1/3	QAP 2/3	QAP 3/3
Proposal	$\pm 8.11 \times 10^{-2}$	$\pm 7.30 \times 10^{-2}$	$\pm 5.51 \times 10^{-2}$
APP	$\pm 2.15 \times 10^{-1}$	$\pm 1.90 \times 10^{-1}$	$\pm 1.52 \times 10^{-1}$
NumSTA	$\pm 9.42 \times 10^{-2}$	$\pm 8.41 \times 10^{-2}$	$\pm 6.95 \times 10^{-2}$
RSSI	$\pm 1.86 \times 10^{-1}$	$\pm 1.78 \times 10^{-1}$	$\pm 1.67 \times 10^{-1}$

Table 11 Maximum confidential interval of throughput Case3.

	QAP 1/3	QAP 2/3	QAP 3/3
Proposal	$\pm 7.51 \times 10^{-3}$	$\pm 6.64 \times 10^{-3}$	$\pm 4.17 \times 10^{-3}$
APP	$\pm 8.22 \times 10^{-2}$	$\pm 7.39 \times 10^{-2}$	$\pm 6.33 \times 10^{-2}$
NumSTA	$\pm 1.25 \times 10^{-2}$	$\pm 1.18 \times 10^{-2}$	$\pm 1.08 \times 10^{-2}$
RSSI	$\pm 9.61 \times 10^{-2}$	$\pm 9.48 \times 10^{-2}$	$\pm 9.06 \times 10^{-2}$

cant differences between Proposed and APP over 100 STAs at the all situations. In Case 3, a comparison shows significant differences between Proposed and APP over 60 STAs and 92 STAs in the situation QAP 1/3 and QAP 2/3, respectively. But except for these situations, there is no significant differences between Proposed and other 3 algorithms.

4. Conclusion

A new AP selection algorithm which enables STA to select an desirable AP in the mixed WLAN environment and the TCP and real-time UDP traffic mixed situation is proposed. This algorithm assigns an AP according to the number of STAs and ATC which is calculated from CUR and AAC. This algorithm is effective in mixed WLAN environment. It is also effective in the mixed traffic situation because the selection criteria are not only ATC but also the number of STA.

It is found that the proposed algorithm yields improvement for the eMOS values of VoIP traffic and can guarantee QoS without degrading the FTP throughput.

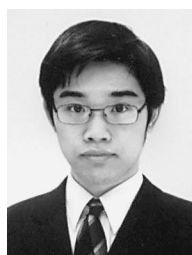
This proposed algorithm has room for improvement to provide optimal communications. The improvement of this proposed algorithm is further study.

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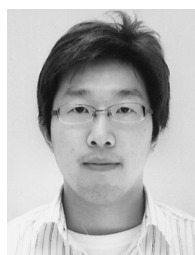
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