Access point selection algorithms for maximizing throughputs in wireless LAN environment†

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Abstract

In wireless LAN technology, access point selection at each station is a critical problem in order to obtain satisfactory throughputs. The current protocol for access point selection is based on the received signal strength, and a concentration of stations causes a degradation of the entire wireless network. In the present paper, we propose two access point selection algorithms for maximizing two types of throughputs. The first algorithm is proposed for maximizing the average throughput of stations, and the second algorithm is proposed for maximizing the minimum throughput of stations. The experimental results of the proposed algorithms indicate that the proposed algorithms achieve a number of performance improvements compared with previous algorithms.

1 Introduction

In recent years, IEEE 802.11 wireless LAN technology has spread tremendously, enabling individuals to connect to the Internet from almost everywhere. The wireless LAN environment consists of access points (APs) and stations (STAs), and each STA selects an available AP in order to connect to the Internet without any centralized control. For the wireless LAN environment, the spread of technology has made multiple APs available for STAs. Thus, the AP selection for each STA is a critical problem for obtaining satisfactory throughputs.

A common AP selection algorithm used in current wireless LAN technology is based on the received signal strength. In the AP selection algorithm, each STA selects one of the available APs with the maximum signal strength. However, the algorithm based on the signal strength may cause a concentration of connections to one of the APs. Since the throughput of each STA decreases in proportion to the number of STAs connected to the same AP [4], the concentration causes the degradation of the entire wireless network [1, 2]. In addition, the values of throughputs are unstable and depend heavily on the locations of the STAs in case of the common algorithm.

Therefore, an efficient decentralized AP selection algorithm is needed in order to avoid over-concentration of STAs, and various AP selection approaches have been considered and proposed [1, 2, 4, 7, 9]. For example, Fukuda et al. [4] proposed an AP selection algorithm, which is referred to as the Maximizing Local Throughput (MLT). In the MLT, the number of STAs connected to the same AP is used as a parameter, and each STA selects one of the available APs so as to maximize its own throughput using the number of STAs and signal strength. The result in [4] shows that MLT achieves better minimum throughput of STAs than the throughput obtained by the common AP selection algorithm.

In the present paper, we first propose two AP selection algorithms for maximizing two types of throughputs. The first AP selection algorithm is proposed for maximizing the average throughput of APs. At each stage of the first algorithm, each STA computes the amount of increase in the throughputs for all APs and selects the AP that maximizes the amount of the increase. The second AP selection algorithm is proposed for maximizing the minimum throughput of STAs. In the second algorithm, each STA computes the minimum throughputs for all APs and selects the AP having the maximum minimum throughput.

In addition, we propose a centralized AP selection algorithm. The algorithm, which is based on a local search method, is proposed for obtaining near-optimal average and

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minimum throughputs, and the obtained throughputs become base measures for decentralized algorithms.

We compare the results of the above three algorithms with those of the common AP selection algorithm and MLT using a simulation environment. The experimental results show that the first algorithm achieves high average throughputs in all cases, and the throughput of the second algorithm is better than MLT in the best case. The results also show that there is a kind of a trade-off between the average and minimum throughputs.

The present paper is organized as follows. In Section 2, we give a brief description of the communication model in the wireless LAN environment. In Section 3, we describe the details of the decentralized and centralized AP selection algorithms. In Section 4, we present the experimental results of the AP selection algorithms. Section 5 concludes the paper.

2 Preliminaries

2.1 Communication model

We first introduce the communication model and throughputs used in the paper. We assume that there are n STAs and m APs in the wireless LAN environment, and $S = \{s_0, s_1, \cdots, s_{n-1}\}$ and $A = \{a_0, a_1, \cdots, a_{m-1}\}$ denote two sets of STAs and APs, respectively.

For each pair of STA s_i and AP a_j, a packet error rate $P_{i,j}$ is defined. The packet error rate $P_{i,j}$ represents the signal strength between STA s_i and AP a_j, and $0 \leq P_{i,j} \leq 1$. Since the packet error rate is the ratio of the number of test packets that are not successfully sent to a destination, a high packet error rate indicates a low signal strength.

Using the packet error rate, we estimate $\theta_{i,j}$, which denotes a throughput between STA s_i and AP a_j for the case in which s_i is connected to a_j, according to the IEEE 802.11 MAC mechanism [6]. Let N_j be the number of STAs that are connected to AP a_j. Then, the throughput $\theta_{i,j}$ is given by the following expression [4].

$$\theta_{i,j} = \frac{Data \cdot (1 - P_{i,j})}{t_T \cdot N_j}$$

In the above expression, t_T and $Data$ denote the transmission time and the size of the transmitted packet, respectively. Since t_T is a constant that depends on the wireless LAN environment, the above expression can be modified to the following throughput $\theta_{i,j}$ when all of the packets are of the same size.

$$\theta_{i,j} = \alpha \times \frac{1 - P_{i,j}}{N_j}$$

In the above expression, α is a constant that depends on the wireless LAN environment. This expression implies that the throughput $\theta_{i,j}$ is linearly dependent on $\frac{1-P_{i,j}}{N_j}$.

We also employ the following assumptions in the communication model for the wireless LAN environment*.

- Each STA knows the packet error rates for all of the APs.
- Each AP knows the number of connected STAs and the packet error rates of all connected STAs. Thus, each AP can compute the sum of the throughputs of the connected STAs as well as the maximum packet error rate among the connected STAs.
- Each AP can send the above three values, which are the number of connected STAs, the sum of the throughputs and the maximum packet error rate, to any STA. In other words, each STA knows these values for all of the APs.

2.2 AP selection problem

In this subsection, we formally define the AP selection problem. The input of the problem is a set of $S = \{s_0, s_1, \cdots, s_{n-1}\}$ and a set of APs $A = \{a_0, a_1, \cdots, a_{m-1}\}$. For each pair of STA s_i and AP a_i, a packet error rate $P_{i,j}$ is also given.

The output of the problem is a set of n pairs of STA and AP, such that $\{(s_0, a_{j_0}), (s_1, a_{j_1}), \cdots, (s_{n-1}, a_{j_{n-1}})\}$. Each pair (s_i, a_{j_i}) implies that STA s_i is connected to AP a_{j_i}. In other words, each STA s_i selects AP a_{j_i} for connection in the wireless LAN environment. In this case, θ_i, which denotes the throughput between s_i and a_{j_i}, is given as follows.

$$\theta_i = \alpha \times \frac{1 - P_{i,j_i}}{N_{j_i}}$$

Since each STA has m candidates to be connected, there are m^n types of solutions to the AP selection problem.

As an example problem, we consider a set of two APs $\{a_0, a_1\}$ and a set of four STAs $\{s_0, s_1, s_2, s_3\}$. In this case, there are 2^4 solutions to the problem, and the following output set indicates that STAs s_0 and s_3 are connected to AP a_0, and STAs s_1 and s_2 are connected to AP a_1.

$$\{(s_0, a_0), (s_1, a_1), (s_2, a_1), (s_3, a_0)\}$$

For the above output, we define the following three objective functions.

(1) Average throughput: The average throughput T_{avg} denotes the average of throughput of the STAs. T_{avg} is defined for an output of AP selection as follows.

$$T_{avg} = \frac{1}{n} \sum_{i=0}^{n-1} \theta_i = \frac{\alpha}{n} \sum_{i=0}^{n-1} \frac{1 - P_{i,j_i}}{N_{j_i}}$$

*Some features in the assumptions are not realized in current wireless LAN technology. The unrealized features are left for improvement in future studies.

In order to maximize the total throughput of the wireless LAN environment, we need an AP selection algorithm that maximizes the average throughput.

(2) Minimum throughput: The minimum throughput T_{min} denotes the minimum throughput among those of the STAs. T_{min} is also defined as follows.

$$\begin{aligned} T_{min} &= \min\{\theta_i \mid 0 \le i \le n-1\} \\ &= \min\left\{\alpha \times \frac{1 - P_{i,j_i}}{N_{i,j_i}} \mid 0 \le i \le n-1\right\} \end{aligned}$$

The low minimum throughput indicates that several STAs are concentrated at one AP. On the other hand, the high minimum throughput indicates that some STA is connected to farther APs so as to avoid concentration of STAs.

(3) Balance index: A balance index [3] is defined as a measure that represents the fairness among STAs. The balance index β is defined for an output of AP selection as follows.

$$\beta = \frac{(\sum_{i=0}^{n-1} \theta_i)^2}{n \times \sum_{i=0}^{n-1} \theta_i^2}$$

The balance index becomes 1 when all of the STAs have the same throughput. On the other hand, the balance index approaches $\frac{1}{n}$ when the throughputs of the STAs are largely imbalanced.

There is some trade off among the above three objective functions. Thus, we propose different AP selection algorithms for maximizing each objective function.

2.3 Known AP selection algorithms

In this subsection, we introduce two known AP selection algorithms. The first is a conventional approach used in the current wireless LAN technology, and the second is an algorithm based on a communication model. The two algorithms are briefly described in the following.

2.3.1 Received Signal Strength (RSS)

The Received Signal Strength (RSS) is a simple and conventional AP selection algorithm. Each STA selects one of available APs according to signal strength. An outline of the algorithm on each STA s_i is given below.

Step 1: For each AP a_j $(0 \le j \le m-1)$, compute $rss_j = 1 - P_{i,j}$.

Step 2: Select AP a_{j_i} such that $rss_{j_i} = \max\{rss_j \mid 0 \le j \le m-1\}$.

If all STAs are uniformly distributed, RSS is sufficient for obtaining sufficient throughputs. However, RSS causes degradation of the minimum throughput when several STAs are close to one AP [1, 2].

2.3.2 Maximizing Local Throughput (MLT)

The Maximizing Local Throughput (MLT) [4] is an AP selection algorithm based on a feature of throughput in the wireless LAN environment. In the wireless LAN environment, the throughput between STA s_i and AP a_j depends linearly on the value $\frac{1-P_{i,j}}{N_j}$, where $P_{i,j}$ is the packet error rate between s_i and a_j, and N_j is the number of STAs connected to AP a_j. In the MLT, each STA selects one of the available APs according to the above value. An outline of MLT on each STA s_i is given below.

Step 1: Receive N_j from each AP a_j $(0 \le j \le m-1)$.

Step 2: For each AP a_j $(0 \le j \le m-1)$, set $N_j = N_j + 1$ in case that s_i is not connected to a_j, and then, compute the following value mlt_j.

$$mlt_j = \frac{1 - P_{i,j}}{N_j}$$

Step 3: Select AP a_{j_i} such that $mlt_{j_i} = \max\{mlt_j \mid 0 \le j \le m-1\}$

In comparison with the RSS, the MLT achieves a high minimum throughput and a sufficient balance index even if several STAs are close to one AP [4, 5]. Although it is known that the values of output throughputs obtained by the MLT vary according to order of connections, the throughputs converge to a high value if the MLT is repeated a constant number of times. In the experiments in Section 4, the MLT is repeated 100 times for each input with the same order.

3 AP selection algorithms

In this section, we first propose two decentralized AP selection algorithms. The first algorithm is proposed for maximizing the average throughput, and the second algorithm is proposed for maximizing the minimum throughput. Both of the algorithms are designed so that roaming occurs on each STA. In other words, the algorithms can be executed repeatedly. We next propose a centralized AP selection algorithm. The algorithm is proposed for obtaining near-optimal average and minimum throughputs, and the obtained throughputs become base measures for decentralized algorithms.

3.1 Maximizing Total Throughput (MTT)

The first AP selection algorithm is called *Maximizing Total Throughput (MTT)*. In each stage of the MTT, each STA computes the amount of increase in the throughputs for all APs and selects an AP that maximizes the amount of increase.

Let us consider a simple example. We assume that there are two APs a_0 and a_1 and four STAs s_0, s_1, s_2, and s_3, and STAs s_0 and s_3 are connected to AP a_0 and STAs s_1 and s_2 are connected to AP a_1. In this case, the sums of the throughputs of STAs connected to APs a_0 and a_1, which are denoted by Θ_0 and Θ_1, are given as follows.

$$\begin{aligned}\Theta_0 &= \theta_0 + \theta_3 \\ &= \alpha \times \frac{(1-P_{0,0}) + (1-P_{3,0})}{2}\end{aligned}$$

$$\begin{aligned}\Theta_1 &= \theta_1 + \theta_2 \\ &= \alpha \times \frac{(1-P_{1,1}) + (1-P_{2,1})}{2}\end{aligned}$$

We now assume another STA, s_4, and consider an appropriate AP for STA s_4. We first consider the case in which s_4 is connected to a_0. In this case, the sum of the throughputs of the STAs connected to AP a_0 becomes as follows.

$$\begin{aligned}\Theta_0 &= \theta_0 + \theta_3 + \theta_4 \\ &= \alpha \times \frac{(1-P_{0,0}) + (1-P_{3,0}) + (1-P_{4,0})}{3}\end{aligned}$$

Then, the amount of increase in the throughput, which is denoted by I_0, is given as follows.

$$I_0 = \alpha \times \left(\frac{(1-P_{0,0}) + (1-P_{3,0}) + (1-P_{4,0})}{3} - \frac{(1-P_{0,0}) + (1-P_{3,0})}{2} \right)$$

We consider another case in which STA s_4 is connected to a_1. In this case, the amount of the increase is similarly obtained as I_1.

$$I_1 = \alpha \times \left(\frac{(1-P_{1,1}) + (1-P_{2,1}) + (1-P_{4,1})}{3} - \frac{(1-P_{1,1}) + (1-P_{2,1})}{2} \right)$$

After computing the above I_0 and I_1, we select one AP so that the selection maximizes the amount of the increase. In this case, AP a_0 is selected for STA s_4 if $I_0 \geq I_1$, otherwise AP a_1 is selected for STA s_4.

We now explain the algorithm more precisely. In the first step of the algorithm, each STA s_i receives N_j and Θ_j, where N_j is the number of connected STAs to AP a_j and Θ_j is the sum of the throughputs of the STAs connected to AP a_j. We assume that S_j denotes a set of STAs connected to AP a_j, and then, Θ_j is expressed as follows.

$$\Theta_j = \frac{\sum_{s_k \in S_j} (1 - P_{k,j})}{N_j}$$

We next compute the sum of the throughputs for the case in which STA s_i is connected to AP a_j. The sum of the throughputs of the STAs connected to AP a_j becomes as follows.

$$\frac{\Theta_j \times N_j + (1-P_{i,j})}{N_j + 1}$$

Therefore, the amount of the increase in the throughput, which is denoted by $\Delta\Theta_j$, is obtained as follows.

$$\Delta\Theta_j = \frac{\Theta_j \times N_j + (1-P_{i,j})}{N_j + 1} - \Theta_j = \frac{(1-P_{i,j}) - \Theta_j}{N_j + 1}$$

In these algorithms, the value of the above expression is computed for each AP, and AP selection is executed according to the obtained value.

We now summarize the algorithm on each STA s_i. The algorithm consists of the following three steps.

Algorithm MTT

Step 1: From each AP a_j $(0 \leq j \leq m-1)$, obtain N_j and Θ_j.

Step 2: For each AP a_j $(0 \leq j \leq m-1)$, set $\Delta\Theta_j = 0$ if s_i is already connected to a_j, otherwise, compute the $\Delta\Theta_j$ as follows.

$$\Delta\Theta_j = \frac{(1-P_{i,j}) - \Theta_j}{N_j + 1}$$

Step 3: Select AP a_{j_i} such that $\Delta\Theta_{j_i} = \max\{\Delta\Theta_j \mid 0 \leq j \leq m-1\}$.

3.2 Increasing Minimum Throughput (IMT)

The second AP selection algorithm is called the *Increasing Minimum Throughput (IMT)*, which is proposed for maximizing the minimum throughput of the STAs. In this algorithm, each STA computes the minimum throughputs for all APs, and selects the AP for which the minimum throughput is the maximum.

Let us consider a simple example again. We assume that there are two APs a_0 and a_1 and four STAs s_0, s_1, s_2, and s_3, and STAs s_0 and s_3 are connected to AP a_0 and STAs s_1 and s_2 are connected to AP a_1. In addition, we consider the case in which another STA, s_4, is selecting an appropriate AP.

In the first step of the IMT, the maximum of the packet error rates is obtained from each AP, and then, the minimum throughput is computed for each AP by assuming that the STA is connected to the AP. For this example, STA s_4 first receives $P_{max_0} = \max\{P_{0,0}, P_{3,0}\}$ and $P_{max_1} = \max\{P_{1,1}, P_{2,1}\}$ from APs a_0 and a_1, respectively. Next, θ_{min_0} and θ_{min_1}, which are the minimum throughputs of APs a_0 and a_1, are computed as follows.

$$\theta_{min_0} = \frac{1 - \max\{P_{max_0}, P_{4,0}\}}{3}$$
$$\theta_{min_1} = \frac{1 - \max\{P_{max_1}, P_{4,1}\}}{3}$$

After computing θ_{min_0} and θ_{min_1} above, we select one of the APs so that the selection maximizes the minimum throughput. For this example, AP a_0 is selected for STA s_4 if $\theta_{min_0} \geq \theta_{min_1}$, otherwise AP a_1 is selected for STA s_4.

We now describe the details of the IMT. In the first step, each STA s_i receives the maximum packet error rate from each AP a_j. We assume that P_{max_j} denotes the received maximum packet error rate from AP a_j, and S_j denotes a set of STAs connected to AP a_j. Then, P_{max_j} is given by the following expression.

$$P_{max_j} = \max\{P_{k,j} \mid s_k \in S_j\}$$

Next, the minimum throughput θ_{min_j} is computed for AP a_j using P_{max_j} and $P_{i,j}$. The minimum throughput θ_{min_j} for AP a_j is obtained as follows.

$$\theta_{min_j} = \frac{1 - \max\{P_{max_j}, P_{i,j}\}}{N_j + 1}$$

In the IMT, the above minimum throughput is computed for each AP, and AP selection is executed so that the minimum throughput becomes the maximum.

We now summarize the second AP selection algorithm on STA s_i as follows.

Algorithm IMT

Step 1: From each AP a_j $(0 \leq j \leq m-1)$, obtain N_j and P_{max_j}.

Step 2: For each AP a_j $(0 \leq j \leq m-1)$, set $N_j = N_j + 1$ if s_i is not connected to a_j, and then, compute the following value of θ_{min_j}:

$$\theta_{min_j} = \frac{1 - \max\{P_{max_j}, P_{i,j}\}}{N_j}$$

Step 3: Select AP a_k such that $\theta_{min_k} = \max\{\theta_{min_j} \mid 0 \leq j \leq m-1\}$.

3.3 Centralized algorithm

The centralized AP selection algorithm is based on a local search method. The local search is a popular paradigm of heuristic algorithms. An overview of the method is as follows.

1. Generate an initial solution.

2. Search each of the neighbors of the current solution. If a better solution is obtained from the neighbor, then repeat this step for the neighbor. The repetition is executed until no new solution is found.

In the first step of the centralized algorithm, we use the best result of MLT, which is a known AP selection algorithm, as described in Section 2, for an initial solution I. (We assume $I = \{(s_0, a_{j_0}), (s_1, a_{j_1}), \cdots, (s_{n-1}, a_{j_{n-1}})\}$.) Then, we compute the target throughput $T(I)$ for the initial input I. The target throughput is the average or minimum throughput.

We next describe the details of the second step of our centralized algorithm. We first define *k-neighbor solutions*, $N_k(I)$, which is a set of all solutions obtained using the following operation.

(1) Select k STAs. (We assume that $S_k = \{s_{i_0}, s_{i_1}, \cdots, s_{i_{k-1}}\}$ denotes a set of selected STAs.)

(2) For each STA s_{i_h} $(0 \leq h \leq k-1)$, change the connected AP from $a_{j_{i_h}}$ to another AP.

We check the target throughput for each solution in $N_k(I)$ in a sequence. If a better throughput is obtained by solution $I' \in N_k(I)$, that is, $T(I) < T(I')$, then we have $I = I'$ and this step is repeated.

We now summarize the proposed algorithm based on the local search method in the following.

Algorithm LOCAL SEARCH

Step 1: Generate an initial solution I using the MLT.

Step 2: Compute $N_k(I)$, and repeat the following substeps until $N_k(I) = \phi$.

(2-1) Choose a solution $I' \in N_k(I)$, and set $N_k(I) = N_k(I) - \{I'\}$.

(2-2) If $T(I) < T(I')$, set $I = I'$, and repeat from the beginning of Step 2.

In general, k must be small in the local search method because the size of $N_k(I)$ is $\binom{n}{k} = \frac{n!}{k!(n-k)!}$. We choose $k = 3$ in our experiments.

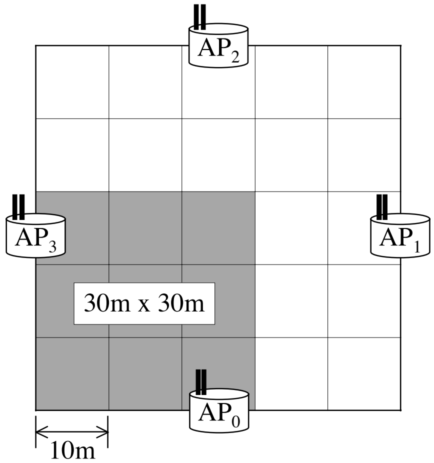

Figure 1. Simulation model

4 Experimental results

In this section, we describe the experimental results for known algorithms and the proposed algorithms. We implemented all of the algorithms in two simulation environments. The first is an original simulation environment using the C language, and the second is Qualnet[8], which is one of the widely used network simulators.

In the simulation, we assume that there are 4 APs and 40 STAs in a 2D plain, which is shown in Figure 1. We first assume a $50m \times 50m$ square area, and each AP is located at the middle point of each side. We also assume that 40 STAs are randomly located in the $30m \times 30m$ gray area shown in Figure 1. The allocation provides a biased situation so that several STAs are close to two APs.

4.1 Original simulation

In each simulation, we randomly generate 100 STA locations. For each STA location, we assume that each packet error rate $P_{i,j}$ is calculated from the distance between STA s_i and AP a_j. Then, we execute the simulation for each STA location using the following steps.

(1) Execute the RSS for the STA location. (The results of the RSS are independent of the order of AP selections.)

(2) Select a permutation of STAs randomly.

(3) Execute three AP selection algorithms, which are MLT, MTT, and IMT, for the STA location in order of the permutation.

(4) Repeat (3) 100 times in order to stabilize the results of the algorithms.

(5) Repeat (2) $\sim$ (4) for 10,000 different permutations. (This is because the results depend highly on the order of AP selections of STAs in the case of MLT, IMT, and MTT.)

(6) Execute the centralized algorithm for the STA location using the best results of the MLT as an initial solution.

Figures 2, 3, and 4 are the results of simulation for average throughputs, minimum throughputs and balance indices for the algorithms. In each figure, the horizontal axis indicates the types of STA locations.

Figures 2(a), 2(b), and 2(c) show the average, best and worst throughputs for the average throughput of STAs, respectively. (Since the throughputs obtained by the RSS and the centralized algorithm are independent of the order of AP selections, these throughputs are the same in the three graphs.) Although the lines for the MTT appear to be missing in the graphs, the values of the throughputs for the MTT are almost identical to the throughputs for the centralized algorithms, as denoted by “MLT+LS”. This implies that the results of the MTT are nearly optimal for the average throughput, and MTT achieves the best results among the decentralized algorithms.

In the same figure, the throughputs of the RSS are disperse. These results imply that the average throughputs obtained by the RSS are unstable and depend heavily on the locations of the STAs. In addition, the throughputs of the MLT and the IMT are similar, but the throughputs of the IMT are inferior to the throughputs of the MLT in the worst case. However, it is confirmed that the inferior throughputs are rare among the average throughputs of the IMT.

Figures 3(a), 3(b), and 3(c) show the average, best and worst throughputs for the minimum throughput of STAs, respectively. The results of the IMT in the best case are sometimes superior to those of the centralized algorithm based on the MLT and the local search. However, in the worst case, the throughputs of the IMT are largely inferior to the throughputs of the MLT. Thus, the throughputs in the worst case are a defect of IMT.

In the same figure, the throughputs of the RSS and the MTT are inferior to those of the other two decentralized algorithms. Since the MTT is designed for maximizing the average throughput, these results imply that a kind of tradeoff exists between the average and minimum throughputs.

Figure 4 shows the balance indices of decentralized algorithms in the best case, and a high balance index implies that the algorithm achieves fairness between STAs. The values of the balance indices show that the MLT and the IMT achieve satisfactory fairness, while the values of the RSS and the MTT are low and disperse.

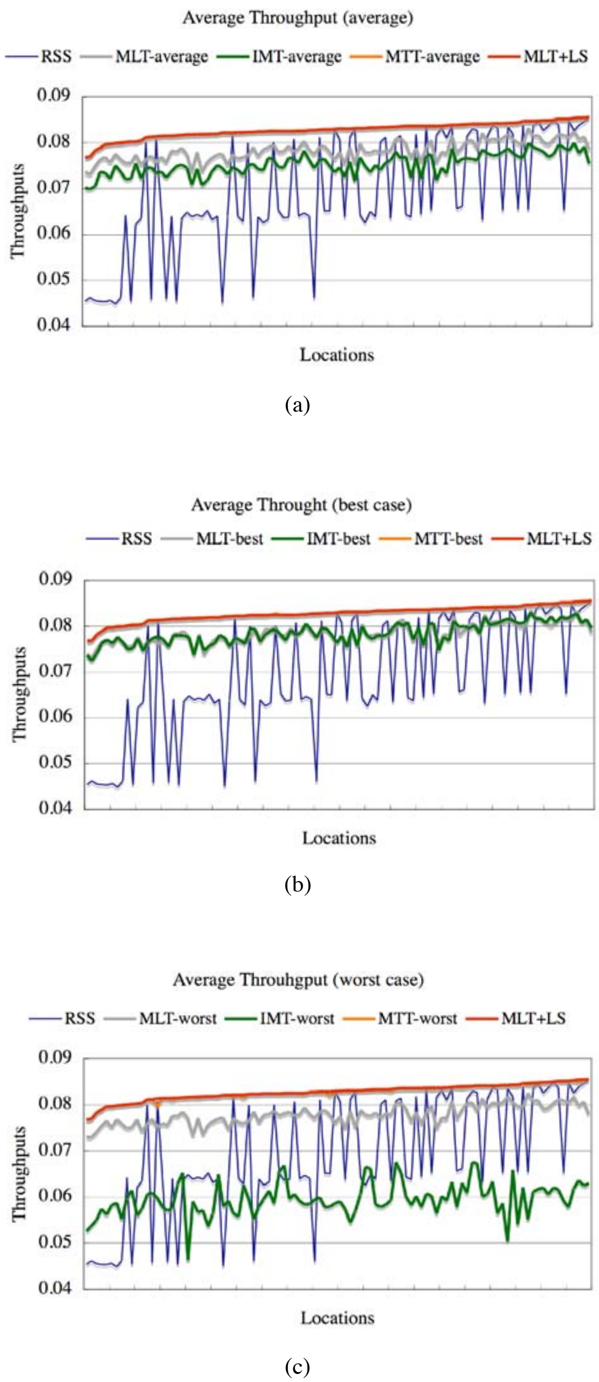

Figure 2. Average throughputs

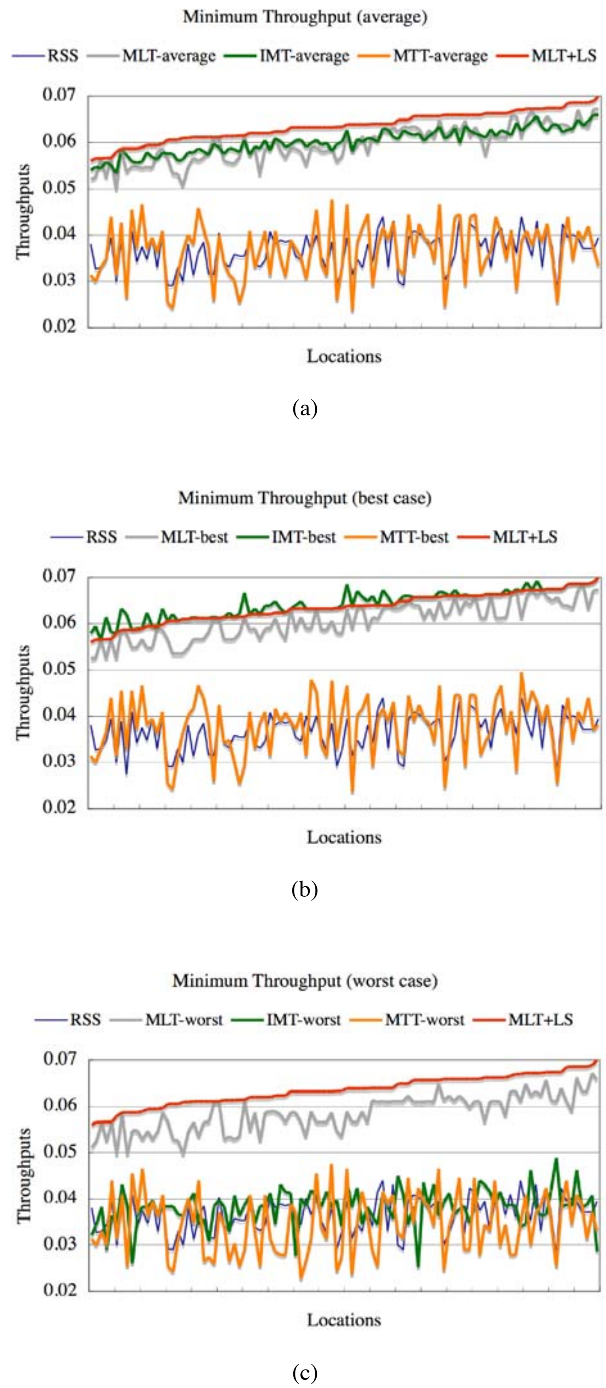

Figure 3. Minimum throughputs

4.2 Qualnet

The simulation on Qualnet is executed for a randomly generated location. Parameters of the simulation environment are as follows.

- simulation time: 25 seconds
- Wireless link: IEEE 802.11b (11Mbps)
- Wired link: IEEE 802.3 (1Gbps)
- IP protocol: IPv4

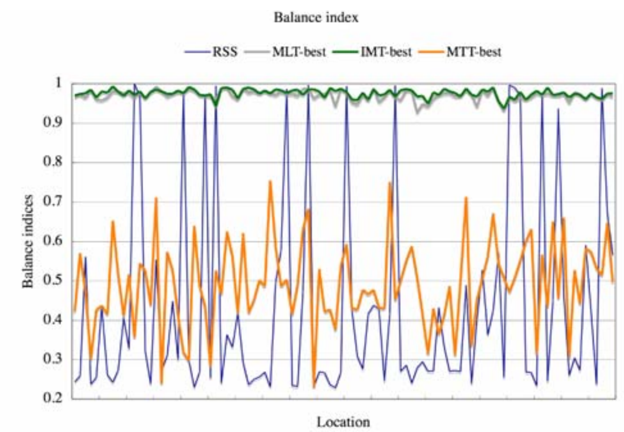

Figure 4. Balance indices

Table 1. Results of Qualnet

	RSS	MLT	IMT	MTT
average throughput (Kbps)	42.834	42.187	40.957	47.927
minimum throughput (Kbps)	20.752	33.62	32.558	18,274

- Application: FTP (packet size=512B, start time=15)

We execute AP selection algorithms, RSS, MLT, IMT and MTT, on Qualnet, and obtain average and minimum throughputs for each algorithm. (We omit the centralized AP selection algorithm because execution of the algorithm needs massive computational power.)

Table 1 shows the obtained throughputs of the simulation. The result shows that the obtained throughputs have similar property to the average case result of the original simulation.

5 Conclusions

In the present paper, we proposed two decentralized algorithms and a centralized algorithm for AP selection in the wireless LAN environment. The first decentralized algorithm is proposed for maximizing the average throughput of STAs, and the second decentralized algorithm is proposed for maximizing the minimum throughput among STAs. The centralized algorithm is proposed for obtaining throughputs that become base measures for decentralized algorithms. The experimental results show that the first algorithm achieves high average throughputs, and the throughputs of the second algorithm are almost the same as those of the MLT.

In the future, we will consider AP selection algorithms for heterogeneous wireless LAN environments. The heterogeneous wireless LAN environments consist of APs and STAs having different standards, such as 802.11b or 802.11g. In these environments, the communication model of the heterogeneous environment is different from the model used in the present paper, and some modifications are needed in order to propose an efficient AP selection algorithm.

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