Design And Evaluation of Time Slot Assignment Algorithm For IEEE 802.16j Relay Networks

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Abstract

In IEEE 802.16j relay networks, wireless communications are carried out based on TDMA where the wireless network resources are divided into multiple time slots and they are assigned to wireless links between relay nodes as transmission opportunities. The network performance is improved by decreasing the total number of different time slots assigned to all links in a single scheduling cycle, because it brings the increase in the transmission opportunities of the links per unit time. Although it can be achieved when multiple links utilize the same time slot, the capacity of such links is degraded due to the radio interference. On the other hand, since all links in the network need to have enough time slots to accommodate their traffic load, degrading the link capacity may increase the total number of different time slots in the scheduling cycle. Therefore, we should determine the time slot assignment by considering the above-mentioned tradeoff relationship. In this paper, we propose heuristic algorithms for time slot assignment problem in IEEE 802.16j relay networks, and evaluate them through extensive simulation experiments. Two algorithms based on different heuristic are introduced. One algorithm assigns a set of time slots to links by a greedy approach. The other algorithm determines a set of links that use a time slot by a brute-force search for maximizing the total link capacity. Performance evaluation results exhibit that the proposed algorithms reduces around 34% and 39% of the total time slots compared with the case where no link utilizes the same time slot, respectively. Meanwhile, they also show that calculation time of the latter algorithm is longer than that of the former algorithm to reduce the total time slots. Thus, we show that there is a tradeoff between performance and calculation time.

Keywords: IEEE 802.16j, Radio Interference, TDMA, Time Slot Assignment, Heuristic Algorithm.

1. INTRODUCTION

Wireless relay networks based on IEEE 802.16 (referred as relay networks below) are attracting increasing attention because they can provide wireless broadband service at low cost [1]. Specifically, IEEE 802.16j [2–4] is the standard that adds a multihop relay function to IEEE 802.16e [5]. By the multihop relay function, we can easily provide wide area access environment. As show in Figure 1, a relay network is composed of a gateway node, relay nodes and client terminals. The gateway node is connected to the backhaul networks with wired links and the relay nodes relay messages between the backhaul networks and the client terminals via wireless links [6].

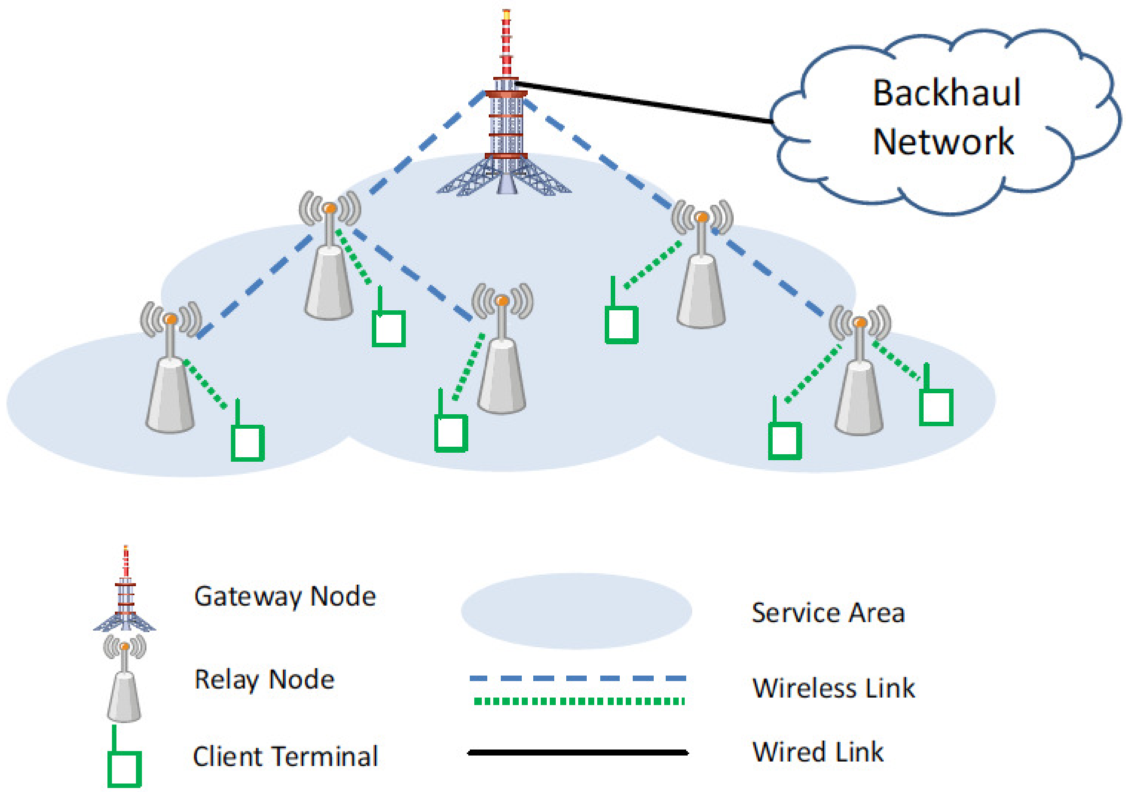

FIGURE 1: IEEE 802.16j Relay Network.

Generally, in wireless networks, when multiple nodes communicate on the same channel at the same time, the nodes cannot communicate correctly due to radio interference [7–9]. IEEE 802.16j adopts Time Division Multiple Access (TDMA) mechanism to reduce the radio interference [10, 11]. In TDMA, the wireless network resources are divided into multiple time slots and they are assigned to wireless links between relay nodes as transmission opportunities. The relay nodes communicate via the wireless links only at assigned time slots. To avoid performance degradation due to radio interference, disjoint time slots are assigned to links that would interfere with each other [12, 13]. Conversely, multiple links can communicate simultaneously at a single time slot if interference is weak. This means the spatial reuse of the wireless network resource [14, 15].

Decreasing the total number of different time slots which assigned to all links in the scheduling cycle, referred as schedule length below, means the improvement of the network performance, since the transmission opportunities of the links per unit time increases [16, 17]. We can reduce the schedule length by the reasonable level of spatial reuse. However, the excessive level of spatial reuse brings strong interference because too many links communicate simultaneously at the same time slot. In addition, the link capacity at an assigned time slot changes according to received signal and interference strengths, which is evaluated by signal to interference noise ratio

(SINR). This is because IEEE 802.16j employs Adaptive Modulation and Coding (AMC) [18–20], which selects the modulation method according to the SINR of the link and determines the link capacity at a time slot. On the other hand, since all links in the network need to have enough time slots to accommodate their traffic load [21, 22], degrading the link capacity may increase the schedule length. Therefore, we should determine the time slot assignment by considering the complex tradeoff between the link capacity and the degree of the spatial reuse.

The past literature [23] revealed that finding the optimum solution for time slot assignment is NP-hard problem, meaning that reasonable heuristic algorithms are required. Although there are researches on the time slot assignment for IEEE 802.16j relay networks, as in [24–29], none of them considers the detailed transmission quality in time slot assignment.

In this paper, we propose heuristic algorithms for time slot assignment problem in IEEE 802.16j relay networks with consideration of the detailed transmission quality. Two algorithms based on different heuristic are introduced. One algorithm is based on a greedy approach that assigns a set of time slots for a link to minimize the number of different time slots utilized by the link. The other algorithm is based on a brute-force search that determines a set of links for a time slot to maximize the total link capacity at the time slot. We conduct extensive simulation experiments to evaluate the performance of these algorithms and assess the tradeoff relationships between the obtained network performance and the calculation time. We also evaluate the performance of these algorithms in the various network size.

The rest of this paper is organized as follows. In Section 2, we explain the network model, the radio propagation model, and the problem definition. We propose the time slot assignment algorithms in Section 3. Section 4 gives the performance evaluation results through simulation experiments. Finally, we present the conclusions of this paper and areas for future work in Section 5.

2. SYSTEM MODEL AND PROBLEM DEFINITION

2.1 Network Model

Figure 2 depicts a relay network model used in this paper. The network is composed of N wireless nodes. One node is a gateway node denoted by v_0 and the others are relay nodes denoted by $v_1, \dots\ v_{N-1}$. When the network topology is being formed, a parameter called as the *estimated transmission distance* is used. Each node constructs links to other nodes within the distance from itself and the tree network topology is constructed the topology construction algorithms such as in [30]. In the network topology, the gateway node is the root of the tree and the relay nodes are the internal or leaf nodes. A communication graph $G = (V, E)$ is defined where $V = \{v_i | 0 \leq i \leq N-1\}$ is the set of all nodes and $E = \{l_i | 1 \leq i \leq |E|\}$ is the set of links. $|E|$ denotes the number of links in the network. To simplify the explanation below, we introduce the notations of $v_m^{(i)}$ and $v_n^{(i)}$ to represent the sender and receiver nodes of the link l_i, respectively.

We assume that the network traffic occurs from the client terminals to the backhaul networks. Q_{all} denotes the amount of total traffic generated from all client terminals during a single frame defined in IEEE 802.16j. The traffic load on each link is determined by the sum of the traffic from the client terminals whose path to the backhaul network includes the link. We denote the traffic load on l_i as Q_i.

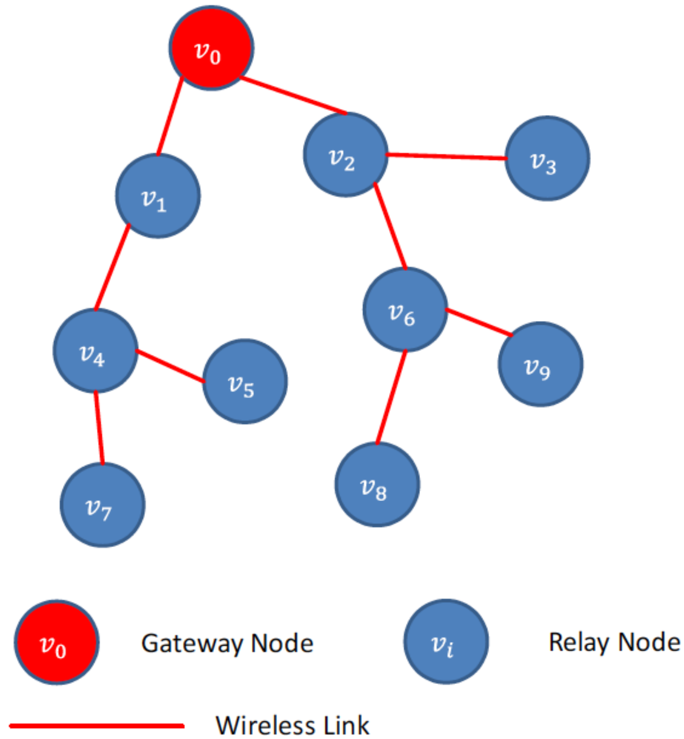

FIGURE 2: Network Model.

2.2 Time Division Multiple Access (TDMA)

IEEE 802.16j adopts TDMA to avoid the performance degradation due to the radio interference. In TDMA, the wireless network resources are divided into multiple time slots and they are assigned to links in the network as transmission opportunities. The relay nodes communicate via the wireless links only at assigned time slots. The time slots are sequentially denoted as $t(1), t(2), \ldots$ from the head of the frame.

We denote the time slot assignment as the matrix A shown below.

$$A = \begin{pmatrix} a_1(1) & a_1(2) & \ldots \\ a_2(1) & a_2(2) & \ldots \\ \ldots & \ldots & \ldots \\ a_{|E|}(1) & a_{|E|}(2) & \ldots \end{pmatrix} \tag{1}$$

Here, $a_i(k)$ represents the assignment information of the time slot $t(k)$ on the link l_i as follows.

$$a_i(k) = \begin{cases} 1 & \text{if } t(k) \text{ is assigned to } l_1 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Also, we introduce the variable $b(k)$ as follows.

$$b(k) = \begin{cases} 1 & \text{if } t(k) \text{ is assigned to one or more links} \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

We denote a schedule length as F, which is defined as follows.

$$F = \sum_{k=1}^{\infty} b(k) \tag{4}$$

Note that the time slot assignment with smaller F means the larger performance since we can accommodate the traffic load on all links in the network with smaller number of different time slots. Moreover, a set of links assigned $t(k)$ is denoted as $E(k)$.

$$E(k)(\subseteq E) = \{l_i | a_i(k) = 1, \forall i\} \tag{5}$$

2.3 Radio Interference Environment

In this paper, we assume the Rayleigh fading channel, which considers multipath fading in non-line-of-sight environments [31, 32]. In this channel, the radio signal strength changes temporally due to various factors such as distance, reflection, diffraction, and shadowing [33]. Then, the radio signal strength received at receiver node v_j from sender node v_i, denoted as $P_{i,j}$, is defined as follows [34].

$$P_{i,j} = R^2 e^{\xi} K r_{i,j}^{-\alpha} P_i \tag{6}$$

Here, R^2 denotes the influence of multipath fading where R is a random variable according to Rayleigh distribution. e^{ξ} denotes the shadowing effect where ξ is a random variable according to normal distribution with mean 0 and variance σ^2. K and α are variables of power decay due to distance. $r_{i,j}$ is the distance between v_i and v_j. P_i is the transmission signal strength of v_i.

On the transmission on the link l_i, the SINR of the radio signal received at receiver node $v_n^{(i)}$ from sender node $v_m^{(i)}$ at time slot $t(k)$ is defined as follows [35].

$$s_i(k) = 10 \log_{10} \frac{P_{m,m}}{P_{noise} + \sum_{l_o \in E(k) \backslash l_i} P_{o,n}} \tag{7}$$

Here, P_{noise} is the strength of environmental noise.

We assume that the receiver node successfully receives the radio signal from the sender node if the SINR at receiver node is larger than B that represents the capture threshold. Because we also assume the Rayleigh fading channel, the SINR is stochastically changed for every communication even if the condition about interference are same. Therefore, the probability at which the SINR at receiver node $v_n^{(i)}$ from sender node $v_m^{(i)}$ at time slot $t(k)$ is larger than B is defined as follows [35].

$$p_{i,B}(K) = p\left[P_{m,n} > 10^{\frac{B}{10}}\left(P_{noise} + \sum_{l_o \in E(k) \backslash l_i} P_{o,n}\right)\right] \tag{8}$$

In this paper, the capacity of a link at assigned a time slot is determined by AMC defined in IEEE 802.16-2009 [3]. AMC selects the modulation method according to the SINR of the link. If the SINR is large, the sender node selects a modulation method that enables high-speed transmission. If the SINR is small, the sender node selects a low-speed modulation method with robustness against bit errors [36, 37]. Considering stochastic fluctuation of SINR in Rayleigh fading channel assumed in this work, we calculate $f_i(k)$, that represents the capacity of the link l_i at a time slot $t(k)$ as follows.

$$f_i(k) = \begin{cases} \sum_{w=0}^{D} d_m(p_{i,u_w}(k) - p_{i,u_{w+1}}(k)) & \text{if } a_i(k) = 1 \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

Here, the capacity of the link l_i becomes $d_w(w = 0,1, \dots D, d_0 = 0)$ when $B_w \leq s_i(k) \leq B_{w+1}$ $(w = 0,1, \dots D, w_0 = -\infty, u_{D+1} = \infty)$ holds as shown in Table 2.

SINR [dB]	Modulation Method	Link Capacity [bits per symbol]
<3	-	0
3-6	BPSK	0.5
6-8.5	QPSK	1
8.5-11.5	QPSK	1.5
11.5-15	16QAM	2
15-19	16QAM	3
19-21	64QAM	4
>21	64QAM	4.5

TABLE 1: Adaptive Modulation and Coding in IEEE 802.16-2009.

2.4 Time Slot Assignment Problem
Smaller schedule length means higher network performance, since the transmission opportunities of the links per unit time increases. Finding the smallest schedule length for time slot assignment is defined as follows.

$$\begin{aligned} &\text{minimize} \quad F = \sum_{k=0}^{\infty} b(k) \\ &\text{subject to} \quad \sum_{k=1}^{\infty} f_i(k) \geq Q_i \qquad (\forall i = 1, 2, \dots, |E|) \\ &\qquad\qquad f_i(k) \geq 0 \qquad (a_i(k) = 1, \forall i = 1, 2, \dots, |E|, \forall k \in \mathbb{N}) \end{aligned} \tag{10}$$

When this problem is solved by brute-force search, $2^{|E| \times F^*}$ time complexity is needed, where F^* is shown as follows.

$$F^* = \sum_{i=1}^{|E|} \left\lceil \frac{Q_i}{d_1} \right\rceil \tag{11}$$

F^* is equivalent to the schedule length when time slots where a link can transmit smallest capacity are assigned to all links without spatial reuse.

3. PROPOSED ALGORITHMS
This section introduces the proposed algorithms for time slot assignment problem explained in Subsection 2.4. We propose two algorithms based on different heuristics called as Time slots for Link (TfL) algorithm and Links for time Slot (LfT) algorithm. In the following subsections, we explain the detailed algorithms in turn.

3.1 Time Slots for Link (TfL) Algorithm
TfL algorithm determines time slots utilized by each link in the pre-determined order. In what follows we assume to assign time slots to links in the order of $(l_1, l_2, \dots, l_{|E|})$. This means that TfL algorithm is equivalent to determining the values in Equation (1) row by row from the top row for link l_1 to the bottom row for link $l_{|E|}$.

We here explain how to assign time slots utilized by l_i, meaning that we determine the values of ith row in Equation (1) after 1st, 2nd, …, $(i-1)$th rows are already calculated. The set of time slots assigned to l_i is obtained by solving the optimization problem defined as follows.

$$\text{minimize} \quad \sum_{k=0}^{\infty} b_i(k) \tag{12}$$

$$\text{subject to} \quad \sum_{k=1}^{\infty} f_j(k) \geq Q_j \quad (\forall j = 1, 2, \dots i-1) \tag{13}$$

$$f_i(k) \geq 0 \qquad (a_i(k) = 1, \forall k \in \mathbb{N}) \tag{14}$$

Here, $b_i(k)$ is shown as follows.

$$b_i(k) = \begin{cases} 1 & \text{if } t(k) \text{ is assigned to one or more links in } \{l_1, l_2, \dots, l_i\} \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

Equation (12) means that we minimize the schedule length for links $l_1, l_2, \dots, l_i$. Equations (13) and (14) represent the constraints in minimization of Equation (12) that the assignment accommodates the traffic load of links $l_1, l_2, \dots, l_i$, and that all links using a time slot have the effective bitrates, respectively. When this problem is solved by brute-force search, $2^{F_i^*}$ of the time complexity is needed where F_i^* is shown as follows.

$$F_i^* = \sum_{k=1}^{\infty} b_{i-1}(k) + \left\lceil \frac{Q_i}{d_1} \right\rceil \tag{16}$$

This equation means that the calculation time for the brute-force search for ith link increases rapidly when i approaches to $|E|$. Therefore, we utilize the following algorithm based on a greedy approach.

When assigning time slots to the link l_i, TfL algorithm first tries to use time slots that have been already assigned to other links to minimize the number of consumed time slots. Then, it uses new time slots that are not yet assigned to any links. In detail for determining whether the time slot $t(k)$ is assigned to link l_i, TfL algorithm calculates the capacity of the other links that are assigned the time slot $t(k)$ when l_i also uses $t(k)$. This is because the SINR would degrade when the number of links using the same time slot increases. When all links using $t(k)$ satisfy their traffic load, $t(k)$ is assigned to the link l_i. After that, we assess whether or not the traffic load on l_i is satisfied. If not, we try to add another time slot for the link l_i.

3.2 Links for Time Slots (LfT) Algorithm

LfT algorithm selects links which utilize each time slot to maximize the total link capacity in the time slot, based on a brute-force search. Therefore, LfT algorithm is equivalent to determining the values in Equation (1) column by column from left to right.

In what follows we present how to select links which utilize $t(k)$, meaning that we determine the values of kth column in Equation (1) after 1st, 2nd, …, $(k-1)$th columns are already calculated. The set of links which utilize the time slot $t(k)$ is obtained by solving the optimization problem which is defined as follows.

$$\text{minimize} \quad \sum_{\forall l_i \in E(k)} f_i(k) \tag{17}$$

$$\text{subject to} \quad a_i(k) = 0 \quad \left(\sum_{K=1}^{k-1} f_i(K) \geq Q_i, \forall i = 1, 2, \dots, |E| \right) \tag{18}$$

$$f_i(k) \geq 0 \qquad (a_i(k) = 1, \forall i = 1, 2, \dots, |E|) \tag{19}$$

Equation (17) means that we maximize the total capacity of links assigned the time slot $t(k)$. Equations (18) and (19) show the constraints in maximization of Equation (17) that we avoid assigning time slots to links whose traffic load is already satisfied, and that all links in $t(k)$ have positive value of the capacity, respectively. When this problem is solved by a simple brute-force search, $2^{|E|-|E^k|}$ of the time complexity is needed where E^k is shown in the following equation.

$$E^k(\in E) = \left\{ l_i \middle| \sum_{k=1}^{K-1} f_i(k) \geq Q_i, \forall i = 1, 2, \dots, |E| \right\} \tag{20}$$

E^k means a set of links which have already been satisfied their traffic load with time slots $t(1), t(2), \dots t(k-1)$. This equation means that the calculation time by brute-force search increases rapidly when $|E|$ increases. Therefore, we introduce the parameter L_{max}, which denotes the upper limit of the number of links using the same time slot. This dramatically suppresses the space for the brute-force search.

After determining the link assignment for time slot $t(k)$, we check whether or not all links are satisfied their traffic load. If not, we move to the link assignment for the next time slot $t(k+1)$.

4. PERFORMANCE EVALUATION RESULTS AND DISCUSSIONS

In this section, we evaluate the performance of the proposed algorithms through simulation experiments.

4.1 Simulation Settings

In the experiments, one gateway is placed at the center of a 1x1 square area, and relay nodes are randomly distributed. The network topology is constructed by the topology construction algorithm shown in [30] so that the hop count from each relay node to the gateway node becomes minimized. All nodes have an estimated transmission distance of 0.2, which is used for the network topology construction. Figure 3 shows an example of the network topology in the simulation experiments. The traffic load on each link is determined by the sum of the traffic from the client terminals whose path to the backhaul network includes the link. The traffic demand from the relay nodes is determined based on their Voronoi Cell [38] size assuming that client terminals are distributed uniformly in the square area, connect to the nearest relay node, and generate the same amount of traffic toward backhaul networks.

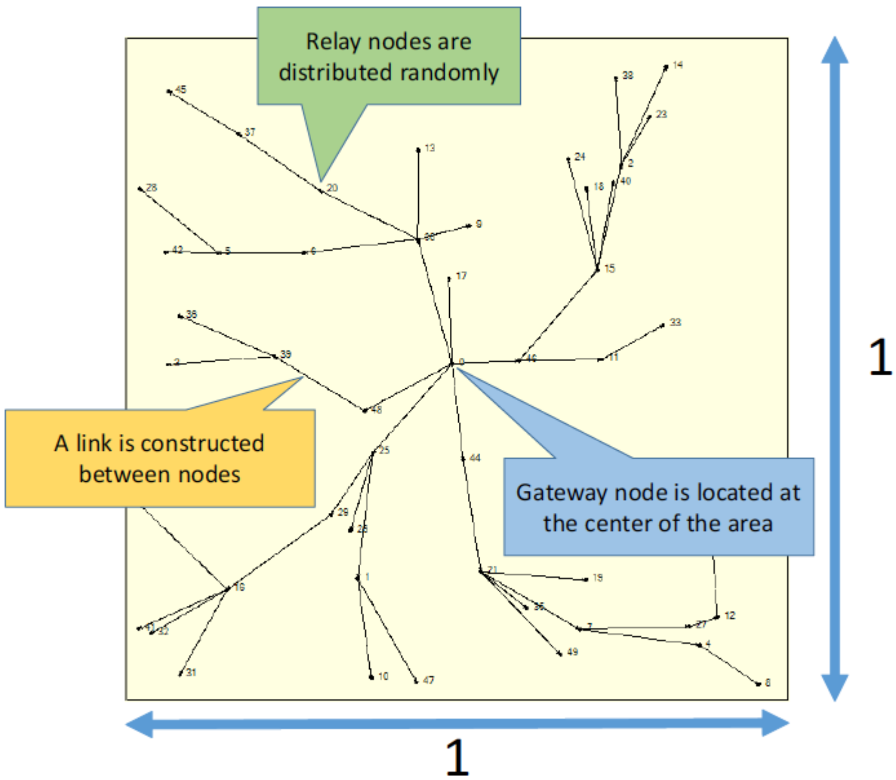

FIGURE 3: An Example of relay network topology for simulation experiments.

For determining the signal strength from the relay node, we assume that the transmission signal strength, power decay, and the degree of shadowing effects are identical for all relay nodes. Then, Equation (8), which represents the probability at which the SINR at receiver node $v_n^{(i)}$ from sender node $v_m^{(i)}$ at time slot $t(k)$ is larger than B, is calculated as follows [39, 40].

$$p_{i,B}(k) = \exp\left(-\frac{BP_{noise}}{P_i r_{m,n}^{-\alpha}}\right) \prod_{l_o \in E(k) \setminus l_i} \frac{1}{1 + B\left(\frac{r_{m,n}}{r_{o,n}}\right)^{\alpha}} \quad (21)$$

Note that α and B are set to 5.0 and 4.0, respectively.

We conduct the simulation experiments for the proposed algorithms in Section 3 with various parameter values. For each parameter set we conduct multiple experiments with different node placements and evaluate the average performance. We also observe the result of each simulation trial to assess the detailed performance characteristics of the proposed methods.

4.2 Evaluation Results and Discussions

4.2.1 Schedule Length

Figure 4 shows the distribution of the schedule length obtained by TfL algorithm. We set the amount of total traffic, which is denoted by Q_{all} is set to 307,200. This is the result of 100 times simulation trials, each of which has a different time slot assignment order of links with a fixed placement of thirty nodes. From this figure, we find that the schedule length obtained by TfL algorithm is distributed widely even when the node placement is identical, that means that the performance is largely affected by the time slot assignment order. Therefore, in the rest of the performance evaluation, we take the shortest schedule length out of 100 simulation trials as the performance of TfL algorithm.

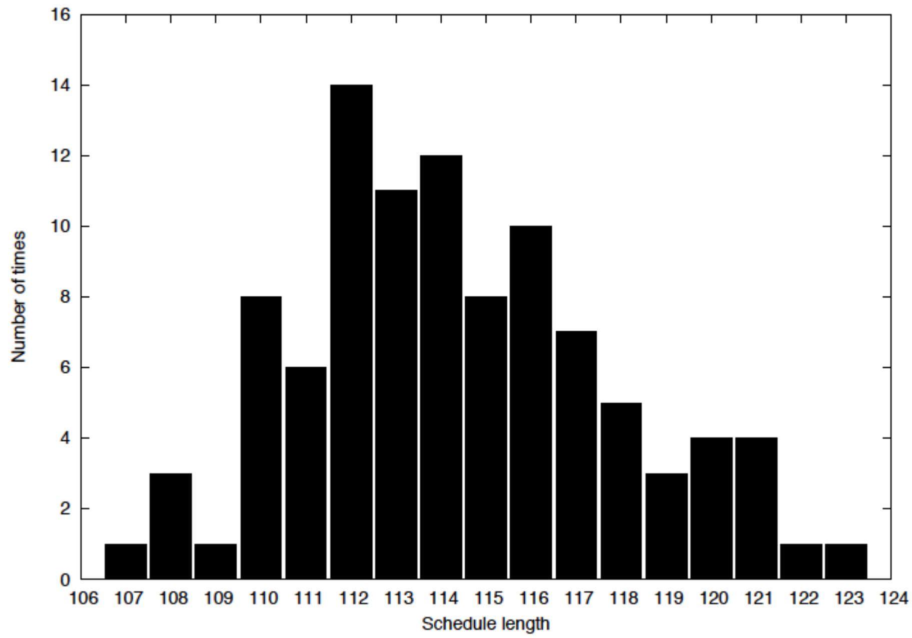

FIGURE 4: Schedule Length Distribution by TfL Algorithm.

Figure 5 plots the schedule lengths of TfL and LfT algorithms for sampled five placements of thirty nodes. Q_{all} is set to 307,200. Note that the results for other node placements have similar tendency. In the graph, the horizontal axis represents the identifier of the node placement, and the vertical axis represents the schedule length. For LfT algorithm, we show the results where the parameter L_{max} is set to one through five. Note that LfT algorithm with L_{max}= 1 represents the case where no spatial reuse of the wireless network resource is exploited, meaning that only one link communicates at each time slot. By comparing the results of LfT algorithm with L_{max} = 1 and other results, we observe that the spatial reuse of the wireless network resources can greatly reduce the schedule length.

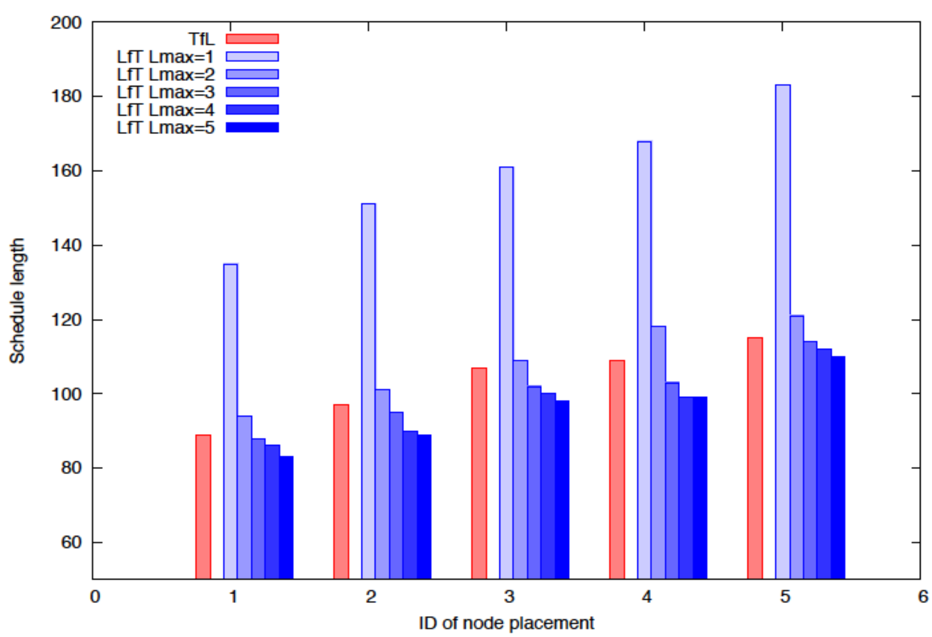

FIGURE 5: Schedule Length of Proposed Algorithms.

Table 2 shows the average reduction ratio of the schedule length of the proposed algorithms against no spatial reuse case. This plots the results of 100 times simulation trials with different node placements. We can see from Figure 5 and Table 2 that the schedule length of TfL algorithm is larger than that of LfT algorithm with larger values of L_{max}. The reason for this difference is due to the characteristics of TfL and LfT algorithms. TfL algorithm tries to assign time slots which are already used by other links. It causes the decrease in the capacity of such links at the time slots. Consequently, a larger number of different time slots are required for the links to satisfy their traffic loads. On the other hand, LfT algorithm selects links to maximize the total link capacity in each time slot. Therefore, in LfT algorithm the interference strength at each time slot is smaller compared with TfL algorithm. We can also observe from Figure 5 that the schedule length of LfT algorithm reduces by increasing values of L_{max}. However, when L_{max} is larger than around three, the degree of performance improvement becomes smaller. This means that the limitation of search space in LfT algorithm is reasonable as expected.

	TfL	LfT $L_{max} = 2$	LfT $L_{max} = 3$	LfT $L_{max} = 4$	LfT $L_{max} = 5$
Reduction Ratio (%)	34.2	31.2	36.2	37.9	38.6

TABLE 2: Average Reduction Ratio of Schedule Length.

4.2.2 Effect of Total Traffic Amount

Figure 6 shows the comparison of the average schedule lengths of both algorithms as a function of the amount of total traffic (Q_{all}). The number of nodes is set to thirty and L_{max} of LfT algorithm is set to five. We conduct 50 times of experiments for each value of Q_{all}. We also plot the 99% confidential intervals of the schedule length with errorbars. From this figure we first find that the schedule length increases with the increase in the amount of total traffic. The reason is that the traffic load of all links increases and the number of required time slot becomes large. We also find that the schedule length of TfL algorithm is shorter than that of LfT algorithm when the amount of total traffic is small, and the relationship becomes opposite with large total traffic amount. This is because of the characteristics of both algorithms in time slot assignment against the traffic load on each link. TfL algorithm explicitly takes care the satisfaction of the traffic load at each time slot assignment for a certain link. On the other hand, LfT algorithm first selects the link combinations to maximize the total link capacity for a certain time slot, and then assesses the satisfaction of traffic loads on the selected links. This difference affects the effectiveness of time slot assignment especially when the total traffic amount is small.

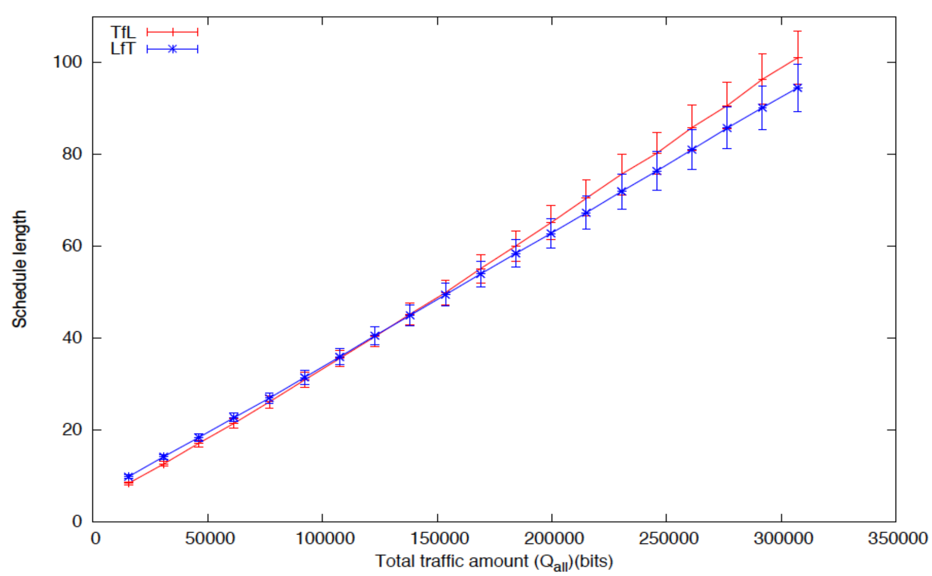

FIGURE 6: Average Schedule Length as a Function of Total Traffic Amount.

4.2.3 Comparison With Optimal Solutions

Figure 7 shows the distribution of the schedule length of the proposed algorithms and optimum solutions for 100 simulation experiments with different node placements. We set the number of nodes to five and Q_{all} to 30,720. We obtained the optimum solutions by simple brute-force search algorithm for all combinations of the time slot assignment to satisfy Equation (10). We observe from this figure that TfL and LfT algorithms give solutions equivalent to the optimal values in 91% and 86% of simulation experiments, respectively. From these results we conclude that both algorithms can give reasonable results of time slot assignment compared with the optimum solutions.

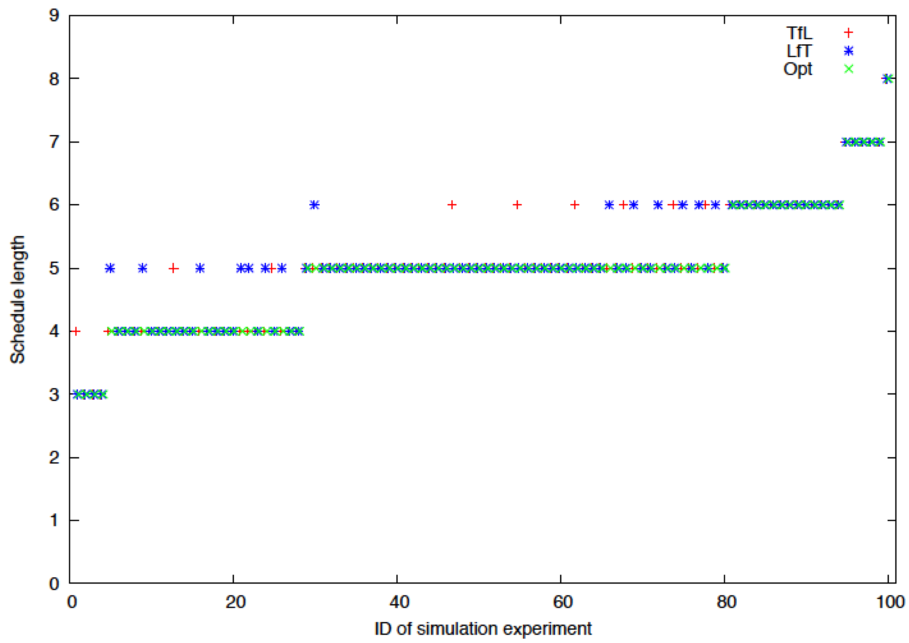

FIGURE 7: Comparison of Proposed Algorithms with Optimum Solutions.

4.2.4 Calculation Time

Figure 8 presents the calculation time required for a single simulation run by TfL and LfT algorithms. In Figure 8, the horizontal axis represents the number of nodes in the network and the vertical axis represents the calculation time. We conducted the simulation experiments on a computer with a 2.93 GHz CPU and 3 GB of RAM.

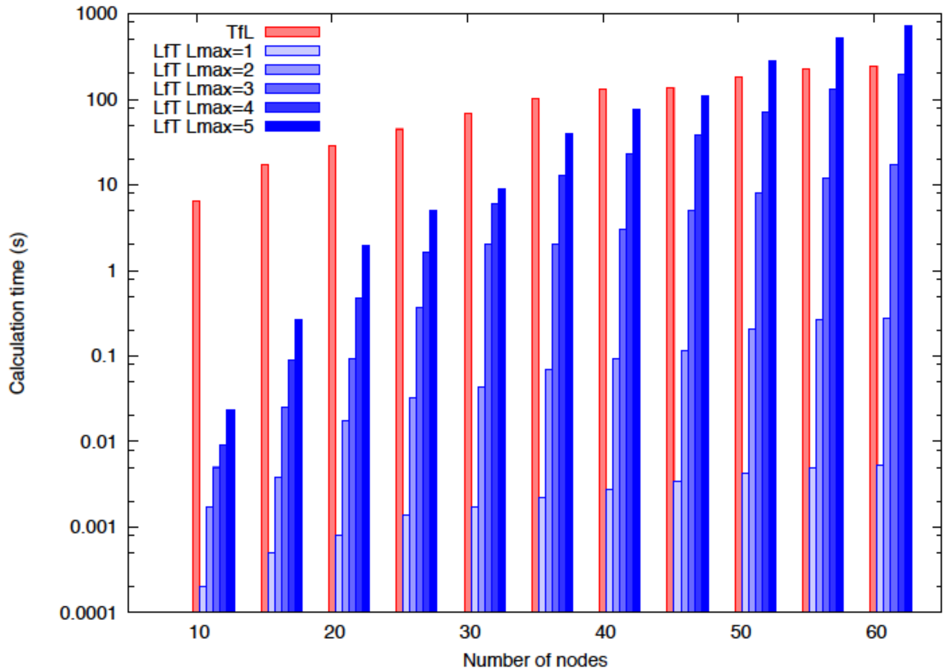

FIGURE 8: Calculation Time of Proposed Algorithms.

From Figure 8, we observe for LfT algorithm that the calculation time increases rapidly with the increase in L_{max} and the number of nodes. This is because the number of link combinations by the brute-force search expands drastically. In detail, when LfT algorithm selects links which utilize the time slot $t(1)$ in the n nodes network, the number of possible combinations of links is $\sum_{l=1}^{L_{max}} \binom{n}{l}$. Therefore, whichever L_{max} and the number of nodes increases, the calculation time for LfT algorithm increases rapidly.

On the other hand, the calculation time for TfL algorithm increases almost linearly with the increase in the number of nodes. The reason is that in TfL algorithm, the number of calculations for the link capacity is $\sum_{x=1}^{n} \frac{Q_i}{d_1}(x-1)$ at most.

4 CONCLUSIONS

In this paper, we proposed two heuristic algorithms for time slot assignment problem in IEEE 802.16j relay networks. One algorithm assigns a set of time slots to links by a greedy approach to minimize the number of consumed time slots, while the other algorithm determines a set of links that use a time slot by a brute-force search for maximizing the total link capacity.

Through extensive simulation experiments, we found that the proposed algorithms can reduce the number of required time slots by up to 34% and 39%, respectively, compared with the case where no link utilizes the same time slot. We also found that calculation time of the latter algorithm is longer than that of the former algorithm. Therefore, we conclude that there is a tradeoff between performance and calculation time in both algorithms and it is necessary to choose the algorithm according to which the performance or the calculation time is more important. Additionally, we showed that the proposed algorithms can obtain the optimum solutions 91% and 86% simulation experiments.

In future work, the comparative evaluation of the proposed method with existing methods is necessary. We also plan to improve the proposed algorithms, for example reducing calculation time and schedule length by exploiting other kinds of heuristic algorithms such as simulated annealing. Furthermore, we will evaluate the proposed algorithms based on other performance metrics such as transmission latency and throughput. Implementation of the proposed method as the driver for the actual WiMAX interface is one of possible future research direction.

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