Joint Optimization of Channel Allocation and AP Selection for WLAN with Multi-Priority Transmissions

Xinwei Chen*, Xiaofeng Zhong*, Shidong Zhou*, and Jie Wei†
* Beijing National Research Center for Information Science and Technology
Department of Electronic Engineering, Tsinghua University, Beijing 100084, China
† School of Electronic and Information Engineering, Beijing Jiaotong University, Beijing 100044, China
Email: cxw22@mails.tsinghua.edu.cn, {zhongxf, zhousd}@tsinghua.edu.cn, jwei@bjtu.edu.cn

***Abstract*—Recent years have witnessed a rapid growth of WiFi pervasively applied in multimedia content distribution. WiFi multicast is widely applied in user-dense scenarios where the spectrum resource is insufficient. Moreover, existing access point (AP) selection and channel allocation algorithms lack in-depth study on per-user throughput requirements. This paper proposes a joint optimization of AP selection and channel allocation method for multi-priority WLAN transmissions to maximize the various users' weighted throughput satisfaction rate. In this method, we first design a 0-1 integer nonlinear programming model to describe the AP selection and channel allocation problem in the scenario of a WiFi multicast task and other tasks with different priorities. Moreover, to lower the complexity of solving mixed-integer nonlinear programming problems, we design a heuristic algorithm to obtain high-efficiency solutions.**

***Index Terms*—Channel allocation, AP selection, multi-priority, utility function, WiFi multicast, 0-1 integer nonlinear programming.**

I. Introduction

With the trend of WLAN pervasively applied in life, services such as one-touch in hospitals, advertising in large shopping malls, and live lectures in enterprises are transmitted via WiFi multicast. However, due to the high throughput requirement and the shortage of wireless spectrum, it is challenging to provide rich and stable multimedia in user-crowded areas. Most of the existing work improves the quality of multicast transmissions by dynamically adjusting the transmission rate and providing feedback [1], [2]. Due to the high bandwidth requirements and the shortage of wireless spectrum, passively adjusting the multicast transmission rate and selecting the appropriate feedback is not a good guarantee of the quality of service (QoS). Thus, in this paper, we concentrate on improving the transmission quality of WiFi systems through access point selection and channel allocation.

Many works have studied the centralized channel allocation problem in WLAN. A poor channel allocation results in substantial contention between the access points (APs) and stations (STAs) and a reduction in the throughput of each AP [3]. To raise the maximum achievable rates, 802.11n extends the bandwidths to 40MHz through channel bonding, and 802.11ac extends the bandwidths to 80MHz and 160MHz. However, much of the current work does not take into account the fact that the bandwidth of a channel may have different values due to channel bonding [3], [4]. On the other hand, the increased interference due to channel bonding is the major constraint for wireless network performance. Nevertheless, in channel allocation-related work, the general approach adopted is to consider channels to be orthogonal to each other, i.e., to ignore energy leakage between adjacent channels, or to avoid channel interference by restricting specific APs nearby from using adjacent channels [3]–[6].

In addition, for channel allocation, the traffic demand of an AP cannot be assumed to be constant and predetermined since it depends highly on the AP selection of each station [7]. Hence finding an appropriate AP selection scheme is another major objective of this study. Under this situation, joint optimization of channel allocation and AP selection can significantly determine the network performance. Furthermore, both channel allocation and AP selection schemes imply the possibility of delay, which is a non-negligible impact on transmission performance. According to the 802.11h standard (later included in amendments like 802.11ax), the AP may notify the associated STAs through Channel Switch Announcement (CSA) frames. The channel switching delay is the sum of the time of broadcasting the CSA frames and the time of the STAs adapting to the new primary channel [8]. The new AP selection scheme can also cause delays. After the new target AP for a STA has been selected, the STA should identify itself to the new AP (Authentication Phase) and its concurrent sessions are transferred from the old AP to the new one (Association Phase) [9]. Therefore, it is necessary to consider the feasibility of channel switching and AP switching based on the tolerance of delay for different types of transmissions.

The contribution of this paper is to propose a joint AP selection and channel allocation method for WLAN with multi-priority transmissions. We consider the AP selection and channel allocation problem after a high-priority transmission with high throughput requirements, such as WiFi multicast being added to the scenario. The rest of this paper is organized as follows. Section II introduces a specific application scenario to draw out our method and conduct a mathematical model of 0-1

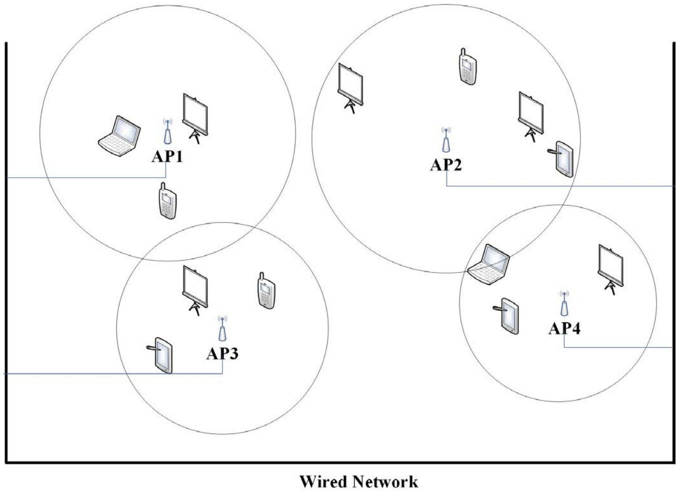

Fig. 1. Network Topology

integer nonlinear programming. A heuristic algorithm to solve the above model is proposed in Section III. In Section IV, the performance of our algorithm is evaluated through simulations. Finally, the conclusion is given in Section V.

II. Problem Formulation

A. Scenario Description

We consider the communication quality assurance problem of adding a WiFi multicast task when multiple unicast tasks already exist in the scenario. For instance, in a large conference hall, WiFi multicast is utilized to display the speaker's video in real-time on multiple screens. The audience's mobile phones and other electronic devices in the venue are WiFi unicast tasks. Nonetheless, priority should be given to guaranteeing the transmission quality of the WiFi multicast, which has a large target throughput. We aim to develop a centralized optimization algorithm for AP selection and channel allocation to obtain excellent performance for the WiFi multicast task.

This paper focuses on an IEEE 802.11 WLAN with an infrastructure network topology, as shown in Fig. 1. On account of the existence of more than one APs and STAs, the network topology of the above scenario is abstracted as a single extended service set (ESS) managed by one particular administrator.

B. Access Categories and Utility Function

Due to the limited spectrum resources, it is worthwhile to obtain a more rational allocation of spectrum resources according to the priority and throughput requirements of different traffic. 802.11e classifies traffic into four Access Categories (ACs), mapped into the priorities defined by the 802.11D standard, as shown in TABLE I [10], [11], which provides the foundation for our AP selection and channel allocation scheme. As mentioned in Section I, switching the AP for the STA and switching the channel for the AP both result in delay, seriously affecting the user experience of tasks with

TABLE I
Station Priority to Access Category(AC) Mappings Defined by 802.11

Priority	802.1D designation	AC	Designation (informative)
lowest	BK	AC_BK	Background
	BE	AC_BE	Best Effort
↓	VI	AC_VI	Video
highest	VO	AC_VO	Voice

high real-time requirements, such as streaming services. Since VI and VO tasks are latency-sensitive, we specify the new AP selection scheme and channel allocation scheme to ensure that these two types of traffic maintain their original APs and the corresponding APs maintain their original channels.

The throughput obtained by the STAs depends on the result of the AP selection scheme and channel allocation scheme, essentially, the utility function. Assigning weight according to priority in the utility function can effectively ensure the QoS for traffic with higher priority. In addition, maximizing the aggregate throughput can potentially waste spectrum resources. Aware of the weakness mentioned above, [12] formulates a problem to maximize the number of secondary users satisfied in terms of throughput. However, such utility functions fail to motivate the system to provide greater throughput for traffic whose throughput has yet to be satisfied. Using the weighted throughput satisfaction rate as the utility function contributes to the efficient use of spectrum resources. We will develop this in detail in the following subsections.

C. System Assumptions and Notation

For unicast tasks, STAs and tasks correspond one-to-one, while a multicast task corresponds to multiple STAs. Helga et al. show that 802.11 MAC works better for APs operating on the same channel than in nearby overlapping channels [13], [14]. Therefore, to optimize the performance and simplify the model when formulating the channel allocation strategy, we restrict channels with spectrum overlap cannot be used simultaneously. IEEE 802.11 employs a carrier sense multiple access with collision avoidance (CSMA/CA) MAC protocol [15]. According to CSMA/CA, when multiple STAs select the same channel, they must use it in turn. To sum up, for the case where there are V traffics simultaneously selecting channel c_m, it is considered that $1/V$ of the time of that channel is used to transmit the data of each STA.

The symbols used in our problem formulation are defined as follows:

- The network consists of N STAs denoted by s_n, $n \in \{0, 1, \cdots, N-1\}$, which include U STAs related to WiFi multicast: $s_0, s_1, \cdots, s_{U-1}$ and $N-U$ STAs for unicast tasks: $s_U, s_{U+1}, \cdots, s_{N-1}$. There are also K APs denoted by a_k, $k \in \{0, 1, \cdots, K-1\}$. The weights of the STAs are denoted by $\boldsymbol{w}^s = [w_0^s, w_1^s, \cdots, w_{N-1}^s]^{\mathrm{T}}$.
- The total M available channels are denoted by c_m, $m \in \{0, 1, \cdots, M-1\}$. The widths of the channels are denoted by $\boldsymbol{W}^c = [W_0^c, W_1^c, \cdots, W_{M-1}^c]^{\mathrm{T}}$.

- The objective throughputs of the STAs are denoted by $\boldsymbol{t}^o = [t_0^o, t_1^o, \cdots, t_{N-1}^o]^{\mathrm{T}}$.
- Each STA's received power for each AP is denoted by a matrix $\boldsymbol{P}^r$ of size $N \times K$. For the $n+1$th row, the element $P_{n,k}^{\mathrm{r}}$ in the $k+1$th column represents the received power of the STA s_n for the AP a_k, which can be obtained by scanning.
- To describe the results of the AP selection and channel allocation, two 0-1 integer matrices are introduced, the matrix $\boldsymbol{X}$ of size $M \times K$, representing the results of channel allocation and the matrix $\boldsymbol{Y}$ of size $K \times N$, representing the results of AP selection. For the matrix $\boldsymbol{X}$, the element $X_{m,k} = 1$ in the $m+1$th row and the $k+1$th column indicates that the AP a_k selects the channel c_m for data transmission. For the matrix $\boldsymbol{Y}$, the element $Y_{k,n} = 1$ in the $k+1$th row and $n+1$th column indicates that the STA s_n selects the AP a_k for data transmission. $\boldsymbol{Z}$ represents the correspondence between channels and STAs, where $\boldsymbol{Z} = \boldsymbol{X} \times \boldsymbol{Y}$. And the initial AP selection and channel allocation matrices are $\boldsymbol{X'}$ and $\boldsymbol{Y'}$ respectively.

D. AP Selection and Channel Allocation Problem

For the AP selection and channel allocation problem, each station associates with only one AP, and each AP associates with only one channel. The above one-to-one correspondences are expressed as follows.

$$\sum_{m=0}^{M-1} X_{m,k} = 1, \forall k \in \{0, 1, ..., K-1\}. \tag{1}$$

$$\sum_{k=0}^{K-1} Y_{k,n} = 1, \forall n \in \{0, 1, ..., N-1\}. \tag{2}$$

The variable $\boldsymbol{v} = [v_0, v_1, \cdots, v_{N-1}]^{\mathrm{T}}$ is introduced to denote the total number of tasks on the selected channel of STA s_n. Therefore, for each STA, when $Z_{m,n} = 1$, i.e., STA s_n selects the channel c_m, then v_n is calculated as

$$v_n = \sum_{n'=U-1}^{N-1} Z_{m,n'}. \tag{3}$$

The throughput obtainable by each STA is defined as $\boldsymbol{t}^s = [t_0^s, t_1^s, \cdots, t_{N-1}^s]^{\mathrm{T}}$ obtainable by each STA. Since interference needs to be taken into account,

$$t_n^s = \frac{1}{v_n} \cdot W_n^{\mathrm{s}} \cdot \log_{10}(SINR_n + 1) \tag{4}$$

is used to calculate the throughput t_n^{s} obtainable by STA s_n. Let $\boldsymbol{W^{\mathrm{s}}} = [W_0^{\mathrm{s}}, W_1^{\mathrm{s}}, \cdots, W_{N-1}^{\mathrm{s}}]^{\mathrm{T}}$ denote the bandwidth of the channel selected by each STA, where the bandwidth of the corresponding channel can be further obtained by

$$W_i^{\mathrm{s}} = \boldsymbol{Z}_{:,i} \times \boldsymbol{W^{\mathrm{c}}}, \tag{5}$$

where $\boldsymbol{Z}_{:,i} = [Z_{0,i}, Z_{1,i}, \cdots, Z_{M-1,i}]$. For STA s_n, its Signal to Interference plus to Noise Ratio (SINR) is calculated as

$$SINR_n = \frac{P_n^{\mathrm{s}}}{P_n^{\mathrm{i}} + P_n^{\mathrm{n}}}, \tag{6}$$

where $\boldsymbol{P^{\mathrm{s}}} = [P_0^{\mathrm{s}}, P_1^{\mathrm{s}}, \cdots, P_{N-1}^{\mathrm{s}}]^{\mathrm{T}}$ denotes the power of the useful signal received by this STA. P_n^{s} is calculated as:

$$P_n^{\mathrm{s}} = \sum_{k=0}^{K-1} (Y_{k,n} \cdot P_{k,n}^{\mathrm{r}}), \tag{7}$$

$\boldsymbol{P^{\mathrm{i}}} = [P_0^{\mathrm{i}}, P_1^{\mathrm{i}}, \cdots, P_{N-1}^{\mathrm{i}}]^{\mathrm{T}}$ denotes the power of the interference signal received by each STA, and $\boldsymbol{P^{\mathrm{n}}} = [P_0^{\mathrm{n}}, P_1^{\mathrm{n}}, \cdots, P_{N-1}^{\mathrm{n}}]^{\mathrm{T}}$ denotes the noise of each STA's channel, which generally equals to the value of white noise.

If other APs in the scenario are adjacent to the channel selected by the AP corresponding to the STA, then for this STA, the received power of the STA to this neighboring AP should become the interference power through the leakage factor. When calculating the SINR of STA s_n, its P_n^{i} is calculated as:

$$P_n^{\mathrm{i}} = \sum_{\forall k' \in \mathcal{A}_n.} (P_{k',n}^{\mathrm{r}} \cdot 10^{o/10}), \tag{8}$$

where o is the leakage coefficient in dB, which can be obtained from the spectral mask, and $\mathcal{A}_n$ is the index set of s_n's adjacent APs.

Since we restrict that channels with partially overlapping spectra cannot be selected simultaneously. A graph $\mathcal{G} = \{\mathcal{V}, \mathcal{E}\}$ is introduced to express the spectral overlap relation between channels, where the vertex set $\mathcal{V} = \{c_m\}_{m=0}^{M-1}$ denotes the channels and the edge set $\mathcal{E} = \{(m, m') : c_m, c_{m'}$ has mutually overlapping frequency bands$\}$. Therefore, the constraint

$$\Big(\sum_{k=0}^{K-1} X_{m,k}\Big) \cdot \Big(\sum_{k=0}^{K-1} X_{m',k}\Big) = 0, \quad \forall (m, m') \in \mathcal{E}. \tag{9}$$

should be satisfied.

Since the VI task and the VO task can neither switch channels nor switch APs. The following constraints should be satisfied.

$$Y_{k,n} = Y'_{k,n}, k \in \{0, 1, \cdots, K-1\}, s_n \in \{\text{VI}, \text{VO}\}. \tag{10}$$

$$X_{m,k} = X'_{m,k}, m \in \{0, 1, \cdots, M-1\}, \text{if } \exists s_n \in \{\text{VI}, \text{VO}\} \text{ on } a_k. \tag{11}$$

The throughput satisfaction rate of N STAs is expressed as $\boldsymbol{r} = [r_0, r_1, \cdots, r_{N-1}]^{\mathrm{T}}$, where

$$r_n = \min\left\{\frac{t_n^{\mathrm{s}}}{t_n^{\mathrm{o}}}, 1\right\}, n \in \{0, 1, 2, \cdots, N-1\}. \tag{12}$$

The utility function is the priority-weighted throughput satisfaction rate of the STAs, denoted as S. In summary, our optimization problem can be constructed as

$$\max_{\boldsymbol{X}} \left\{S = \sum_{n=0}^{N-1} w_n^{\mathrm{s}} \times r_n\right\}, \quad \text{s.t.} \quad (1), (2), (9), (10) \text{ and } (11). \tag{13}$$

III. Two-Stage Greedy Iterative (TSGI) Algorithm

Due to the large number of channels (taking the WiFi 5GHz band as an example, there are 23 channels after channel bonding), the computations cannot be afforded in general scenarios. For example, the computational complexity for N STAs, K APs and M channels is $O(M^K \times K^N)$. Therefore, in this section, an efficient algorithm whose computational complexity is $O((M \times K) + (K \times N))$ to the above model is presented.

In algorithm 1, we propose a two-stage greedy iterative (TSGI) algorithm for AP selection and channel allocation. The main idea is to fix one of the optimization variables to solve the other optimization variable and iterate the solution in two stages until the solution converges. When fixing one of the optimization variables, the greedy idea is used to solve the other optimization variable. For the AP selection stage, the TSGI algorithm guarantees the STAs with higher priority to obtain a better throughput satisfaction rate. Similarly, for the channel allocation stage, the TSGI algorithm guarantees the performance of APs with higher total task priority, which is determined by the total weight of tasks on APs.

We give different weights to the WiFi multicast task and the four categories of tasks above. w_0, w_1, w_2, w_3, w_4 represents the weight of WiFi multicast, VI tasks, VO tasks, BE tasks, and BK tasks, respectively, satisfying the following relationship

$$w_0 > w_1 > w_2 > w_3 > w_4. \tag{14}$$

The main steps of the algorithm are as follows: For initialization, we obtain the AP selection scheme $\boldsymbol{Y'}$ before the WiFi multicast task joins and the channel allocation scheme $\boldsymbol{X'}$. To determine whether to continue the iteration, we maintain a variable d that represents the score difference between two iterations. The iteration is stopped when d is less than the threshold d_c (line 3). In order to select APs and channels according to priority, we define the index $\boldsymbol{i} = [i_0, i_1, \cdots, i_{N-1}]^{\mathrm{T}}$ satisfying the constraint: $w^{\mathrm{s}}_{i_0} \geq w^{\mathrm{s}}_{i_1} \geq \cdots \geq w^{\mathrm{s}}_{i_n} \geq \cdots \geq w^{\mathrm{s}}_{i_{N-1}}$, and define

$$\tilde{\boldsymbol{Y}} = [\boldsymbol{Y}^{\mathrm{T}}_{:,i_0}, \boldsymbol{Y}^{\mathrm{T}}_{:,i_1}, \cdots, \boldsymbol{Y}^{\mathrm{T}}_{:,i_{N-1}}]^{\mathrm{T}}; \tag{15}$$

$$\tilde{\boldsymbol{P}}^{\mathrm{r}} = [{\boldsymbol{P}^{\mathrm{r}}_{:,i_0}}^{\mathrm{T}}, {\boldsymbol{P}^{\mathrm{r}}_{:,i_1}}^{\mathrm{T}}, \cdots, {\boldsymbol{P}^{\mathrm{r}}_{:,i_{N-1}}}^{\mathrm{T}}]^{\mathrm{T}}; \tag{16}$$

$$\tilde{\boldsymbol{P}}^{\mathrm{n}} = [{\boldsymbol{P}^{\mathrm{n}}_{:,i_0}}^{\mathrm{T}}, {\boldsymbol{P}^{\mathrm{n}}_{:,i_1}}^{\mathrm{T}}, \cdots, {\boldsymbol{P}^{\mathrm{n}}_{:,i_{N-1}}}^{\mathrm{T}}]; \tag{17}$$

$$\tilde{\boldsymbol{w}}^{\mathrm{s}} = [w^{\mathrm{s}}_{i_0}, w^{\mathrm{s}}_{i_1}, \cdots, w^{\mathrm{s}}_{i_{N-1}}]^{\mathrm{T}}, \tag{18}$$

where

$$\boldsymbol{Y}_{:,i_n} = [Y_{0,i_n}, Y_{1,i_n}, \cdots, Y_{K-1,i_n}]; \tag{19}$$

$$\boldsymbol{P}^{\mathrm{r}}_{:,i_n} = [P^{\mathrm{r}}_{0,i_n}, P^{\mathrm{r}}_{1,i_n}, \cdots, P^{\mathrm{r}}_{K-1,i_n}]; \tag{20}$$

$$\boldsymbol{P}^{\mathrm{n}}_{:,i_n} = [P^{\mathrm{n}}_{0,i_n}, P^{\mathrm{n}}_{1,i_n}, \cdots, P^{\mathrm{n}}_{K-1,i_n}]. \tag{21}$$

$\mathcal{M}$ represents the mapping relationship before and after sorting: $\boldsymbol{w}^{\mathrm{s}} \to \tilde{\boldsymbol{w}}^{\mathrm{s}}$, $\boldsymbol{Y'} \to \tilde{\boldsymbol{Y}}'$, $\boldsymbol{t}^{\mathrm{o}} \to \tilde{\boldsymbol{t}}^{\mathrm{o}}$ (line 2). For VI and VO tasks, their STAs keep their original APs (line 6). The multicast-related STAs need to be restricted to selecting the same AP since the multicast task has the highest priority weight, the STAs for WiFi multicast need to select the AP with the highest overall score first (line 9). By traversing all APs for all STAs, for STA s_n, the total score is obtained, and the AP corresponding to the highest total score is selected as the AP for this STA.

Similar to AP selection, in the stage of selecting channels for APs, we denote $\boldsymbol{W}^{\mathrm{A}} = [W^{\mathrm{A}}_0, W^{\mathrm{A}}_1, \cdots, W^{\mathrm{A}}_{K-1}]^{\mathrm{T}}$ as the total weight of tasks on APs, which determines the order of channel selection for APs (line 19). Regarding the priority order, it is necessary to find the index $\boldsymbol{j} = [j_0, j_1, \cdots, j_{K-1}]^{\mathrm{T}}$ satisfying the constraint: $W^{\mathrm{A}}_{j_0} \geq W^{\mathrm{A}}_{j_1} \geq \cdots \geq W^{\mathrm{A}}_{j_{K-1}}$. And define $\tilde{\boldsymbol{X}} = [\boldsymbol{X}_{:,j_0}, \boldsymbol{X}_{:,j_1}, \cdots, \boldsymbol{X}_{:,j_{K-1}}]$, where $\boldsymbol{X}_{:,j_n} = [X_{0,j_n}, X_{1,j_n}, \cdots, X_{M-1,j_n}]^{\mathrm{T}}$; $\hat{\boldsymbol{P}}^{\mathrm{r}} = [\tilde{\boldsymbol{P}}^{\mathrm{r}}_{:,j_0}, \tilde{\boldsymbol{P}}^{\mathrm{r}}_{:,j_1}, \cdots, P^{\mathrm{r}}_{:,j_{K-1}}]$, where $\tilde{\boldsymbol{P}}^{\mathrm{r}}_{:,j_n} = [\tilde{P}^{\mathrm{r}}_{0,j_n}, \tilde{P}^{\mathrm{r}}_{1,j_n}, \cdots, \tilde{P}^{\mathrm{r}}_{M-1,j_n}]^{\mathrm{T}}$. Similar to AP selection, $\mathcal{M}^A$ represents the mapping relationship during AP sorting.

TSGI algorithm maintains an optional channel set, denoted as $\mathcal{V}^{\mathrm{s}}$. During initialization, all channels are available for selection, so $\mathcal{V}^{\mathrm{s}}$ is initialized to the set of all channels at initialization (line 4). When a new channel is selected, the channels that have overlapping spectrum with the selected channel are removed from $\mathcal{V}^{\mathrm{s}}$ according to the constraint (9) (line 28). After traversing the optional channels for all APs according to the total weight order on the AP (line 24) and selecting the channel that guarantees the higher total weight on that AP and the other APs ahead of it in weight order as the channel for that AP, we can obtain the optimal AP selection and channel allocation scheme through one round of iterations. After one iteration, we check whether the score converges. If the score has not converged, the TSGI algorithm continues the iteration (line 30). The final AP selection scheme and channel allocation scheme are obtained when the score S converges.

IV. Simulation Results

In this section, we validate the performance of our TSGI algorithm through simulations. First, we introduce the scenario of our simulations. There are 7 multicast-related STAs in the scenario, one of which is the source side of the cast screen, which shares the screen through the AP with the remaining 6 screens. The remaining 15 STAs correspond to unicast tasks, and there are a total of 4 APs providing services. The settings for the objective throughput are designed regarding the throughput requirements for video transmission and file transfer. In order to make the parameters of the simulation closer to reality, we obtain the commercial AP transmit power P_t and randomly generate the coordinates of STAs and APs. We refer to

$$\begin{aligned} PL_{ent}(d_{i,j}) = 40.05 + 20 \times log_{10}(\min\{d_{i,j}, 10\}) \\ +(d_{i,j} > 10) \times 35 \times log_{10}(\frac{d_{i,j}}{10}) + 7 \times W_{i,j}. \end{aligned} \tag{22}$$

in [16] to calculate the path loss PL in dB of the power, where PL_{ent} means the path loss for the enterprise scenario. And

Algorithm 1 TSGI Algorithm

Input:
$\{\boldsymbol{X}', \boldsymbol{Y}', \boldsymbol{W}^{\text{c}}, \boldsymbol{P}^{\text{r}}, \boldsymbol{P}^{\text{n}}, \boldsymbol{t}^{\text{s}}, \mathcal{G}\{\mathcal{V}, \mathcal{E}\}, \boldsymbol{w}^{\text{s}}, o\}$;
Output:
$\boldsymbol{X}, \boldsymbol{Y}$;
Sort $\boldsymbol{w}^{\text{s}}$,$\boldsymbol{t}^{\text{o}}$,$\boldsymbol{X}'$,$\boldsymbol{P}^{\text{r}}$,$\boldsymbol{P}^{\text{r=n}}$ by priority $\boldsymbol{w}^{\text{s}}$, and get $\mathcal{M}$, $\tilde{\boldsymbol{w}}^{\text{s}}$, $\tilde{\boldsymbol{t}}^{\text{o}}$, $\tilde{\boldsymbol{X}}'$,$\tilde{\boldsymbol{P}}^{\text{r}}$,$\tilde{\boldsymbol{P}}^{\text{n}}$;
Initialize $d = d_c + 10$;
while $d \geq d_c$ **do**
  Initialize the channel allocation matrix $\boldsymbol{X}$ to a zero matrix;
  for $n \in \{n : \tilde{w}^{\text{s}}_n = w_1$ or $\tilde{w}^{\text{s}}_n = w_2\}$ **do**
    $\tilde{X}_{k,n} = \tilde{X}'_{k,n}$ for $k \in \{0, 1, \cdots, K-1\}$;
  end for
  for $k = 0$ to $K-1$ **do**
    Calculate the overall score of the U WiFi multicast STAs if WiFi multicast choose AP a_k: S^U_k;
    Find $k^* = \max_k \{S^U_k\}$ and assign $\tilde{X}_{k^*,u} = 1$ for $u \in \{0, 1, \cdots, U-1\}$;
  end for
  for $n = U$ to $N-1$ **do**
    if $\tilde{w}^{\text{s}}_n \neq w_1$ and $\tilde{w}^{\text{s}}_n \neq w_2$ **then**
      for $k = 0$ to $K-1$ **do**
        Calculate the overall score of the current $n+1$ tasks if STA s_n choose AP a_k: S^n_k;
      end for
      Find $k^* = \max_k \{S^n_k\}$ and assign $\tilde{X}_{k^*,n} = 1$;
    end if
  end for
  Sort $\boldsymbol{Y}$, $\tilde{\boldsymbol{P}}^{\text{r}}$by $\boldsymbol{W}$, and get $\tilde{\boldsymbol{Y}}$,$\mathcal{M}^A$, $\hat{\boldsymbol{P}}^{\text{r}}$;
  Initialize the channel allocation matrix $\boldsymbol{Y}$ to a zero matrix;
  Initialize the selectable channel set $\mathcal{V}^s = \mathcal{V}$;
  Calculate $\boldsymbol{W}^{\text{A}}$.
  for $k = 0$ to $K-1$ **do**
    for $m \in \{m : c_m \in \mathcal{V}^s\}$ **do**
      Calculate the overall score of the current tasks on $k+1$ APs if AP k choose channel m: S^k_m;
    end for
    Find $m^* = \max_m \{S^k_m\}$ and assign $\tilde{Y}_{m^*,k} = 1$;
    Remove $c_{m'}$ from $\mathcal{V}^s$, $\quad \forall E_{m^*,m'} \in \mathcal{E}$;
  end for
  Calculate the overall score $S^{O\prime}$ according to $\tilde{\boldsymbol{X}}$ and $\tilde{\boldsymbol{Y}}$, $d = S^{O\prime} - S^O$, $S^O = S^{O\prime}$.
end while
From $\tilde{\boldsymbol{X}}$, $\tilde{\boldsymbol{Y}}$ we get the final optimal allocation matrix $\boldsymbol{X}$, $\boldsymbol{Y}$according to the inverse of $\mathcal{M}$, $\mathcal{M}^A$.

obtain the received power P_r of the STA to each AP in the simulation experiment from

$$PL = 10log_{10}\frac{P_t}{P_r}, \tag{23}$$

where $d_{i,j}$ denotes the distance between the STA and the AP, and $W_{i,j}$ denotes the number of walls between them.

In simulations, we observe the throughput satisfaction rate of each task as the number of unicast tasks increases. We choose the scheme maintaining the original channel allocation, selecting the AP with the maximum throughput satisfaction rate that can be obtained by WiFi multicast task as the baseline. The throughput satisfaction rate of each type of task in the WiFi multicast network in the allocation scheme obtained by the TSGI algorithm is compared with the baseline.

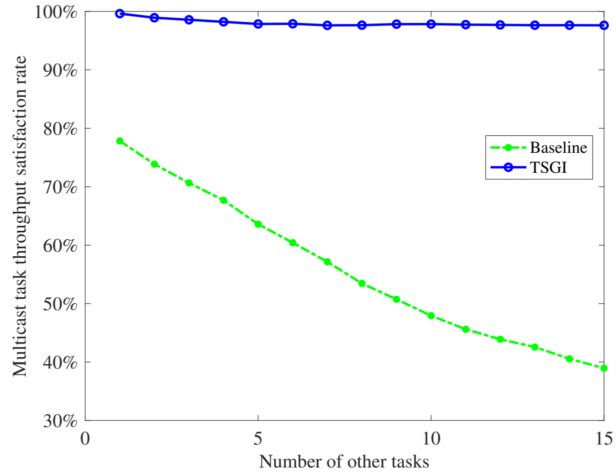

Fig. 2. The multicast task throughput satisfaction rate with respect to the number of tasks except for the multicast task.

Compared with the baseline, our approach improves the performance of tasks in the system, especially the WiFi multicast task, by switching channels for low-priority tasks with low real-time requirements while restricting VI and VO tasks to keep their original APs and their APs' channel allocation schemes. By allowing BE and BK tasks to switch APs and allowing APs to switch channels, the throughput satisfaction rate of the multicast task can be maintained at a high level, as shown in Fig. 2. As the number of tasks increases, the advantage of the TSGI algorithm becomes increasingly apparent. The obtained throughput satisfaction rate of the multicast task is 1.3-2 times higher than the baseline. With the increase in the number of other tasks, there is a trend of further improvement. For VI and VO tasks' STAs, the performance obtained by the TSGI algorithm is improved by 10%-75% compared to the baseline, as shown in Fig. 3. As the number of unicast tasks increases, the performance gain over the baseline becomes increasingly significant. For BE and BK tasks, as shown in Fig. 4, the average throughput satisfaction rate can be improved by up to 44% by using the TSGI algorithm. As the number of tasks increases, the number of switched STAs also increases. As shown in Fig.5, our approach obtains better performance at the cost of channel switching for tasks that do not require high real-time performance, which manifests its potential in being applied in user-dense scenarios.

V. Conclusion

In this paper, we considered the AP selection and channel allocation problem in the scenario with multi-priority transmissions and took the adjacent channel inference into account. The AP selection and channel allocation problem that allows BE and BK tasks to switch channels was abstracted as a 0-1 integer nonlinear programming problem. In order to reduce the complexity of solving our model, this paper proposed a two-stage greedy iterative algorithm to tackle the problem with high efficiency, which fixed the channel allocation scheme of

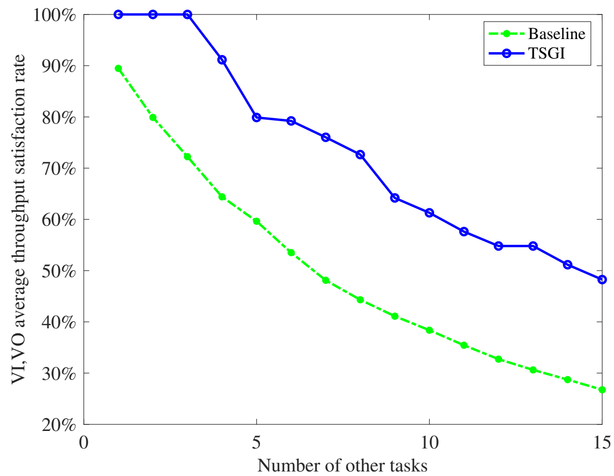

Fig. 3. VI, VO tasks' average throughput satisfaction rate with respect to the number of tasks except for the multicast task.

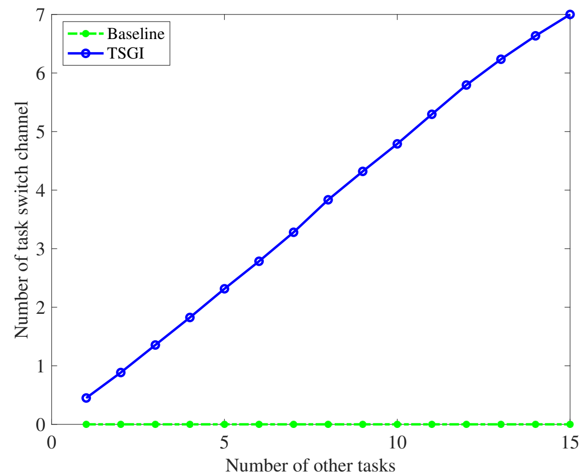

Fig. 5. The number of tasks switching channels after optimization with respect to the number of tasks except for the multicast task.

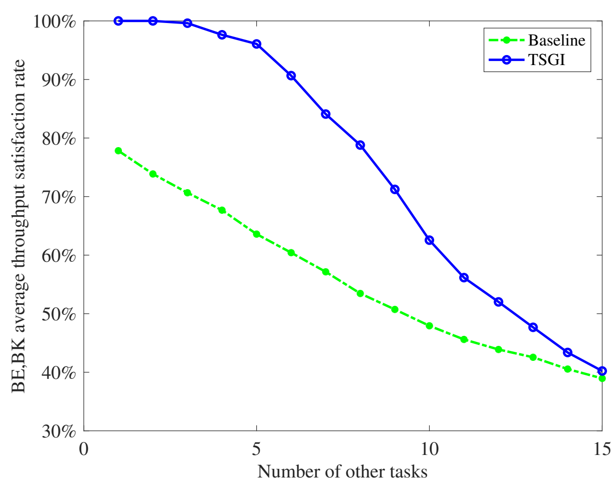

Fig. 4. BE, BK tasks' average throughput satisfaction rate with respect to the number of tasks except for the multicast task.

APs for the AP selection and fixed AP selection scheme for channel allocation. The iterative solution was obtained when the optimization objective converged. Simulations validated that our TSGI algorithm can improve the overall performance of the multi-priority transmission system by proposing AP selection schemes as well as channel allocation schemes, especially to ensure the throughput satisfaction rate of the WiFi multicast task. The proposed TSGI algorithm ensures the efficient utilization of spectrum resources in WiFi networks.

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