# AP Selection Algorithm with Adaptive CCAT for Dense Wireless Networks

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***Abstract*—Wireless Local Area Networks (WLANs)-enabled devices are now everywhere and their rapid spread has created dense deployment environments. For such dense WLANs, the High Efficiency WLAN Study Group (HEW SG) was formed, and as an extension of their activity, effort on standardization of IEEE 802.11ax Task Group (TG) was initiated. The goal of the TG on IEEE 802.11ax is to improve per-station (STA) throughput of dense WLANs in the presence of interfering sources. To attain this aim, the TG is currently working on Clear Channel Assessment Threshold (CCAT) adjustment. As the CCAT is increased, more concurrent transmissions are permitted, leading to more interference. By using a small CCAT, the amount of interference can be reduced, but the transmission opportunity decays. Thus, we present an algorithm that adjusts CCAT based on the co-channel interference and transmission opportunity for network capacity improvement in dense WLANs. In addition, traffic load may not be fairly shared by all serving Access Points (APs) due to the typical Received Signal Strength (RSS)-based AP selection algorithm. In this paper, therefore, we propose an AP selection algorithm that chooses both AP and CCAT providing the highest achievable throughput for a STA by considering the co-channel interference and the traffic load status in dense WLANs. Simulation results show that our proposed algorithm achieves better performance in terms of the average per-STA throughput and Jain's Fairness Index (JFI) in dense wireless networks with various scenarios.***

## I. INTRODUCTION

Wireless Local Area Networks (WLANs) [1] are pervasively implemented to provide users with broadband wireless connectivity. Due to its ease of deployment, convenience, and cost efficiency, WLANs are becoming more and more dense. The proliferation of WiFi equipped devices will continue to drive growth in deployed WLANs. However, dense deployment of WLANs causes significantly increased overall interference, and as a result a significantly lowered achievable throughput. Thus, it is sensible to consider technologies that can resolve or mitigate deteriorated throughput of dense WLANs.

In this context, the High Efficiency WLAN Study Group (HEW SG) was formed in May 2013, and as an extension of their activity, IEEE 802.11ax Task Group (TG) has started in May 2014 [2]. This group is targeting ways to enhance IEEE 802.11 physical (PHY) and Medium Access Control (MAC) layers in 2.4 GHz and 5 GHz band with a focus on improving spectrum efficiency and achieving a 4-fold throughput increase compared with IEEE 802.11ac-2013 in high density scenarios. To attain this aim, the 802.11ax TG is currently working on Clear Channel Assessment Threshold (CCAT) adjustment as one of the main issues under consideration [3].

Since WLAN transmission is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), each station (STA) examines the status of the channel prior to transmission by comparing the measured received energy in the wireless channel with the CCAT. The STA attempts channel access only if the measured energy level of the channel is less than the CCAT indicating that the channel is idle; otherwise, the STA backs off and waits for a random period of time. In IEEE 802.11ax, CCAT is adjusted based on the Received Signal Strength (RSS) level of the beacon signal from the associated AP, $R$, as $(R-m)$ dBm every predefined time period, where $m$ represents a margin [3].

As with this CCAT algorithm in dense WLANs, a STA located near to its respective AP has a higher CCAT, i.e., lower Carrier Sensing (CS) range. It increases the transmission opportunity, but more concurrent transmissions are permitted, leading to more interference. When using a small CCAT, the amount of interference can be reduced but the transmission opportunity decays. It is noteworthy that in the dense deployment of WLANs, the multiple WLANs are operated on the same channel due to limited non-overlapped channels, and thus the network throughput is mainly limited by co-channel interference. Therefore, we propose to adjust CCAT based on both the amount of co-channel interference and transmission opportunity for network capacity improvement in high density WLAN environments.

In addition, traffic load in dense networks may not be fairly shared by all serving APs due to the uncoordinated nature of AP selections among STAs. More specifically, STAs typically select and associate with an AP with the highest RSS. Thus, in this paper, we propose an AP selection algorithm that chooses a combination of AP and CCAT providing the highest achievable throughput for a STA by considering the co-channel interference and the traffic load status in high density WLAN environments.

The rest of this paper is organized as follows. Section II describes our motivations and summarizes related works. Section III describes our AP selection algorithm. In Section IV, we report the results of simulation experiments that demonstrate the performance improvements of the proposed algorithm in terms of per-STA throughput and Jain's Fairness Index (JFI) [4]. Finally, we conclude the paper in Section V.

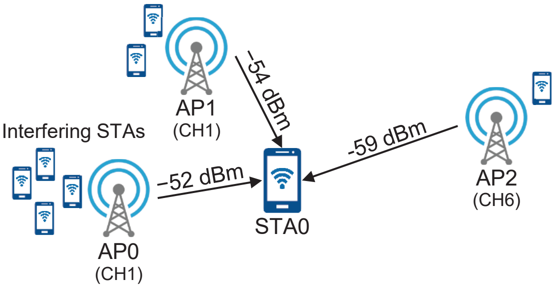


Fig. 1: Example of RSS-based AP selection.

## II. RELATED WORK AND MOTIVATION

The impact of CCAT on the performance of the wireless network has been studied by a number of researchers [5]–[14]. The authors in [5]–[7] attempt to identify the optimum CCAT in wireless networks and conclude that the fixed CCAT should be optimized to improve the network throughput performance.

Thus, several algorithms have been proposed for optimal CCAT [8]–[14]. Yang *et al.* show that MAC overhead has a significant impact on the choice of the optimal CCAT and then choose the optimal CCAT based on the MAC overhead [8]. The authors in [9] and [10] propose a heuristic algorithm that tunes CCAT according to the varying network conditions, i.e., packet loss. Park *et al.* also use packet error rate to update CCAT, but not differentiate between various cause of packet loss [11]. The authors in [12] and [13] propose a centralized algorithm for adjusting CCAT based on loss differentiation. In their work, all the STAs use the same CCAT. Haghani *et al.* assume that an AP periodically broadcasts its Busy/Idle (BI) signal to the STAs [14]. In their work, individual STA uses the BI signal from the AP in order to adjust their CCAT. Despite the fact that these CCAT tuning algorithms [8]–[14] shows that their algorithms enhance the aggregate throughput in wireless networks, they consider no dense environments.

For dense WLAN deployments, IEEE 802.11 TG suggests a CCAT adaptation algorithm to optimize spatial reuse and enhance throughput performance [2] [3]. Their algorithm dynamically changes the CCAT based on the RSS of the beacon signal of the associated AP. In [15]–[18], the demonstration of CCAT adaptation algorithm is carried out, and it is found that significant per-STA throughput enhancement can be achieved. The throughput are evaluated in dense scenario [19] by adjusting threshold values. However, these algorithms adjust CCAT only for certain AP although other available APs within STAs' vicinity exist. Therefore, we select AP and CCAT jointly. In our approach, as tuning CCAT and selecting an optimal AP, we aim to maximize per-STA throughput. Furthermore, we aim to increase fairness among WLANs.

The current technique of AP selection is for a STA to choose the AP with the strongest RSS. This simple RSS-based method causes each STA to suffer from degraded throughput due to channel contention when a large number of users are crowded together. Furthermore, this method fails when a large number of STAs and APs are deployed densely due to the co-channel interference among the APs and the STAs.

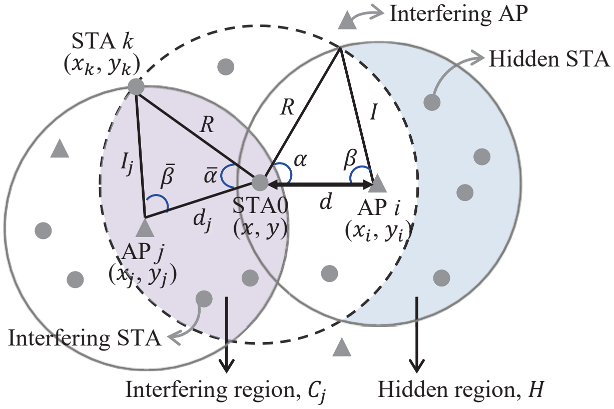


Fig. 2: System model.

Fig. 1 shows an example of RSS-based AP selection. STA0 sees three available APs (denoted as AP0, AP1, and AP2, respectively) in Fig. 1, where the RSS values from these APs observed at STA0 are -52 dBm, -54 dBm, and -59 dBm, respectively. In the RSS-based algorithm, STA0 chooses AP0 based on the RSS value. However, we see that the number of interfering APs and STAs, which all operate on the same channel, are one AP and six STAs for channel 1 and one STA for channel 6, respectively. Thus, selecting AP2 could yield a higher throughput because of less number of interfering APs and STAs (i.e., less interference). If the interference levels are almost the same for three APs, the throughput depends on the APs' load. To reflect these multiple factors into estimating the throughput, we utilize the channel utilization at APs, the RSS from the APs, and the locations of STAs and APs.

## III. AP SELECTION IN DENSE WLAN ENVIRONMENTS

In this section, we describe our proposed AP selection algorithm for dense WLANs.

### *A. System Model*

We consider a network topology consisting of multiple STAs and APs, as shown in Fig. 2. In Fig. 2, the circles with dash line and solid line represent the CS range of STA0 and the coverage areas of the APs, respectively. All STAs are uniformly deployed over the 2-D plane with the density of $\lambda$.

In Fig. 2, $d$ represents the distance between STA0 and AP $i$. Let $r_i$ denote the measured RSS of AP $i$ observed at STA0. We can obtain $d$ using the log-distance power law model [20] as

$$d \cong 10^{(P_0 - r_i)/10\gamma}, \tag{1}$$

where $P_0$ is the signal strength at the distance $l_0$ from the AP and $\gamma$ is the path loss exponent. Typically, $l_0$ is set to 1 m [20].

$I_j$ and $R$ in Fig. 2 represent the radii for AP $j$'s coverage and STA0's CS range, respectively. Using the same approach as for obtaining $d$ in Eq. (1), we calculate $I_j$ and $R$ as $I_j = 10^{(P_0 - \theta)/10\gamma}$ and $R = 10^{(P_0 - P_c)/10\gamma}$, where $\theta$ is the minimum RSS value required for transmitting a packet from STA0 to AP $i$ and $P_c$ is the CCAT of STA0.

Assume that STA0 associates with AP $i$ and AP $j$ uses the same channel as AP $i$ in Fig. 2. An aggressive CS allows the existence of hidden STAs, i.e., the CS range of STA0 does not cover the area of AP $i$ completely. The area where the hidden STAs are located is called hidden region, $H$. The STAs in $H$ are capable of starting new transmissions since they are out of the CS range. The simultaneous transmission in $H$ can disturb the reception of AP $i$. The transmissions of the STAs connected to AP $j$ which are located in the CS range of STA0 also interfere the transmissions of STA0. The area where the interfering STAs are located is called interfering region, $C_j$.

Based on $d$, $I_j$, and $R$, we first estimate $H$ and $C_j$. Using $H$ and $C_j$, we then derive the average number of hidden STAs, $n_h$, and the mean channel utilization of interfering STAs in AP $j$, $\bar{u}_j$. We will use $n_h$ and $\bar{u}_j$ when estimating the achievable throughput for the AP selection algorithm in next subsection.

*1) Number of Hidden STAs:* $H$ is within the coverage area of AP $i$, but outside the CS range of STA0, and is given by

$$H = I^2\pi - \left\{ \left( \frac{R^2\pi^2}{\alpha} - \frac{R^2 \sin 2\alpha}{2} \right) + \left( \frac{I_j^2\pi^2}{\beta} - \frac{I_j^2 \sin 2\beta}{2} \right) \right\}, \tag{2}$$

where $\alpha$ and $\beta$ are illustrated in Fig. 2 and are given by $\alpha = \cos^{-1}\left(\frac{R^2+d^2-I_j^2}{2\cdot R\cdot d}\right)$ and $\beta = \cos^{-1}\left(\frac{I_j^2+d^2-R^2}{2\cdot I_j\cdot d}\right)$.

By using Eq (2), the average number of hidden STAs in the hidden area, $n_h$, is given by

$$n_h = \frac{H}{I^2\pi} n_i, \tag{3}$$

where $n_i$ is the number of STAs connected to AP $i$ and we can obtain $n_i$ from the beacon of the AP $i$.

*2) Channel Utilization of Interfering STAs:* The interfering STA $k$ is placed at $(x_k, y_k)$ such that $\sqrt{(x_k - x_j)^2 + (y_k - y_j)^2} \leq I_j$ and $\sqrt{(x_k - x)^2 + (y_k - y)^2} \leq R$. We then have $C_j$ as follows

$$C_j = \left( \frac{R^2\pi^2}{\bar{\alpha}} - \frac{R^2 \sin 2\bar{\alpha}}{2} \right) + \left( \frac{I_j^2\pi^2}{\bar{\beta}} - \frac{I_j^2 \sin 2\bar{\beta}}{2} \right) \tag{4}$$

where $\bar{\alpha} = \cos^{-1}\left(\frac{R^2+d_j^2-I_j^2}{2\cdot R\cdot d_j}\right)$ and $\bar{\beta} = \cos^{-1}\left(\frac{I_j^2+d_j^2-R^2}{2\cdot I_j\cdot d_j}\right)$ in Fig. 2. By using Eq. (1), $d_j$ can be calculated.

Let $\hat{u}_j$ be the WiFi channel utilization of the interfering AP $j$. STA0 can obtain $\hat{u}_j$ from the AP $j$ through the beacon frame. Since the STAs are placed randomly according to a uniform distribution, the mean channel utilization of interfering STAs connected to AP $j$, $\bar{u}_j$ is given by

$$\bar{u}_j = \frac{C_j}{I_j^2\pi} \hat{u}_j. \tag{5}$$

### *B. Throughput Estimation*

In this subsection, we estimate the achievable throughput by using $n_h$ and $\bar{u}_j$, which we derived in the previous subsection. Our goal is to estimate the achievable throughput at each AP available to STA0 for all the APs. Let $S$ denote the throughput per STA, defined as the fraction of time the channel is used to successfully transmit payload bits. Letting $E[L]$ be the average packet payload size, we are now able to express $S$ as the ratio

$$S = \frac{P_{\text{success}} E[L]}{P_{\text{success}} T_s + P_{\text{collision}} T_c + P_{\text{idle}} \sigma}, \tag{6}$$

where $T_s$ and $T_c$ represent the average time the channel is sensed busy because of a successful transmission and a collision, respectively. $\sigma$ is the duration of an empty slot. $T_s = H_{\text{phy}} + H_{\text{mac}} + T_{\text{frame}} + SIFS + ACK + DIFS$ and $T_c = H_{\text{phy}} + H_{\text{mac}} + T_{\text{frame}} + DIFS$, where $T_{\text{frame}}$ is the average time to transmit the frame payload, and $H_{\text{phy}}$ and $H_{\text{mac}}$ are the average transmission times of PHY and MAC headers, respectively [1].

Let $P_{\text{success}}$, $P_{\text{idle}}$, and $P_{\text{collision}}$ denote the probabilities that a successful transmission occurs in a time slot, all STAs are idle in a time slot, and there is a collision in a time slot, respectively. Hence,

$$\begin{aligned} P_{\text{success}} &= n_c p (1-p)^{n_c - 1}(1 - P_L) \\ P_{\text{idle}} &= (1-p)^{n_c} \\ P_{\text{collision}} &= 1 - P_{\text{success}} - P_{\text{idle}} \end{aligned} \tag{7}$$

where $n_c$ is the average number of STAs in the CS range of STA0.

Let $\bar{A}_i$ be a set of interfering APs that use the same channel with AP $i$, consisting of AP $j$. Using Eq. (5), the number of competing STAs, $n_c$, in Eq. (7) depends on the utilization of STAs associated to interfering AP $j$ and is given as

$$n_c = \lambda R^2 \pi \big[1 - \prod_{j \in \bar{A}_i} (1 - \bar{u}_j)\big]. \tag{8}$$

In Eq. (7), $p$ denotes the probability that a STA transmits in a given time slot and $P_L$ is the Packet Error Rate (PER) caused by collisions with STA0. Let $\hat{u}$ and $u$ be the WiFi channel utilization (i.e., the fraction of time that the channel is active) and the channel utilization of STA0 itself, respectively. STA0 can obtain $\hat{u}$ from the AP $i$. Thus, we can express $p$ as [21]

$$p = \frac{u\sigma}{(1-\hat{u})T_b + \hat{u}\sigma}, \tag{9}$$

where $T_b = (1 - P_L)T_s + P_L T_c$ is the average time that the WiFi channel is sensed busy.

Let $\rho$ be the average packet generation rate at STA0. The utilization $u$ can be expressed in terms of $\rho$ as

$$u = \frac{1}{\rho}(T_s + \frac{P_L}{1 - P_L} T_c), \tag{10}$$

which is limited by $p = \frac{2(1-2P_L)}{(1-2P_L)(W+1)+P_L W(1-(2P_L)^\eta)}$ in saturated conditions where $W$ is the initial contention window size and $\eta$ is computed from the maximum window size, $2^\eta W$, since the utilization stabilizes to the saturation value when the system reaches saturation [21] [22].

By substituting Eq. (10) in Eq. (9), we can obtain

$$p = \frac{T_b}{\rho(1 - P_L)\{(1-\hat{u})T_b + \hat{u}\sigma\}}. \tag{11}$$

In the network allowing the existence of hidden STAs, the PER is dominated by the hidden STAs. In this way, we ignore the PER due to simultaneous transmission in the interfering range [23]. Thus, $P_L$ is determined by the average number of STAs in the hidden region. The condition of a successful transmission occurs is that there are no concurrent

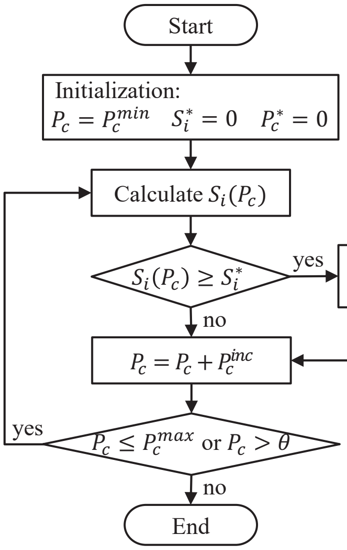


Fig. 3: Flow chart of the proposed algorithm used for each AP

transmissions in the hidden region. From the principle of CSMA, if STA0 starts a transmission, all STAs within the related CS range will not start new transmissions. Therefore, we have $P_L = n_h/n_c$ [23].

### C. AP Selection Algorithm

In this subsection, we propose an AP selection algorithm that chooses AP and CCAT as considering the co-channel interference and the channel utilization to increase the achievable throughput and JFI. To do this, we introduce two new parameters for each available AP $i$ within STA0's vicinity: $S_i^*$ and $P_c^*$ to indicate the maximum achievable throughput and the CCAT when STA0 achieves $S_i^*$, respectively. We also define a function $S_i(P_c)$ which returns the achievable throughput and is affected by the value of $P_c$ ($P_c^{min} \leq P_c \leq P_c^{max}$).

Let $A$ denote a set of the available APs consisting of AP $i$. When STA0 turns the WiFi interface on, STA0 scans for IEEE 802.11 beacon frames from APs ($\in A$). For each AP $i$, as shown in Fig. 3, STA0 estimates $S_i(P_c)$ as varying $P_c$ and chooses $S_i^*$ and $P_c^*$ according to the following procedure:

1) Initialize as $P_c = P_c^{min}$, $S_i^* = 0$, and $P_c^* = 0$.
2) Calculate $S_i(P_c)$ by using Eq. (6).
3) Compare $S_i(P_c)$ and $S_i^*$. If $S_i(P_c) \geq S_i^*$ that means $P_c$ shows higher throughput, set $P_c^* = P_c$ and $S_i^* = S_i(P_c)$; otherwise, go to step 4).
4) Increment $P_c$ by $P_c^{inc}$. If $P_c \leq P_c^{max}$ or $P_c > \theta$, return to step 2); otherwise, return to step 1) for next AP $i$ ($\in$ $A$).

After the above procedure, STA0 can obtain tuples of <AP $i$, $S_i^*$, $P_c^*$ > for APs ($\in A$). Among the tuples, STA0 chooses the tuple that shows the highest achievable throughput, then connects to the AP with the CCAT.

## IV. PERFORMANCE EVALUATION

In this section, we evaluate the performance of our algorithm in dense WLAN environments in terms of the average per-STA throughput and Jain's Fairness Index (JFI).

TABLE I: Parameter values for simulation [1] [3]

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| MAC & PHY | IEEE 802.11ac | Frequency | 5 GHz |
| Bandwidth | 20 MHz | Packet size | 1024 bytes |
| $H_{\text{phy}}$ | 192 $\mu s$ | $H_{\text{mac}}$ | 28 bytes/$r$ |
| $T_{\text{frame}}$ | 512 bytes/$r$ | $SIFS$ | 10 $\mu s$ |
| $ACK$ | 304 $\mu s$ | $DIFS$ | 50 $\mu s$ |
| $P_c^{min}$ | -82 dBm | $P_c^{max}$ | -40 dBm |

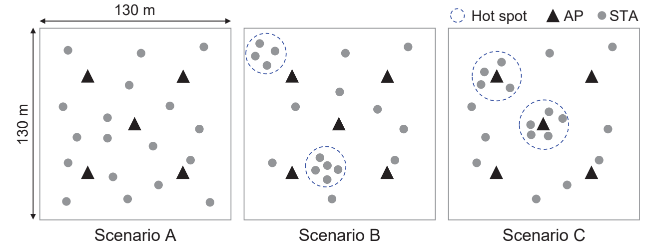


Fig. 4: Simulation scenarios.

### A. Simulation Environment

We evaluate the performance of the proposed algorithm through simulations using Network Simulator Version 3 (NS-3) [24]. We compare the average per-STA throughput of the proposed algorithm with that of DSC in which CCAT is set to $R - m$ as mentioned above [3]. We also measure the fairness among STAs with JFI as $\frac{(\sum_{i=1}^{n} x_i)^2}{n\sum_{i=1}^{n} x_i^2}$, where there are $n$ STAs and $x_i$ is the throughput for the $i$th connection [4]. JFI is a value between 0 (unfair) and 1 (fair), and JFI is maximum when all STAs receive the same allocation.

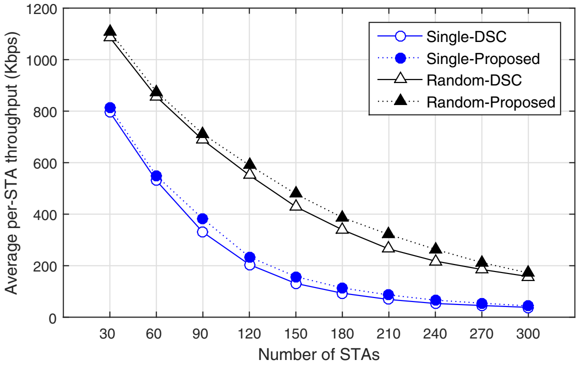
Based on the dense networks scenarios defined by IEEE 802.11ax WG [2] [19], we consider a small enterprise of 130 m x 130 m with the bottom left coordinates, ($x$,$y$) = (0,0), and the top right coordinates, ($x$,$y$) = (130,130), as shown in Fig. 4. In the simulation area, we place five APs at (65,65) m, (40,40) m, (40,90) m, (90,40) m, and (90,90) m, respectively. We vary the number of STAs from 30 to 300.

We take IEEE 802.11ac protocol to evaluate the performance of the proposed algorithm. The average packet generation rate at each STA is randomly chosen from 10 to 20 Mbps. The parameters of PHY and MAC layers used in the simulation are listed in Table I.

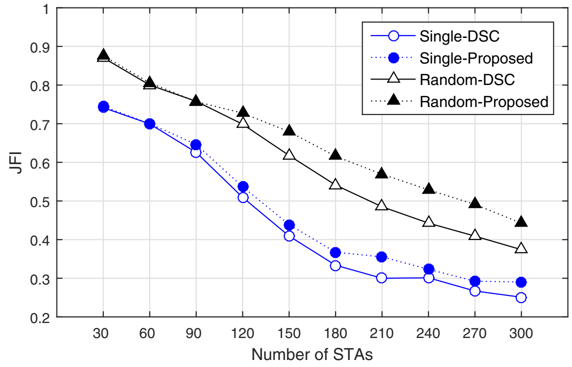
We consider two channel assignment strategies: 1) Single channel: all APs choose the same channel, for example, channel 6 by default; and 2) Random channel: each AP independently selects one of the two non-overlapped channels.

Fig. 4 shows three different scenarios for STA distribution based on uniform distribution. In *Scenario A*, STAs are uniformly distributed within the simulation area (see Fig. 4(a)). In *Scenarios B* and *C*, half of the STAs are uniformly distributed within the scenario, while the other half are uniformly distributed within circular hot spots of 10 m radius. We define hot spot as high density of STAs. The hot spots are located at two random position and at two random APs for *Scenarios B* and *C*, respectively (see Figs. 4(b) and (c)).

For each simulation scenario, the simulation time is 100 s,

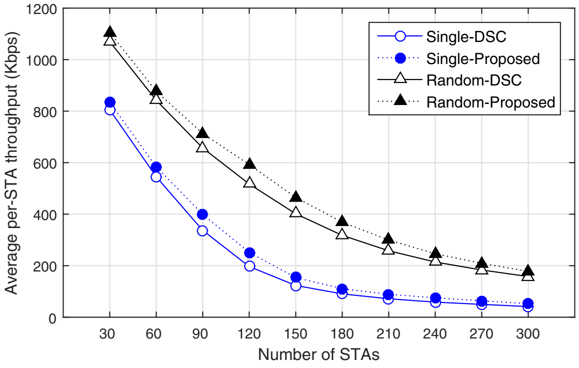


(a) Average per-STA throughput

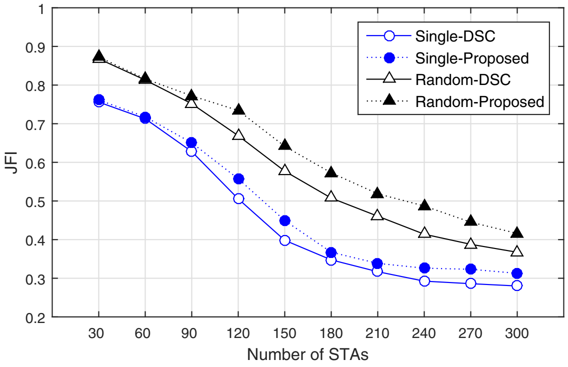


(b) JFI

Fig. 5: Average per-STA throughput and JFI in Scenario A.



(a) Average per-STA throughput



(b) JFI

Fig. 6: Average per-STA throughput and JFI in Scenario B.

and the results are obtained via averaging values from 50 different runs with different seeds.

### *B. Simulation Results*

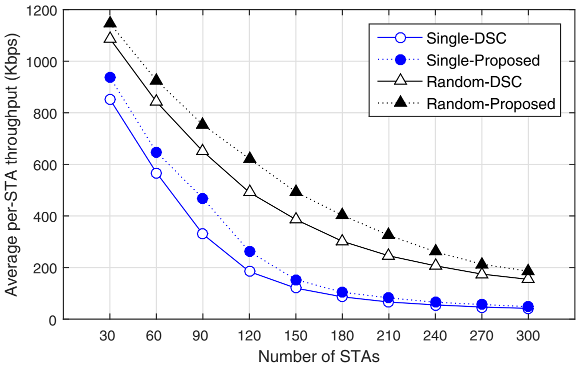
Fig. 5 plots the variation of the average per-STA throughput and JFI according to the number of STAs when DSC and the proposed algorithm are simulated using single and random channel assignments in Scenario A. It can be seen from Fig. 5(a) that the proposed algorithm achieves better performance than the DSC algorithm in terms of the average per-STA throughput. In addition, we can see from Fig. 5(b) that, as the throughput decreases, JFI gets lower for both algorithms, but the proposed algorithm has higher fairness than DSC regardless of channel assignments and the number of STAs. This is because our algorithm chooses the AP with the optimal CCAT that would provide the highest achievable throughput while DSC selects the AP based only on RSS.

Fig. 6 plots the variation of the average per-STA throughput and JFI according to the number of STAs when DSC and the proposed algorithm are simulated using single and random channel assignments in Scenario B. The throughput and JFI in Scenario B show almost the same behavior as that in Scenario A, indicating that the proposed algorithm performs achieves better performance than DSC. Compared to Scenario A, however, the throughput gain due to the proposed algorithm in Scenario B is larger than that in Scenario A, in where STAs are uniformly distributed. This is because, in DSC, the STAs within hot spots in Scenario B choose a near AP while the STAs in the proposed algorithm chooses the AP considering both the traffic load status and the co-channel interference without considering RSS.

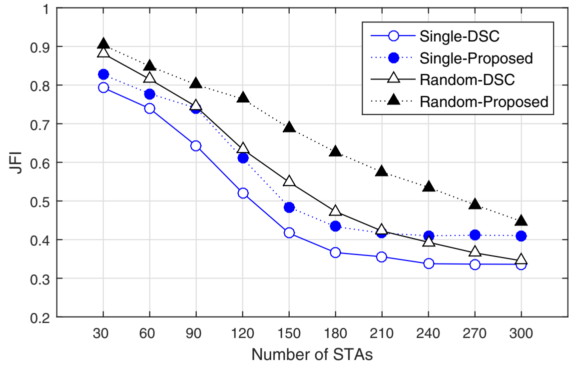
Fig. 7 plots the variation of the average per-STA throughput and JFI according to the number of STAs when DSC and the proposed algorithm are simulated using single and random channel assignments in Scenario C. As with Scenarios A and B, the proposed algorithm in Scenario C outperforms DSC in terms of the throughput and JFI, while the performance gain due to the proposed algorithm is the largest in all scenarios. This is due to the fact that the distances between the AP and the STAs in hot spots is the shortest in Scenario C, meaning essentially that STAs in DSC set CCAT based on the RSS of near AP, resulting in low transmission opportunities at heavily populated APs, while the proposed algorithm considers both the co-channel interference and the traffic load status.

As can be seen in Figs. 5-7, the performance in random channel assignment is better than that in single channel assignment for all scenarios. It is because, as STAs that use the same channel increase, there will be more contention, and hence it results in decreased throughput and JFI.

As shown in Fig. 8, to see the effect of AP locations on the performance of our algorithm and DSC, we measure the average per-STA throughput in Scenario C when APs are randomly distributed. We can see from Figs. 7(a) and 8 that our algorithm achieves better performance than DSC



(a) Average per-STA throughput



(b) JFI

Fig. 7: Average per-STA throughput and JFI in Scenario C.

regardless of the AP locations. We can also observe from the figures, the throughput with random AP locations has slightly higher performance than that with fixed AP locations. It is because the average distance between APs when APs are randomly placed is larger than that when the AP locations are fixed, resulting in decrease of interference.

## V. CONCLUSION

We have presented an AP selection algorithm that chooses a combination of AP and CCAT providing the highest achievable throughput for a STA by considering both the co-channel interference and traffic load status for dense wireless networks. Simulation results showed that the proposed algorithm increases the average per-STA throughput and JFI regardless of the number of STAs and channel assignment strategies in three scenarios with the fixed AP locations. We have also shown that the proposed algorithm outperforms DSC when APs are randomly distributed.

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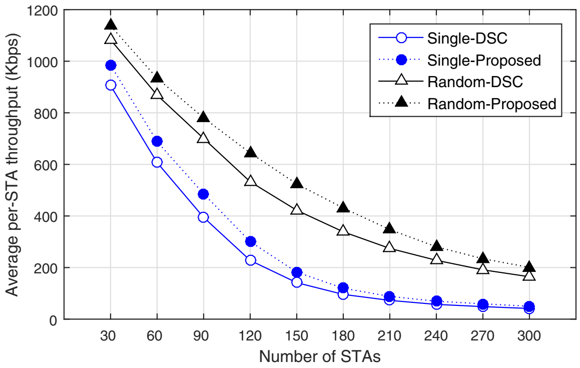

Fig. 8: Average per-STA throughput when APs are randomly distributed in Scenario C.

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