A Coexistence Method of Short-Range Heterogeneous Network Based on Cell Cooperation

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Abstract. The rapid economic development has promoted the rapid increase of mobile traffic and mobile devices. Short-range wireless networks working in unlicensed frequency bands have attracted widespread attention due to their advantages of openness, freeness and high rate. Therefore, there are many types of short-range wireless networks working in unlicensed frequency bands, such as WLAN, Bluetooth, ZigBee, etc. When the above two or more networks are arranged in the same place, serious interference between the networks will be caused by spectrum overlap. The hybrid MAC network can flexibly configure time slots of Time Division Multiple Access (TDMA) and Carrier Sense Multiple Access with Collision Avoid (CSMA/CA). Therefore, a coexistence method of short-range heterogeneous network based on cell cooperation (CM-HNCC) was proposed to solve the coexistence of hybrid MAC network and Wi-Fi. This algorithm can reduce the delay of high priority traffic and improve the throughput of hybrid MAC network under the premise of ensuring network fairness. Finally, the effectiveness of CM-HNCC is verified by establishing mathematical model and simulation.

Keywords: Short-range heterogeneous network · Unlicensed frequency band · High-priority traffic · Community collaboration

1 Introduction

The rapid development of global economy has promoted the rapid increase of communication traffic, but the spectrum resources are limited [1]. Therefore, WLAN (IEEE802.11be/IEEE802.11ax), Bluetooth, ZigBee and other networks working in ISM (Industrial Scientific Medical) band have been developed rapidly because of their advantages of openness, freeness and high rate [2].

Heterogeneous network refers to the network where multiple access networks and internet service provider (ISP) coexist, and is a common form of wireless network. The emergence of heterogeneous network makes the fusion and coexistence

D.-J. Deng et al. (Eds.): SGIoT 2022, LNICST 497, pp. 342–354, 2023.
https://doi.org/10.1007/978-3-031-31275-5_31

of heterogeneous network become the development trend of future communication. Scholars have done a lot of research on the coexistence of heterogeneous networks. Lin et al. [3] dynamically adjusted the value of the contention window (CW) to obtain the maximum throughput. In order to address the performance degradation of long term evolution (LTE)and wireless fidelity (Wi-Fi) heterogeneous networks in dense scenarios, S. Sagari et al. [4] proposed dynamically selecting access channels by sensing channel state. If the channel to be accessed is found to be idle, then the channel is accessed, otherwise, continue to find other channels. A. Dziedzic et al. [5] used machine learning to determine the number of current Wi-Fi cells, and adjusts the duty ratio of LTE according to the number of Wi-Fi cells. C. Chen et al. [6,8] discussed the coexistence performance of LTE and Wi-Fi under the condition of fixed CW length. Y. Song et al. [8] studied how to obtain the maximum system throughput by obtaining the optimal CW length.

However, there are few studies on the coexistence of hybrid MAC networks with other networks. In this paper, we introduce a hybrid MAC networks, and study its coexistence with Wi-Fi. Both the hybrid MAC network and Wi-Fi work in ISM band. When they work in the same area at the same time, they will interfere with each other. TDMA time slot in hybrid MAC network will be affected by Wi-Fi, which will cause collision and reduce the performance of hybrid MAC network. In CSMA/CA time slot, due to the addition of Wi-Fi, the number of competitive nodes increases, which further increases the collision probability and reduces the performance of hybrid MAC network and Wi-Fi.

A coexistence method of short-range heterogeneous network based on cell cooperation (CM-HNCC) is proposed to solve this problem. The main idea is that predict the high and low priority traffic (represented by LT) of hybrid Mac and the traffic of Wi-Fi, then calculate the TDMA duration according to the traffic. When the hybrid MAC network is in the time division multiple access (TDMA) time slot, Wi-Fi stops sending packets to ensure the transmission quality of hybrid MAC network. CW of LT traffic in the hybrid MAC network is appropriately adjusted, so as to increase the competitiveness of Wi-Fi in CSMA/CA time slot. Finally, the performance of Wi-Fi is guaranteed, the throughput of hybrid MAC high priority traffic (represented by HT) is improved, and the time delay is reduced.

The paper is outlined as follows. In the Sect. 2 we mainly introduce the frame structure of hybrid MAC network. In Sect. 3 CM-HNCC is introduced. In Sect. 4 the theoretical throughput calculation method is introduced. In Sect. 5 validates the effectiveness of CM-HNCC by simulation results. Concluding remarks are given in Sect. 6.

2 Architecture of Hybrid MAC Network

The time slot distribution of hybrid MAC network is shown in Fig. 1. T-s time slot uses TDMA communication technology. C-s time slot uses distributed coordination function (DCF) mechanism. Hybrid MAC network will send beacon frame at B time slot.

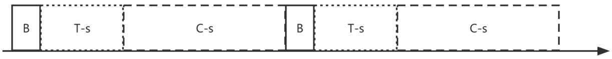


Fig. 1. Time slot distribution of hybrid MAC network.

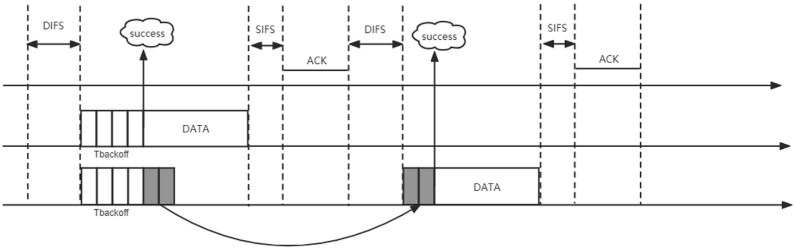
In C-s time slot, DCF mechanism is adopted [9]. The DCF mechanism is a basic access method for nodes to access wireless channels. It combines CSMA/CA technology and acknowledge character (ACK) technology, and uses binary exponential backoff to avoid conflicts. The DCF mechanism is shown in Fig. 2. If the node senses that the channel is the state of ideal within a DIFS (distributed inter frame spacing) duration, it will select a random value in the initial contention window $(0, CW-1)$ as the initial value of backoff counter. When the backoff counter decreases to 0, the data will be transmitted (as shown in Fig. 2(a)). Collision occurs if the backoff counter of two or more nodes decrease to 0 at the same time, that will double the contention window (as shown in Fig. 2(b)). Select a random value in the doubled CW to repeat the above process. When the CW reaches the maximum contention window ($CW_{\max}$), the size of the CW will remain unchange if a collision occurs again. The HT traffic and the LT traffic of the hybrid MAC network compete for the channel in C-s time slot. The initial CW of HT traffic is smaller than the initial CW of LT traffic. The $CW_{\max}$ of HT traffic is smaller than that of LT traffic. Therefore, the probability that the HT traffic successfully sends data in the C-s time slot is greater than that of LT traffic.

In T-s time slots, each node transmits data within the time period allocated by the center control node (CCN). There will be no packet collision and loss in T-s time slots if the channel is ideal. Priority delivery of HT traffic is ensured in T-s time slot. LT traffic can also be sent in T-s time slots when there is only LT traffic.

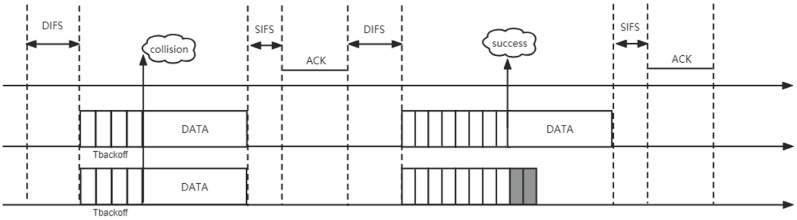
3 CM-HNCC

The CM-HNCC algorithm consists of three steps, as shown in Fig. 3: Step 1 - forecast the traffic of hybrid MAC network and Wi-Fi. Calculate the length of T-s time slot using Algorithm 1. Step 2 - update the CW of LT traffic using Algorithm 2. Step 3 - Wi-Fi keep silence in T-s time slot.

The hybrid MAC network has T-s and C-s time slots. Priority delivery of HT traffic is ensured in T-s time slot. LT traffic can also be sent in T-s time slots when there is only LT traffic. In C-s time slot, HT and LT traffic access the channel using DCF mechanism. CM-HNCC algorithm requires Wi-Fi to keep silence when hybrid MAC network is in T-s time slot to ensure the quality of service (QoS) of HT traffic. The length of T-s time slot is very important. The longer the T-s time slot length, the less friendly it is to Wi-Fi. If T-s time slot length is too short, QoS of HT traffic cannot be guaranteed. This paper proposes



(a) Successful transmission.



(b) The collision.

Fig. 2. DCF mechanism.

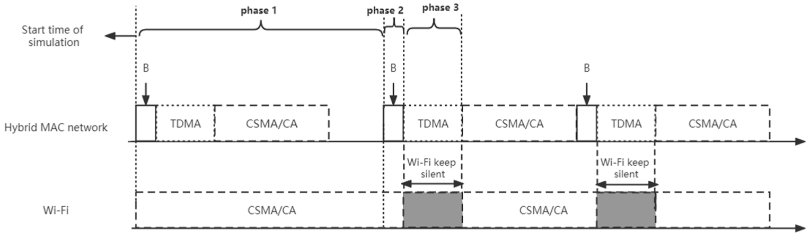


Fig. 3. CM-HNCC.

Algorithm 1 to solve this problem. The core idea of this algorithm is to confirm the length of T-s time slot according to the proportion of various traffic rate.

B_{vo} indicates the traffic rate of HT. B_{BE} indicates the traffic rate of LT. B_{be} indicates the rate of Wi-Fi. $T_{\min}$ indicates minimum value of T-s time slot duration. T_1 indicates the time duration needed for a successful transmission in hybrid MAC network. T_2 indicates the time duration needed for a successful transmission in Wi-Fi. T_{TDMA} indicates the length of T-s time slot.

Algorithm 1. T-s time slot confirmation algorithm based on traffic prediction.

```
Input: $B_{vo}$  $B_{BE}$  $B_{be}$  $T_{\min}$  $T_1$  $T_2$
Output: $T_{TDMA}$.
$T_{TDMA} = 0$
$t_{vo} = 0$  $t_{BE} = 0$  $t_{be} = 0$  $t_{vo}$ $t_{BE}$ $t_{be}$ respectively indicate the transmission duration of HT and LT, transmission duration of Wi-Fi traffic.
$t_{vo} = S_{vo}/T_1$
$t_{BE} = S_{BE}/T_1$
$t_{be} = S_{be}/T_2$
if $t_{vo} + t_{BE} + t_{be} < 1$ then
    $T_{TDMA} = t_{vo} \cdot (t_{vo} + t_{BE})/(t_{vo} + t_{BE} + t_{be})$
else
    $T_{TDMA} = t_{vo}/(t_{vo} + t_{BE} + t_{be}) \cdot (t_{vo} + t_{BE})/(t_{vo} + t_{BE} + t_{be})$
end if
if $T_{TDMA} < T_{\min}$ then
    $T_{TDMA} = \min(T_{\min}, t_{vo})$
end if
return $T_{TDMA}$
```

CM-HNCC algorithm requires Wi-Fi to keep silence when hybrid MAC network is in T-s time slot. The QoS of HT can be guaranteed by that way, but this method reduces the ability of Wi-Fi to compete for channel resources. To solve this problem, Algorithm 2 was proposed. Algorithm 2 can dynamically increase the CW of LT to increase the ability of Wi-Fi to compete for channel resources in C-s time slot.

CW_{old} indicates the initial value of contention window of LT business in hybrid MAC network . d indicates the adjustment step of contention window. CW_{new} indicates the initial value of contention window of LT after update. Pu represents the theoretical throughput of Wi-Fi after increasing CW of LT traffic. Pu can be calculated by formula 16.

Finally, Wi-Fi keep silence when hybrid MAC network is in T-s time slot. The hybrid MAC network first broadcasts beacon frame, which contains beacon interval, T-s time slot duration, T-s time slot duration and other information. After the STAs of hybrid MAC network receive the beacon frame, they set them own T-s time slot period and C-s time slot period according to the information from beacon frame.

Algorithm 2. competitive window adjustment algorithm.

```
Input: $T_{TDMA}$  $CW_{old}$  $d$
Output: $CW_{new}$
$CW_{new} = 0$
$P_o$ represents the theoretical throughput of Wi-Fi at $T_{TDMA} = 0$
while $P_u \cdot (1 - T_{TDMA}) < P_o$ do
    $CW_{old} = CW_{old} + d$
end while
$CW_{new} = CW_{old}$
return $CW_{new}$
```

Nodes of Wi-Fi can also receive beacon frame sent by hybrid MAC network. AP of Wi-Fi puts T-s time slot duration into its own beacon frame (See Fig. 4). The beacon frame contains a quiet element field, and Wi-Fi silence can be realized through network allocation vector (NAV). The structure of quiet element field is shown in Fig. 5. Quiet element field contain 8 bytes in total. Quiet Count (QC) means that Quiet Period (QP) will start after the time of $TBTT \cdot QC$. QP is the silent period. Quiet Duration is the duration of silence. Quiet Offset (QO) is the time offset. In this paper. Quiet Duration is the length of T-s time slot of hybrid MAC network, QC is 0, QP is 1, QO is 0.

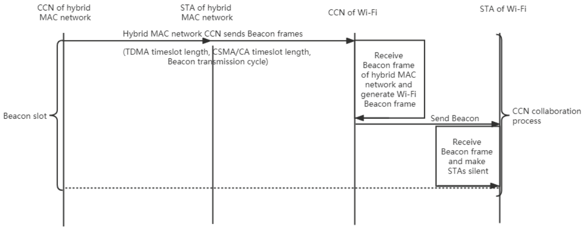
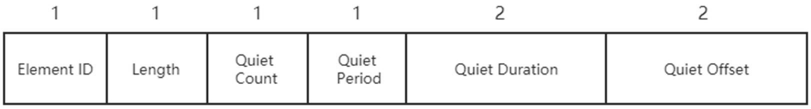


Fig. 4. Beacon frames interaction.



1	1	1	1	2	2
Element ID	Length	Quiet Count	Quiet Period	Quiet Duration	Quiet Offset

Fig. 5. Quiet element structure.

The silence time and duration of Wi-Fi are shown in Fig. 6. When the nodes of Wi-Fi receive the beacon frame sent by CNN, they obtain the corresponding silence time and duration from the beacon. Nodes of Wi-Fi keep silent for the corresponding period of time without sending any packets. After the end of silence, nodes of Wi-Fi normally compete for the channel to send packets.

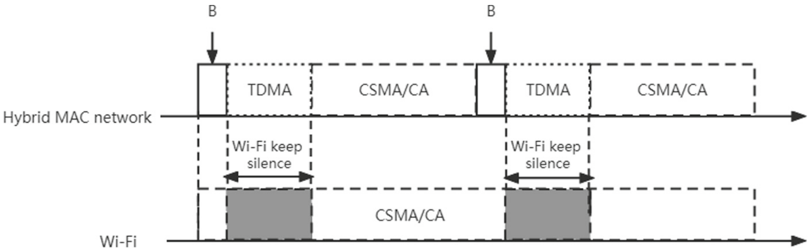


Fig. 6. Wi-Fi keep silence in TDMA time slot.

4 Analysis of Theoretical Throughput

G. Bianchi et al. [10] use a very simple method to analyze the saturated throughput of IEEE802.11 working in DCF mechanism. Ahmed N et al. [11] analyze the unsaturated throughput of IEEE802.11 with single traffic. In the case of hidden terminals, Fu-Yi Hung et al. [12] analyze the saturated and unsaturated throughput of Wi-Fi with single traffic. However, there is little research on the saturated throughput of heterogeneous network. Therefore, this paper proposes an analysis method to analyse the theoretical throughput of heterogeneous network, in the assumption of ideal channel conditions, no hidden terminal and finite number of terminals. This method can accurately obtain the throughput.

Theoretical analysis is divided into two parts. Firstly, the Markov model is used to study the backoff stage of a Wi-Fi node and a hybrid MAC network node, and further obtain the probability of nodes in each state. Then we analyze the behavior of each node and calculate the theoretical throughput.

Suppose that the maximum backoff stages of Wi-Fi is m_1 and the $CW_{\min}$ is w_1. The maximum backoff stages of hybrid MAC network is m_2 and the $CW_{\min}$ is w_2. As shown in Fig. 7, there are $(m_1+1)\cdot(m_2+1)$ states of the whole Markov chain. Each state is represented by $p\,(i,j)$. i indicates that the node of Wi-Fi has collided i times and j indicates that the node of hybrid MAC network has collided j times.

According to the knowledge of statistics, if the contention window is $(0, W)$, then the average number of backoff value is $(W+1)/2$. The probability of a node sending a packet in a backoff slot is $2/(W+1)$. Therefore, when the status is $p\,(i,j)$, the probability that a Wi-Fi node sends packet in a backoff slot is

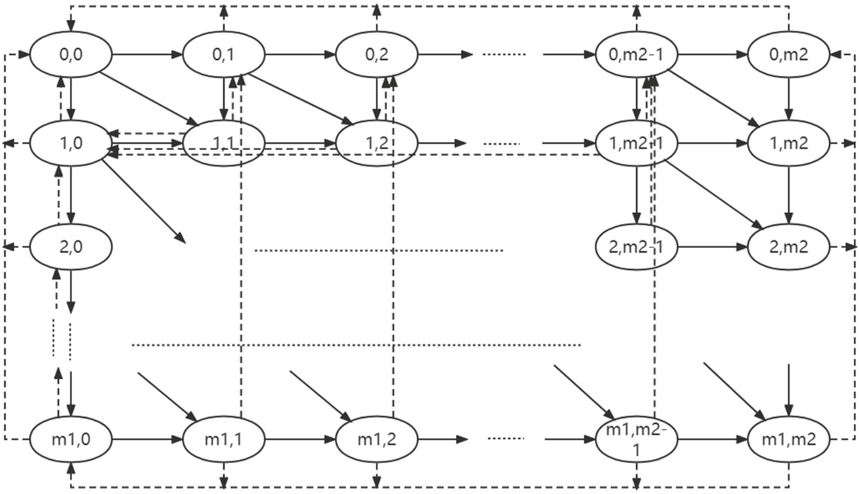


Fig. 7. Backoff stages markov chain model.

$P_{bi} = 2/(2^i \cdot (w_1 + 1))$. The probability that a hybrid MAC network node sends a packet in a backoff slot is $P_{uj} = 2/(2^j \cdot (w_2 + 1))$.

P indicates the average probability of each node sending packets in a backoff slot. n_1 indicates the number of nodes in hybrid MAC network. n_2 indicates the number of nodes in Wi-Fi network. $n = n_1 + n_2$ indicates the total number of nodes of heterogeneous network. $P_{ij-ideal}$ indicates the probability that the backoff slot is idle in state $p\,(i, j)$.

$$P_{ij-ideal} = (1 - P_{bi}) \cdot (1 - P_{uj}) \cdot (1 - P)^{n-2}. \tag{1}$$

P_{ij-sb} indicates the probability that a node of Wi-Fi successfully sends packets.

$$P_{ij-sb} = P_{bi} \cdot (1 - P_{uj}) \cdot (1 - P)^{n-2}. \tag{2}$$

P_{ij-su} indicates the probability that a node of hybrid MAC network node successfully sends packets.

$$P_{ij-su} = (1 - P_{bi}) \cdot P_{uj} \cdot (1 - P)^{n-2}. \tag{3}$$

P_{ij-cbu} indicates the collision probability between a node of Wi-Fi and a node of hybrid MAC network.

$$P_{ij-cbu} = P_{bi} \cdot P_{uj} \cdot (1 - P)^{n-2}. \tag{4}$$

P_{ij-sB} indicates the probability that the background traffic sends package successfully.

$$P_{ij-sB} = (1 - P_{bi}) \cdot (1 - P_{uj}) \cdot (1 - P)^{n-3} \cdot P. \tag{5}$$

P_{ij-cbB} indicates the collision probability between a Wi-Fi node and the background traffic flow.

$$P_{ij-cbB} = P_{bi} \cdot (1 - P_{uj}) \cdot \left[1 - (1 - P)^{n-2}\right]. \tag{6}$$

P_{ij-cuB} indicates the collision probability between a node of hybrid MAC network and the background traffic flow.

$$P_{ij-cuB} = (1 - P_{bi}) \cdot P_{uj} \cdot \left[1 - (1 - P)^{n-2}\right]. \tag{7}$$

$P_{ij-cbuB}$ indicates the collision probability between a node of hybrid MAC network , a node of Wi-Fi and the background traffic flow.

$$P_{ij-cbuB} = P_{bi} \cdot P_{uj} \cdot \left[1 - (1 - P)^{n-2}\right]. \tag{8}$$

When the markov chain reaches the steady state, the inflow probability of each state is equal to the outflow probability. According to this theorem, the steady-state probability P_{ij} of each state can be calculated by numerical method.

The throughput of system can be calculated by Eq. 9. T_{bs} indicates the successful transmission duration of Wi-Fi. T_{bc} indicates the collision duration of

Wi-Fi. T_{us} indicates the average successful transmission duration of hybrid MAC network. T_{uc} indicates the collision duration of hybrid MAC network. The successful transmission duration and collision duration of Wi-Fi and hybrid MAC network can be calculated by Eq. 10.

$$S = \frac{L_s(\text{payloadinformationtransmittedinaslottime})}{L_{sum}\,(\text{engthofaslottime})} \tag{9}$$

$$\left(\begin{array}{c} T_s = H + T_{payload} + SIFS + \delta + ACK + DIFS \\ T_c = H + T_{payload} + DIFS + \delta \end{array} \right. \tag{10}$$

where $H = MAC_{hdr} + PHY_{hdr}$ represents the transmission duration of package header. δ represents propagation delay. SIFS (short inter frame space) refers to short frame interval. DIFS (DCF inter frame space) indicates DCF frame interval. ACK indicates the transmission duration of ACK.

In state $p\,(i, j)$, the duration of idle time , duration of successful transmission time and duration of collision time can be calculated by Eq. (11–13).

$$T_{ij-ideal} = P_{ij-ideal} \cdot \sigma \cdot P_{ij} \tag{11}$$

$$T_{ij-s} = P_{ij-sb} \cdot T_{bs} + P_{ij-su} \cdot T_{us} \cdot P_{ij} + P_{ij-sB} \cdot \left[\frac{P_{ij-sb} \cdot T_{bs} \cdot n_1 + P_{ij-su} \cdot T_{us} \cdot n_2}{P_{ij-sb} \cdot n_1 + P_{ij-su} \cdot n_2} \right] \cdot P_{ij} \tag{12}$$

$$\begin{gathered} T_{ij-c} = P_{ij-cbu} \cdot \max\,(i+1, j+1) \cdot T_{bc} + P_{ij-cbB} \cdot (i+1) \cdot T_{bc} \cdot P_{ij} \\ + P_{ij-cuB} \cdot (j+1) \cdot T_{uc} \cdot P_{ij} \\ + P_{ij-cbuB} \cdot \max\,(i+1, j+1) \cdot \max\,(T_{bc}, T_{uc}) \cdot P_{ij} \end{gathered} \tag{13}$$

where σ represents the length of a backoff slot. $T_{ij-ideal}$ indicates the idle time duration under the state of $p\,(i, j)$. T_{ij-s} indicates the successful transmission duration under the state of $p\,(i, j)$. T_{ij-c} indicates the collision duration under the state of $p\,(i, j)$.

In state $p\,(i, j)$, T_{ij-bs} indicates the successful transmission duration of Wi-Fi. T_{ij-us} indicates the successful transmission duration of hybrid MAC network.

$$T_{ij-bs} = P_{ij-su} \cdot T_{us} \cdot P_{ij} + P_{ij} \cdot P_{ij-sB} \cdot \left[\frac{P_{ij-su} \cdot T_{us} \cdot n_2}{P_{ij-sb} \cdot n_1 + P_{ij-su} \cdot n_2} \right] \tag{14}$$

$$T_{ij-us} = P_{ij-sb} \cdot T_{bs} \cdot P_{ij} + P_{ij} \cdot P_{ij-sB} \cdot \left[\frac{P_{ij-sb} \cdot T_{bs} \cdot n_1}{P_{ij-sb} \cdot n_1 + P_{ij-su} \cdot n_2} \right] \tag{15}$$

The theoretical throughput of Wi-Fi (S_{be}) can be calculated by Eq. 16. The theoretical throughput of hybrid MAC network (S_u) can be calculated by Eq. 17.

$$S_{be} = \frac{\sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-bs}}{\sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-ideal} + \sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-s} + \sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-c}} \tag{16}$$

$$S_{u} = \frac{\sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-us}}{\sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-ideal} + \sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-s} + \sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-c}} \tag{17}$$

Then the total throughput of Wi-Fi and hybrid MAC networks can be calculated by Eq. 18.

$$S_{sum} = \frac{\sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-s}}{\sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-ideal} + \sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-s} + \sum_{0}^{m_1}\sum_{0}^{m_2} T_{ij-c}} \tag{18}$$

5 Performance Evaluation

The simulation platform used is integrated System & Link Level Simulation Platform [13]. This simulation platform can simulate the short-range wireless network at system level and link level.

When $n_1 = 5$, $m_1 = 4$, $n_2 = 5$, $m_2 = 4$, the steady-state probability of each state in markove chain is shown in Table 2.

Figure 8 shows the variation of throughput of Wi-Fi, hybrid MAC network, and heterogeneous network with $CW_{\min}$ of hybrid MAC network. The $CW_{\min}$ of Wi-Fi is 31, and the number of STAs in both the hybrid MAC and Wi-Fi is 5. As can be seen from the Fig. 8, the theoretical throughput and simulation throughput of Wi-Fi are basically equal. The theoretical throughput of hybrid MAC network is approximately equal to the simulation throughput. The total simulation throughput is approximately equal to the theoretical throughput. The results show that the theoretical model is correct (Table 1).

The number of nodes in both Wi-Fi and hybrid MAC networks is 5. The $CW_{\min}$ of HT traffic is 7. Set the $CW_{\max}$ of HT traffic to 31. The $CW_{\min}$ of LT traffic is 31. The $CW_{\max}$ of LT traffic is 511. The C-s time slot is 20000 µs. The T-s time slot changes dynamically. The $CW_{\min}$ of Wi-Fi is 31 and the $CW_{\max}$ is 511. The change of the throughput of Wi-Fi and the total throughput of hybrid MAC with the HT traffic rate is shown in Fig. 9(a). The variation of HT traffic time delay with HT traffic rate is shown in Fig. 9(b).

As can be seen from Fig. 9(a), the throughput of Wi-Fi is basically unchanged after using CM-HNCC, which shows that this method can ensures the fairness between networks. The throughput of hybrid MAC is improved after using CM-HNCC. As can be seen from Fig. 9(b), CM-HNCC can significantly reduce the time delay of HT and ensure the real-time performance of HT.

Table 1. System parameters and additional parameters used in simulation.

Parameter names	Wi-Fi	hybrid MAC network
Propagation delay σ	1 µs	1 µs
Packet header H	8 µs	10 µs
Packet transmission duration	148 µs	179 µs
SIFS	16 µs	16 µs
DIFS	43 µs	43 µs
ACK transmission duration	32 µs	32 µs
Slot time	9 µs	9 µs

Table 2. Steady-state probability of markov chain.

$P(i,j)$	$j=0$	$j=1$	$j=2$	$j=3$	$j=4$
$i=0$	0.2747	0.1384	0.0741	0.0398	0.0030
$i=1$	0.1284	0.0724	0.0369	0.0190	0.0014
$i=2$	0.0634	0.0350	0.0181	0.0091	0.0009
$i=3$	0.0322	0.0165	0.0085	0.0043	0.0006

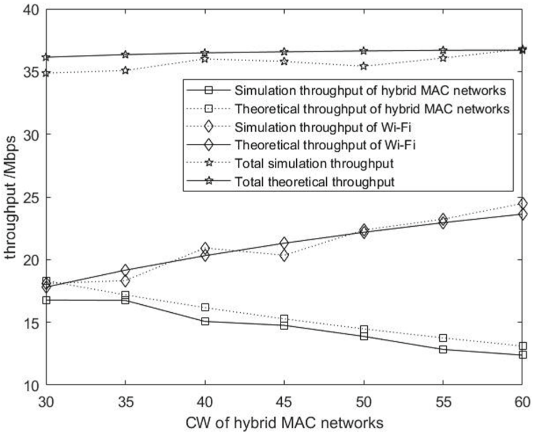
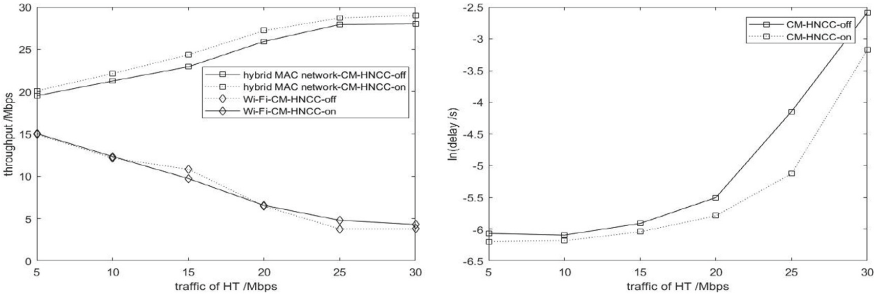


Fig. 8. Simulation and theoretical throughput vary with *CW* of hybrid MAC network.

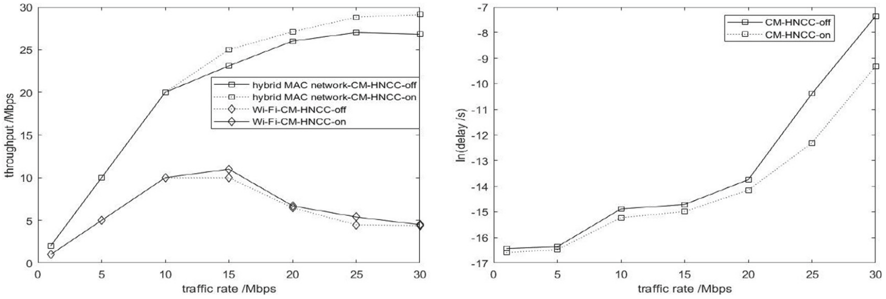
The abscissa of Fig. 10(a) and Fig. 10(b) is the HT rate of the hybrid MAC network. The traffic rate of Wi-Fi, HT and LT are equal. Before and after using CM-HNCC algorithm, the throughput of Wi-Fi has no obvious change, which shows that CM-HNCC algorithm can ensure the fairness between networks. When the traffic rate is low, the total throughput of hybrid MAC network does not change significantly. However, with the increasing of traffic rate, the CM-



(a) Throughput changing with HT traffic rate.

(b) HT delay changing with HT traffic rate.

Fig. 9. Throughput and HT time delay changing with HT traffic rate.



(a) Throughput changing with traffic rate.

(b) HT time delay changing with traffic rate.

Fig. 10. Throughput and HT delay changing with traffic rate.

HNCC algorithm can significantly increase the total throughput of the hybrid MAC network. It can be seen from Fig. 10(b) that the CM-HNCC algorithm can significantly reduce the time delay of HT traffic.

6 Conclusion

In heterogeneous networks consisting of Wi-Fi and hybrid MAC network, CM-HNCC was proposed to solve the problem of coexistence of Wi-Fi networks and hybrid MAC network. CM-HNCC can ensure fairness between networks and improve network performance. The Wi-Fi network can be IEEE802.11be or IEEE802.11ax.

When the traffic rate of the heterogeneous network consisting of Wi-Fi and hybrid MAC network is low, the throughput of the hybrid MAC network is not significantly improved by using CM-HNCC algorithm, and the time delay of HT is not significantly decreased. With the increase of traffic rate, the throughput of hybrid MAC network is improved, while the time delay of HT is significantly reduced.

Acknowledgement. This work was supported in part by the National Natural Science Foundations of CHINA (Grant No. 61871322, No. 61771390, and No. 61771392), and Science and Technology on Avionics Integration Laboratory and the Aeronautical Science Foundation of China (Grant No. 20185553035, and No. 201955053002).

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