Multi-service Communication Isolation of Underground Pipe Gallery Based on WiFi6

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Abstract. There are a variety of services in underground pipe gallery, and these services should be isolated during data transmission to ensure communication security. WiFi6(802.11ax) has the advantages of fast transmission rate, low energy consumption and low cost, and is suitable for carrying the underground pipe gallery communication service. In order to ensure the reliability of underground pipe gallery service transmission, it is necessary to study the communication isolation technology of WiFi6. In this paper, a communication isolation technology based on WiFi6 is proposed, and the communication isolation architecture of underground pipe gallery is designed to realize communication service isolation in frequency domain and spatial domain. In the frequency domain, a spectrum isolation scheme based on guardband is designed. In the spatial domain, a spatial stream isolation scheme based on service grouping is designed. Then, an isolation resource allocation method based on improved KM algorithm is proposed to realize the optimization of multi-service isolation. The simulation results show that the proposed communication isolation scheme can realize the communication isolation of underground pipe gallery with lower resource cost.

Keywords: Communication service isolation · WiFi6 · Underground pipe gallery · Guardband · KM algorithm

1 Introduction

The underground pipe gallery contains lines and pipes of different systems, such as water, electricity and gas, which share the space of the underground pipe gallery and have various communication demands [1]. In underground pipe gallery, data interaction between multiple types of services is generally achieved by wireless communication, which reduces wiring costs [2]. WiFi6(802.11ax), as the latest generation of IEEE 802.11 protocol that can be compared with 5G in terms of communication capability [3], becomes a technology selection suitable for multi-service communication in underground pipe gallery. In addition, multiple services in the underground pipe gallery should be isolated to ensure that communication services with different requirements [4], such as production, scheduling, management, and administration, do not affect each other.

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Therefore, it is necessary to design a proper communication isolation scheme according to the service characteristics of underground pipe gallery and the technical characteristics of WiFi6.

Compared with traditional WiFi technology, WiFi6 has great progress in energy consumption, data transmission speed and multi-service carrying capacity [5, 6]. OFDMA (Orthogonal Frequency Division Multiple Access) and MU-MIMO (Multi-User Multiple-Input Multiple-Output) are two important technologies in WiFi6. They can physically divide communication resources and play a role in communication service isolation. OFDMA is a frequency division multiplexing technology, which divides the bandwidth into multiple non-overlapping subcarriers [7]. The subcarrier bandwidth in WiFi6 is defined as 78.125 kHz, and several OFDMA subcarriers can form a RU (Resource Unit). The orthogonality between subcarriers ensures that there will be no interference in signal transmission, thus ensuring the isolation of subcarriers and achieving physical isolation effect [8]. MU-MIMO technology allows multiple users to access the channel at the same time through physical multi-antenna [9]. Due to the spatial multi-path propagation characteristics, when the spacing between each antenna unit is large enough, the multipath fading between receiver and transmitter antennas tends to be independent, and the service transmission channel also tends to be independent [10], realizing isolation in the spatial transmission process. WiFi6 can support OFDMA and MU-MIMO at the same time. When the number of subcarriers contained in RU is greater than or equal to 106, it can support MU-MIMO [11].

In this paper, a multi-service communication isolation scheme of underground pipe gallery based on WiFi6 is designed by combining the characteristics of underground pipe gallery and WiFi6. Firstly, an underground pipe gallery communication multi-service isolation architecture is designed to achieve service isolation in frequency domain and spatial domain. After that, the physical isolation method of multi-service in underground pipe gallery is designed. The service isolation method based on guardband is proposed in frequency domain, and the service isolation method based on service grouping is proposed in spatial domain. In the resource allocation stage, the mapping relationship between services and resources is established by using the algorithm based on graph theory. Finally, the feasibility of the communication isolation scheme is verified by simulation.

2 Multi-service Communication Isolation Architecture

In view of the technical characteristics of WiFi6 multi-service transmission and the isolation requirements of different communication services in underground pipe gallery, this paper proposes a communication multi-service isolation architecture based on WiFi6, which realizes multi-service isolation from the perspectives of frequency domain and spatial domain. The specific architecture is shown in Fig. 1. The isolation architecture consists of three layers: service layer, frequency domain layer and spatial domain layer, which bear different functions respectively.

In the service layer, the communication requests sent by each terminal are summarized and the communication services are classified according to the differences in communication service resource requirements and isolation requirements. After that,

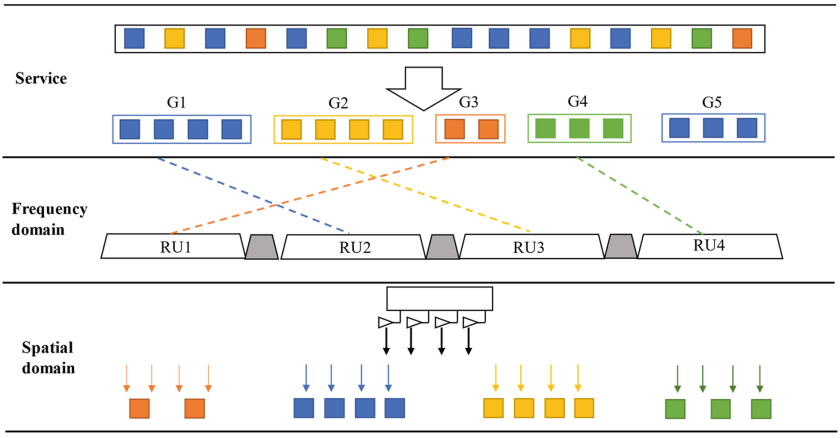

Fig. 1. Underground pipe gallery communication service isolation architecture.

communication services are divided into multiple service groups based on service types for subsequent communication isolation and resource allocation.

In the frequency domain layer, a spectrum isolation scheme based on the guardband is designed to realize the isolation of services in the frequency domain by limiting the distance of RU carrying services in the spectrum. According to the isolation requirements of service group and the guardband provided by RU, the mapping relationship between service group and RU is established based on the idea of graph theory. The RU specification of frequency domain division is 106-tone RU, which is the minimum RU that can support MU-MIMO, facilitating communication resource reuse and secondary isolation in spatial domain.

In the spatial domain layer, a spatial stream isolation scheme based on service grouping is designed. After the service group obtains RU, the spatial stream resources in the spatial domain are allocated among the services within the service group. Since different services are transmitted by different spatial streams in different spatial paths, the spatial stream isolation is realized.

In the isolation architecture, when a terminal sends a communication service request, the service type will be determined at the service layer first, and it will form a service group with several similar services. Secondly, in the frequency domain layer, the service groups compete for RU resources on the spectrum. At this time, all the service in the same RU is of the same kind of service, and the isolation of different kinds of service is realized in the frequency domain. Then, after the service group successfully obtains RU, the spatial stream under the RU is allocated among the services within the service group. The services obtain different spatial streams and transmit them in different paths, and realize the services isolation within a service group in the spatial domain. Finally, the resource allocation scheme is issued, and the communication service is designated to in certain spatial streams under a certain RU or is notified that the resource request fails. In this way, communication services can be isolated in both frequency domain and spatial domain, and different isolation requirements of communication services can be taken into account.

3 Multi-service Communication Isolation Method for Underground Pipe Gallery Based on WiFi6

3.1 Spectrum Isolation Scheme Based on Guardband

Isolation Mechanism Based on Guardband. The guardband is used to enhance the isolation in the frequency domain. It treats each RU as an independent channel and achieves isolation by limiting the distance between RU that transmitting services.

The guardband is the empty spectrum between channels. Frequency division multiplexing technology modulated different services to different spectrum positions. When the spectrum distance between services is wide enough, it can ensure that the signals do not interfere with each other [12]. OFDMA technology in WiFi6 divides the working bandwidth into several subcarriers, and the orthogonality of subcarriers provides natural isolation in frequency domain. There are Pilot subcarriers, DC subcarriers, Guard subcarriers and Null subcarriers on the channel [13]. The DC subcarriers, Guard subcarriers and Null subcarriers are not used for data transmission, but are used to resist interference from adjacent channels or adjacent subchannels. Figure 2 shows the division scheme of 106-tone RU at 20 MHz/40 MHz/80 MHz working bandwidth, while the null subcarriers and pilot subcarriers are not shown in the figure. When all RU on the spectrum carry data, some RU are too close to each other on the spectrum to meet the high isolation requirements of some services. Therefore, guardband can restrict the spectrum distance between RU carrying different services to ensure service isolation.

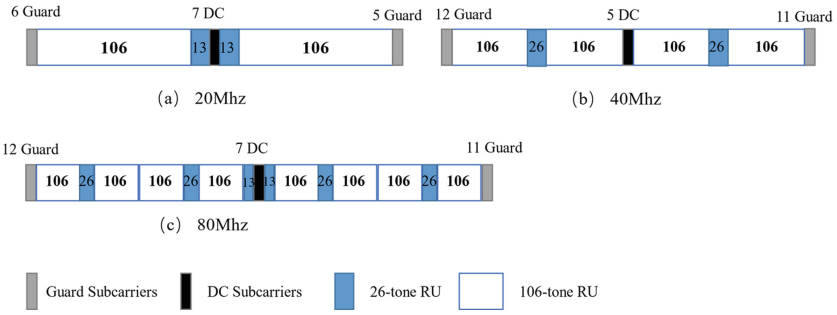

Fig. 2. 106-tone RU at 20 MHz/40 MHz/80 MHz.

According to the channel characteristics of WiFi6, when the guardband mechanism is adopted, part of the subcarriers originally used for data transmission will also be used for spectrum isolation due to the protection requirements of services, and part of communication resources will be sacrificed to enhance the isolation in the frequency domain. Multiple services of the same type form a service group. When service group applies for RU resource in the frequency domain, the guardband of the service group must be the same as that of the services in the service group. Figure 3 shows the allocation method of RU resources in the frequency domain at a certain time. Service can only be transmitted on the RU whose guardband is greater than the isolation requirement, and different types of services are in different RU.

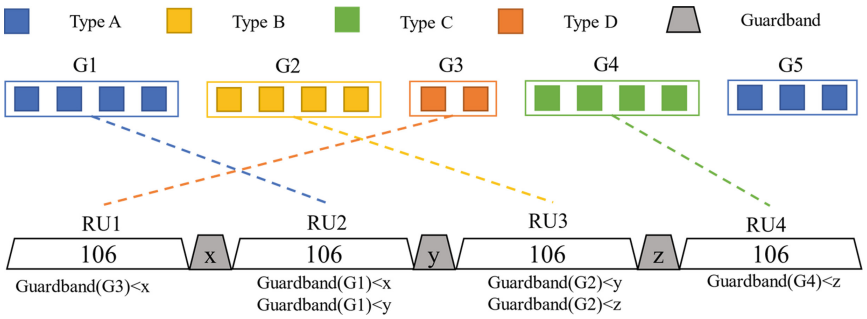

Fig. 3. Spectrum isolation mechanism based on guardband.

Guardband Calculation Method. WiFi6 guardband calculation mainly considers WiFi6 spectrum characteristics and service isolation requirements. WiFi6 and 5G both use OFDMA to divide spectrum resources, and some frequency bands in 5G are close to WiFi6 frequency band [14], so 5G guardband has strong reference for WiFi6 guardband.

The calculation formula of the guardband in 5G is Formula (1), Where $GB_{5G}(SCS, BW_{Band})isguardband$. BW_{Band} is the working bandwidth, SCS is the subcarrier space, NRB is the number of RB, and 12 consecutive subcarriers are defined as 1 RB.

$$GB_{5G}(SCS, BW_{Band}) = \frac{BW_{Band} - SCS * NRB * 12}{2} - \frac{SCS}{2} \tag{1}$$

Table 1. Guardband corresponding to different SCS and BW values in 5G.

SCS	BW = 5 MHz	BW = 10 MHz	BW = 20 MHz	BW = 30 MHz	BW = 40 MHz
15 kHz	242.5 kHz	312.5 kHz	452.5 kHz	592.5 kHz	552.5 kHz
30 kHz	505 kHz	665 kHz	805 kHz	945 kHz	905 kHz
60 kHz	N/A	1010 kHz	1330 kHz	1290 kHz	1610 kHz

Table 1 shows the guardband corresponding to some working bandwidths in 5G. Under the same working bandwidth, the value of the GB increases with the value of the SCS [15], while the value of the $\frac{GB(SCS)}{SCS}$ shows a downward trend on the whole. In WiFi6, the SCS is 78.125 kHz, and the $\frac{GB(60\text{ KHz})}{60\text{ KHz}} > \frac{GB(78.125\text{ KHz})}{78.125\text{ KHz}}$ can be judged to be true by the changing trend of 5G guardband.

$$GB_{RU}(RUband, \sigma_{Service}) = GB_{5G}\left(60, BW_{\left\lceil \frac{RUband}{5} \right\rceil * 5}\right) * \frac{78.125}{60} * \sigma_{Service} \tag{2}$$

The calculation method of RU guardband in WiFi6 is formula (2), the formula calculates a reference value according to 5G Guardband and introduces $\sigma_{Service}$. $\sigma_{Service}$ is the service impact factor, and its value is related to service isolation requirement.

When the total bandwidth of 106-tone RU is substituted, $GB_{RU}(78.125\ \text{KHz} * 106) = 1315\ \text{KHz} * \sigma_{Service}$. Because RU is only a sub-channel of WiFi6 working bandwidth, its environmental interference is far less than that of the complete channel with the same bandwidth. The bandwidth of a normal 20 MHz WiFi6 working channel edge Guard subcarriers is about 500 kHz, and the reference value calculated by the above method exceeds the isolation requirements of normal services. To save precious spectrum resources, the value of $\sigma_{Service}$ is usually less than 1.

Table 2. Service classification and their isolation requirements in underground pipe gallery.

Service type	Isolation requirement	$\sigma_{Service}$	Transmission rate	Latency requirement	Typical service
Data collection	Low	0.1	≤10 Mbps	Low	Temperature sensing
Video and image	Medium	0.4	5–100 Mbps	Medium	Machine room monitoring
Voice call	High	0.7	≤2 Mbps	High	Real-time call
Emergency	Highest	1.0	2–100 Mbps	Highest	Fire alarm

Table 2 shows the service classification and their isolation requirements in underground pipe gallery. Put $\sigma_{Service}$ of four types of underground pipe gallery communication services into Formula (2), and calculate that the guardband of data collection services is 131.5 kHz, that of video image services is 526 kHz, and that of voice call services is 920.5 kHz. The guardband of emergency services is 1315 kHz.

3.2 Spatial Stream Isolation Scheme Based on Service Grouping

In the spatial domain, this paper uses the characteristics of WiFi6 multi-antenna to carry different services under the same service group with different spatial streams to realize the isolation of services that have the same isolation requirements.

When the service group successfully obtains RU, the spatial stream resources obtained by each RU through spatial division multiplexing are allocated within the service group. The division of the service group will affect the utilization rate of spatial resources. When there are too many services in a service group, some services in the service group cannot obtain spatial stream resources. When there are too few services in a service group, spatial resources are wasted. Therefore, service groups need to be divided based on the number of spatial resources of the WiFi6 device. Set the number of spatial streams supported by the WiFi6 device is N_{stream}, the service group division method is as follows:

1. **Statistical Service Information.** The number of services participating in this round of resource allocation is M, and the service is $V = \{V_1, V_2, \ldots, V_M\}$, the transmission rate requirement is $R = \{R_1, R_2, \ldots, R_M\}$, service group number X, X is

initialized to 1. The transmission rate of RU is B, and its calculation method is formula (3). SBL is the bit of each Symbol, $Code_{rate}$ is the bit rate, $N_{Subcarrier}$ is the number of subcarriers, N_{MIMO} is the number of spatial streams, Symbol is the signal transmission time in the time domain, a fixed value of 12.8 us, GI is the gap of interframe, β is the ratio of the actual transmission rate to the theoretical transmission rate in the current communication environment. When calculating the RU transmission rate of 106-tone RU, $N_{Subcarrier}$ is set to 106 and N_{MIMO} is set to 1.

$$B = (SBL \times Code_{rate} \times N_{Subcarrier} \times N_{MIMO}) \div (Symbol + GI) * \beta \quad (3)$$

2. **Create a Service Group G_X.** Set the value of $Num_X = 0$, indicates the number of allocated spatial streams. Select a service that is not added to the service group and select its service type K as the service type to be received by service group G_X.
3. **Add service to G_X.** All services that meet $V_i = k$ are sorted by the waiting time. The services with long waiting time are placed at the front of the sequence and then traversed in sequence. Calculates the number of spatial streams R_i/B required by service according to its transmission rate requirement. If $Num_X + R_i/B \leq N_{stream}$, the service is added successfully. When $Num_{mimo} + R_i/B > N_{stream}$, the join fails. G_X does not add new service when either of the following conditions is met: $Num_{mimo} = 8$ or the services that meet $V_i = k$ have been traversed. If all services have been added to the service group, the division of service groups is complete, and the value of X is the number of service groups. Otherwise, X = X + 1, to Step2.

When a service group obtains a RU in the frequency domain, RU obtains multiple spatial streams through MU-MIMO technology space division multiplexing, and these spatial streams are distributed among the services in the service group. According to the division method of service groups, the spatial stream resources under each RU can meet the transmission requirements of all the services in the service group, and the services can obtain one or more spatial streams according to their own transmission rate requirements. For example, when MCS = 9, the maximum transmission rate of a single-stream 106-tone RU is about 50 Mbps [16]. If the transmission rate of a service is required to be 80 Mbps, 2 spatial streams are allocated to it, so that the transmission rate can meet the requirements of the service. Figure 4 shows the distribution of spatial streams in a RU. The service type of this service group is video and image service, and one or more spatial streams are allocated to it according to the transmission rate requirements of each service.

After the spatial stream allocation scheme is determined, the AP measures the channel characteristics from each antenna to each terminal. Then, according to the channel characteristics, the AP performs precoding calculation on the data to be sent, and sends the precoding signal on each antenna. The result is that when data reaches each terminal, it contains only the data from its own terminal, eliminating the data from other terminals, and forming a directional beam to each terminal. Multiple input antennas and multiple output antennas can simultaneously transmit different data on different spatial paths, and their spatial irrelevance brings spatial isolation of services. The isolation intensity between spatial streams is related to the antenna design of WiFi6 devices. The larger the antenna spacing, the stronger the antenna isolation.

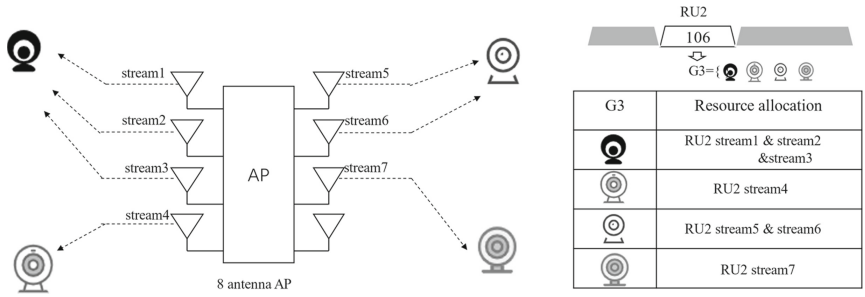

Fig. 4. MIMO spatial streams allocation method.

3.3 Isolated Resource Allocation Method Based on Improved KM Algorithm

Different types of service in the underground pipe gallery have different isolation requirements, and isolation capabilities of RU at different positions on the spectrum are also different, so the mapping between service and communication resources needs to be established according to the isolation requirements of service. In the process of resource allocation, isolation factor is introduced to test the advantages and disadvantages of allocation scheme. The isolation factor is related to the isolation and other requirements of services. In this paper, the isolation factor parameters of data collection service, video and image service, voice call service, and emergency service are respectively set to 1,5,9,25. At the same time, in order to prevent some services from obtaining communication resources for a long time, the isolation factor parameter is updated with the service waiting time, and at the end of each TXOP, the isolation factor for all services that do not receive communication resource increases by 1.

At the beginning of each round of resource allocation, the AP obtains the service information uploaded by the STA. The isolation factor of service is $L = \{L_1, L_2, \ldots, L_M\}$. Divide service groups based on service types and isolation requirements, and calculate the comprehensive isolation factor $GL = \{GL_1, GL_2, \ldots, GL_X\}$, corresponding to service group $G = \{G_1, G_2, \ldots, G_X\}$, and GL_x is the sum of service isolation factors in G_x. Then, calculate the service guardband requirement $GV = \{GV_1, GV_2, \ldots, GV_X\}$.

After the division of the service group is completed, the RU resources in the frequency domain are allocated. The quantity of 106-tone RU under the current working bandwidth is Y, and the distance between 106-tone RU and the nearest 106-tone RU on the spectrum is $DR = \{DR_1, DR_2, \ldots, DR_Y\}$. At this point, the constraints on resource allocation can be abstracted into the following:

1. When $GV_x < DR_y$, G_x can get RU_y.
2. Each service group can only get one RU.
3. Each RU can only be assigned to one service group.

The objective function can be expressed as formula (4), the matching relationship between RU and service group is recorded as $GR = \{GR_1, GR_2, \ldots, GR_X\}$, when G_x

gets RU_y, $GR_x = RU_y$, otherwise $GR_x = Null$.

$$\max\left[f(GR)\right] = max\sum_{x=1}^{X}[GL_x * (GR_x \neq Null)] \tag{4}$$

This problem can be solved by the idea of graph theory. The problem is abstracted into a matching problem of weighted bipartite graph, and the improved Kuhn-Munkres (KM) algorithm is used to solve it. The two point sets of the bipartite graph are $G = \{G_1, G_2, \ldots, G_X\}$ and $RU = \{RU_1, RU_2, \ldots, RU_Y\}$. According to constraint condition ①, when $GV_x < DR_y$, there is a weighted edge $E\left(G_x, RU_y\right)$ between G_x and RU_y, and the weight is GL_x. According to the constraint condition ②③, no two edges in the final set of desired edges have the same vertices. When the sum of edge weights in the final edge set is the largest, the objective function gets the optimal solution.

1. Add "virtual edge" and "virtual point", add "virtual point" to the point set with fewer points to make the number of centralized points of the two points the same, add "virtual edge" to transform the graph into a complete bipartite graph, the weight of "virtual edge" is 0.
2. Take a feasible vertex labelling l on the graph $Graph = (G, RU; E)$, then get the l equality subgraphs $Graph_l$ of $Graph$, which is $Graph_l$, satisfying the pair $\forall G_x \in G, RU_y \in RU$, have $l(G_x)+l\left(RU_y\right) \geq w\left(G_x, RU_y\right)$, where $w\left(G_x, RU_y\right)$ is the weight of edge $E\left(G_x, RU_y\right)$, initially set $(G_x) = \max_{y \in Y} w\left(G_x, RU_y\right)$, $l\left(RU_y\right) = 0, \forall G_x \in G, RU_y \in RU$. Any matching Match (can be ∅) on $Graph_l$ is used as the starting match.
3. If *Match* saturates each vertex of G, then *Match* is the optimal match and stops; otherwise, take any vertex u that is not saturated by *Match*, let $S = \{u\}, T = \emptyset$.
4. If the neighbor set $Neighbor_{Graph_l}(S)$ ↄT, go to Step 5. Otherwise, $Neighbor_{Graph_l}(S) = \mathrm{T}$. Calculate α_l, and new feasible vertex labels $\tilde{l}$. Let $l = \tilde{l}, Graph_l = Graph_{\tilde{l}}$.

$$\alpha_l = \min_{G_x \in S, RU_y \notin T}\left\{l(G_x) + l\left(RU_y\right) - w\left(G_x, RU_y\right)\right\} \tag{5}$$

$$\tilde{l}(v) = \begin{cases} l(v) - \alpha_l, v \in S \\ l(v) + \alpha_l, v \in T \\ l(v), v \notin Tv \notin S \end{cases} \tag{6}$$

5. Select $RU_y \in Neighbor_{Graph_l}(S)\backslash T$, if RU_y is *Match*-saturated, set $\left(RU_y, G_x\right) \in Neighbor_{Graph_l}(S)$, make $S \leftarrow S \cup \{G_x\}, T \leftarrow T \cup \left\{RU_y\right\}$, go to Step 4. Otherwise, RU_y is *Match* -unsaturated, and there is a *Match*-augmenting path P, let $M = M \Delta E(P)$, go to Step3.

Through the above algorithm, the Match obtained is the maximum weight edge set. KM algorithm is used to solve the maximum weight problem under perfect matching [17], but the final solution result of this problem need not be perfect matching. Therefore, "virtual point" and "virtual edge" are added. As shown in Fig. 5, RU5 is the added

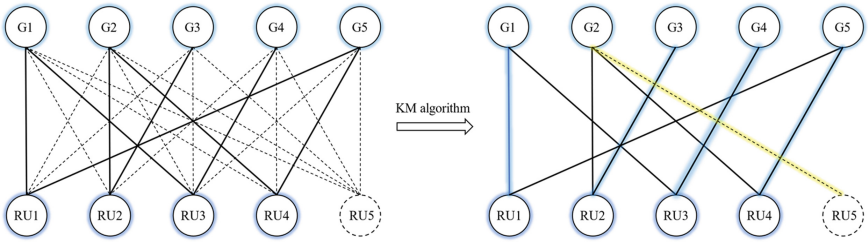

Fig. 5. Improved KM algorithm to solve RU assignment problem.

"virtual point", and the mapping between RU5 and G2 means that G2 has not obtained RU resources.

After the allocation of RU is completed, MU-MIMO technology is used to reuse 106-tone RU to obtain several spatial streams, which are allocated according to the transmission rate requirements of each service in the service group carried by this RU. Finally, distribute the resource allocation plan to each STA. At this time, if there are services in the resource request sequence that have not been allocated resources, increase their isolation factor by one and let them participate in the next round of resource allocation.

4 Simulation

In order to verify the feasibility of the proposed multi-service isolation scheme, a simulation experiment is carried out. The test network consists of 1 AP and 30 STAs, and all devices support 8*8 MU-MIMO. The wireless channel model conforms to Rayleigh fading. Working band is 2.4 GHz, working bandwidth is 40 MHz, MCS value is 9, 256 QAM modulation, bit rate is 5/6, Symbol bit length is 8, Symbol Time is 13.6 us (frame gap GI is 0.8 us, basic transmission Time is 12.8 us), TXOP is 5 ms.

The theoretical maximum rate of 40 MHz is $(8 * 5/6 * 468 * 8)/(12.8 + 0.8) = 1835$ Mbps, and the theoretical maximum rate of single-stream 106-tone RU is $(8 * 5/6 * 106 * 1)/(12.8 + 0.8) = 52$ Mbps. However, the actual transmission rate generally cannot reach the theoretical value, and the simulation assumes that the actual transmission rate is 50% of the theoretical transmission rate, that is, 26 Mbps.

Firstly, the performance of service isolation in frequency domain and spatial domain is verified. The isolation in frequency domain is realized by OFDMA technology and guardband. Under the working bandwidth of 40 MHz, there are four 106-tone RU. When they all transmit data, the guardband they can provide for service is 2187.5 kHz, 546.875 kHz, 546.875 kHz and 2187.5 kHz respectively. Figure 6 shows RU allocation at 40 MHz at a certain time, RU_1 and RU_4 can meet the requirements of four kinds of service isolation, RU_2 and RU_3 can meet the "Data collection" and "video and image" isolation requirements of the service. Four types of different services can find suitable RU to meet their guardband requirements.

MU-MIMO technology by making different service in different spatial path transmission to realize, so the isolation performance is associated with antenna hardware design. WiFi6 antenna isolation refers to the ratio of the signal transmitted by one antenna and

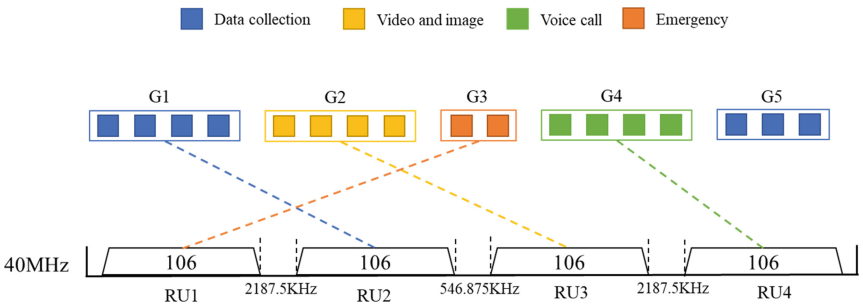

Fig. 6. The allocation of RU resources in 40 MHz.

the signal received by the other antenna to the signal of the transmitting antenna. That is, the less signal one antenna receives from the other antenna, the better the isolation between the two antennas and the lower the degree of interference. Currently, the isolation degree of WiFi6 devices on the market is generally higher than 15 dB in 2.4 GHz and 5 GHz bands, which meets the communication service isolation requirements of underground pipe gallery.

Secondly, the data transmission of different types of services is compared. Due to the large difference in the number of various communication services in the underground pipe gallery, different proportions were set for the four types of services in the simulation. Data collection services account for 50%, denoted as A in figure, video and image services account for 20%, denoted as B; Voice call services account for 20%, denoted as C, and emergency services account for 10%, denoted as D. Figure 7 shows the variation of latency with the number of STA. With the increase of the number of active STA, the average waiting time of the four types of service increases. In the vertical comparison, services with higher isolation have lower average latency. Emergency service can receive faster response from communication resources. Figure 8 shows the change of the average throughput of services with the number of STA. It can be seen that the throughput of emergency services and video and image services is larger, which is related to the higher transmission rate requirements of them.

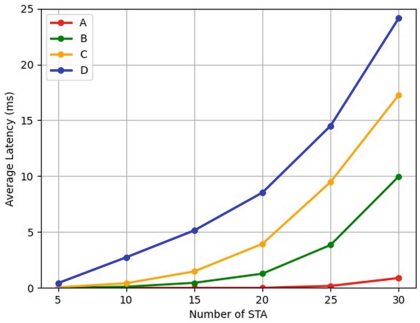

Fig. 7. Latency varies with the number of active STAs.

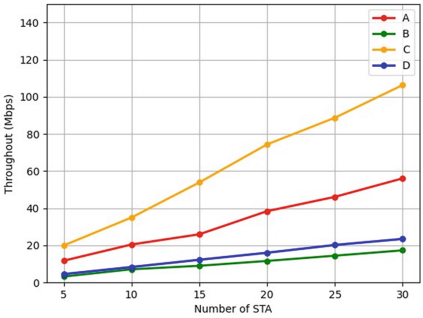

Fig. 8. Throughout varies with the number of active STAs.

Then, resource usage is compared with that without the service isolation solution. The channel division method in the comparison scheme is the same as that in the isolation scheme, but the spatial streams on 106-tone RU is not limited to the same type of service, and the resource allocation principle is FCFS (first-come-first-served). Figure 9 shows the variation of the average latency with the number of active STA of the two resource allocation schemes. The average latency of the isolation scheme is slightly higher than that of the comparison scheme, and the more active STA, the greater the latency gap. Figure 10 shows the variation of the throughout with the number of active STA of the two resource allocation schemes. When the number of active STAs is the same, the throughput difference between the two schemes is about 11%–23%, and the comparison scheme is slightly higher than the isolation scheme. Simulation results show that the resource allocation scheme has low resource cost while ensuring communication service isolation.

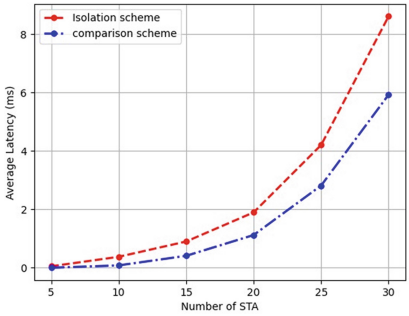

Fig. 9. Latency comparison of the two schemes.

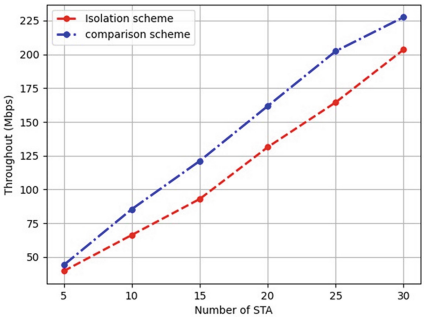

Fig. 10. Throughout comparison of the two schemes.

5 Conclusion

In this paper, a multi-service communication isolation method based on WiFi6 is designed to solve the communication isolation problems of different services in underground pipe gallery. Compared with the traditional wireless communication isolation scheme, the service isolation scheme in this paper is implemented based on the 802.11ax protocol, with low cost and strong scalability. It mainly uses the channel characteristics of WiFi6 frequency domain and spatial domain. This paper proposes a communication multi-service physical isolation architecture based on WiFi6 is proposed to realize the physical isolation of communication services from the two levels of frequency domain and spatial domain. In the isolation process, services are divided into service groups according to different service isolation requirements. In the frequency domain, the spectrum isolation scheme based on guardband is used to isolate different types of services. In the spatial domain, the isolation of same type services is realized by the spatial stream isolation scheme based on service grouping, and the isolation resource allocation mechanism is established through the improved KM algorithm based on the idea of graph theory. Through simulation verification, the solution can provide reliable isolation guarantee for services with different isolation requirements, and services with high isolation requirements such as emergency services can quickly receive resource responses, and pay a small resource cost while ensuring communication isolation.

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