Impact of Channelization on Two Power Allocation Schemes at 6 GHz Band

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***Abstract*—In this paper we study the impact of channel center frequency and bandwidth of interferer and victim links on maximum permissible power for two power allocation schemes, namely channel-based and PSD-based. The three different channelization scenarios are considered in the comparison, i.e., 1) when interferer channel is inside the victim channel, 2) when the two channels partially overlap, and 3) when the victim channel is inside the interferer channel. The performance evaluation results show that in the first scenario both power allocation schemes show the same result. In case of the second scenario the difference between two methods mainly depends on the overlapping area of interferer and victim channels. Finally, in the third scenario the difference in power allocation depends on the bandwidth of the victim channel. In addition, the number of power quantization levels is directly proportional to the power difference between two schemes.**

Keywords— Channelization, 6GHz, fixed service links, PSD, Wi-Fi, EIRP, frequency sharing.

I. Introduction

World-wide proliferation of mobile devices and continuous growth of new multimedia services, such as augmented reality (AR), virtual reality (VR), and mixed reality (MR) leads to continuous demand is network resources. According to the recent reports [1], it is expected that in 2028 every smartphone will consume 47 GB of data per month on average, compared to 16 GB per month in 2022. It is also predicted that the total mobile data traffic will reach 329 EB per month in 2028. Data transmission using 4G/5G mobile networks may not be always preferrable due to high cost. In such case using unlicensed band for data offloading is a great way to cope with the increasing traffic demand. Recently, many countries [2 – 4] have adopted 6 GHz spectrum for unlicensed use. Different device classes, i.e., devices with different power emission limits must follow different rules for accessing the spectrum. For instance, standard power device (SPD) defined by FCC must query an automated frequency coordination (AFC) for the available frequency and maximum permissible power levels before starting any transmission at 6 GHz band. In other words, AFC plays the role of a shield to protect existing services, such as fixed communication and broadcasting links, earth satellite stations and special incumbents from unwanted interference caused by unlicensed devices. The device performing request to AFC may specify the channel numbers or frequency ranges for which it inquires the maximum permissible power levels. The former refers to the channel-based scheme, where maximum equivalent isotropic radiated power (EIRP) is specified for each requested channel, and the latter refers to the power spectrum density based, where power level is specified per each 1 MHz of the requested frequency range.

In this work we show how channelization of interferer and victim links affects the maximum power allocation for channel-based and PSD-based schemes. By "channelization" term we assume channel bandwidth and center frequencies of corresponding channels. Two schemes are compared in terms of maximum permissible EIRP for the interferer channel. By default, Wi-Fi channels are considered as interferer and fixed communication service channels are considered as victims. Three interferer and victim channel layouts are evaluated for the comparison of two schemes. In scenarios where Wi-Fi channel is completely included in victim channel the maximum EIRPs were same. In case of partial overlapping both allocation methods may cause higher or lower power levels depending on the channel overlapping area. Finally, the difference between two schemes depends on the bandwidth of the victim link in the scenarios where victim channel is inside the Wi-Fi channel. The rest of the paper is organized as follows. In section II we introduce some of the related work and assumptions made for power calculations. Section III describes some details of channel-based and PSD-based power allocation schemes. In section IV we analyze the impact of channelization on output power levels for three channel layouts. Finally, in section V we conclude the paper.

II. Related Work and Assumptions

In our previous work [5] we studied the performance of channel-based in PSD-based power allocation schemes for different reference interference-to-noise rations (RINR). Compared to that work, here we mostly focus on the architecture where the maximum permissible power levels are pre-calculated and stored at AFC by means of protection contours. In addition, here we analyze the scenario with narrow band victim channel of 5 MHz to highlight the cases when the bandwidth difference is high.

For the performance evaluations we use power quantization, where EIRP can be any value from the $P = \{24, 27, 30\}$ dBm and PSD any value from $D = \{11, 14, 17\}$ dBm/MHz. Any EIRP level other than defined in set P should be quantized to the closest lower of P. The values of D are derived from P assuming 20 MHz width channel, i.e., summing 20 bins of 1 MHz power values of D result in corresponding values of P. We defined three levels of power quantization for performance evaluation. The values of P and D and the quantization level were selected solely to show the trend and dependency. Since different regulatory bodies may require different power limits the actual values should vary depending on the rules applied in different countries. For instance, in US FCC mandates determining the frequency availability starting from 36 dBm down to 21 dBm with step no greater than 3 dB. Applying this requirement results to quantization level of six.

III. CHANNEL-BASED AND PSD-BASED POWER ALLOCATION SCHEMES

Both PSD-based and channel-based power allocation methods should use emission mask [6] shown in Fig. 1. The following equation shows the maximum EIRP calculation for PSD-based scheme,

$$EIRP_{PSD} = \min_{i\in[-0.5N,0.5N]} PSD_i + 10\lg(N) \quad (1)$$

where *PSDi* is the maximum transmission power for 1 MHz *i*, *N* is the nominal bandwidth of interferer channel. Equation 1 only shows the maximum possible EIRP value, which can be further reduced following the out-of-channel emission limits defined by mask data shown in Fig. 1. Equation (2) shows the maximum EIRP calculation for channel-based scheme,

$$EIRP_{Ch} = min\left(EIRP_{ref}, EIRP_j + FDR\left(f_{off}, B, N\right)\right) \quad (2)$$

where $EIRP_{ref}$ is the maximum channel EIRP defined by regulatory, $EIRP_j$ is the maximum channel EIRP calculated using location information of interferer, and FDR is the frequency dependent rejection, which is the function of the frequency offset between victim and interferer channels with corresponding bandwidths *B* and *N*.

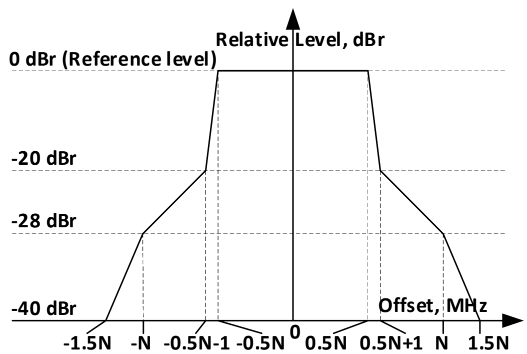

Fig. 1. Interferer spectrum emission mask for channel bandwidth *N*

IV. IMPACT OF CHANNELIZATION

Three scenarios are considered for comparison between channel-based and PSD-based power allocation schemes: 1) when Wi-Fi channel completely included into the victim channel, 2) both channels partially overlap, and 3) victim channel is completely included into the Wi-Fi channel. In order to compare these scenarios three channel layouts were used in calculations. Fig. 2 shows the first channel layout with victim channel of 30 MHz and center frequency of 5974.85 MHz. Wi-Fi channelization follows the rules defined in [7]. The graph at the bottom of Fig. 2 shows the PSD_i for each 1 MHz bin *i*. As shown in Table I, for both CH1 and CH9 $EIRP_{ch}$ is 3 and 6 dB higher than $EIRP_{PSD}$. This is because FDR for these two cases is more than 3 and 6 dB. Another example of scenario 2) is shown for CH3 and CH11. For CH3 PSD-based scheme shows higher EIRP because FDR for channel-based scheme is less than 3 dB due to large overlapping area. On the other hand, for CH11 $EIRP_{Ch}$ shows 3 dB higher value due to the small overlap. In case of scenario 1) both channel-based and PSD-based EIRP show the same result for CH5. For the scenario 3), i.e., CH7, FDR only adds additional 3 dBm to the lowest 24 dBm to get the final power level of $EIRP_{Ch}$, while eighty 11 dBm/MHz bins result in 30 dBm of $EIRP_{PSD}$.

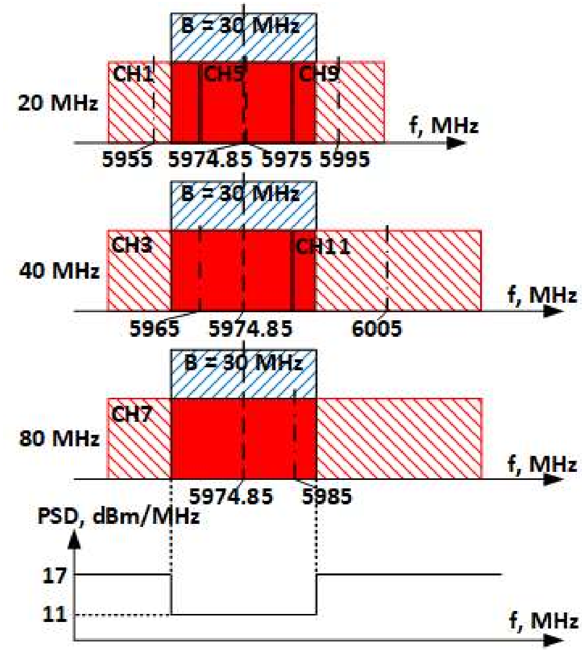

Fig. 2. Channel layout with F_c = 5974.85 MHz and B = 30

TABLE I. WI-FI CHANNEL EIRP VALUES OF TWO POWER ALLOCATION SCHEMES FOR VICTIM WITH F_c = 5974.85 MHZ AND B = 30 MHZ

Wi-Fi channel	$EIRP_{PSD}$, dBm	$EIRP_{Ch}$, dBm
CH1 (20 MHz)	24	27
CH5 (20 MHz)	24	24
CH9 (20 MHz)	24	30
CH3 (40 MHz)	27	24
CH11 (40 MHz)	27	30
CH7 (80 MHz)	30	27

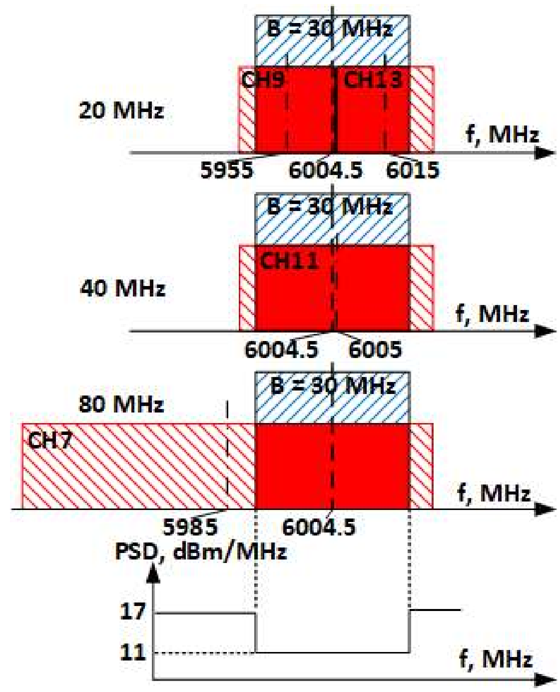

Fig. 3. Channel layout with F_c = 6004.5 MHz and B = 30 MHz

TABLE II. WI-FI CHANNEL EIRP VALUES OF TWO POWER ALLOCATION SCHEMES FOR VICTIM WITH F_c = 6004.5 MHZ AND B = 30 MHZ

Wi-Fi channel	$EIRP_{PSD}$, dBm	$EIRP_{Ch}$, dBm
CH9 (20 MHz)	24	24
CH13 (20 MHz)	24	24
CH11 (40 MHz)	27	24
CH7 (80 MHz)	30	27

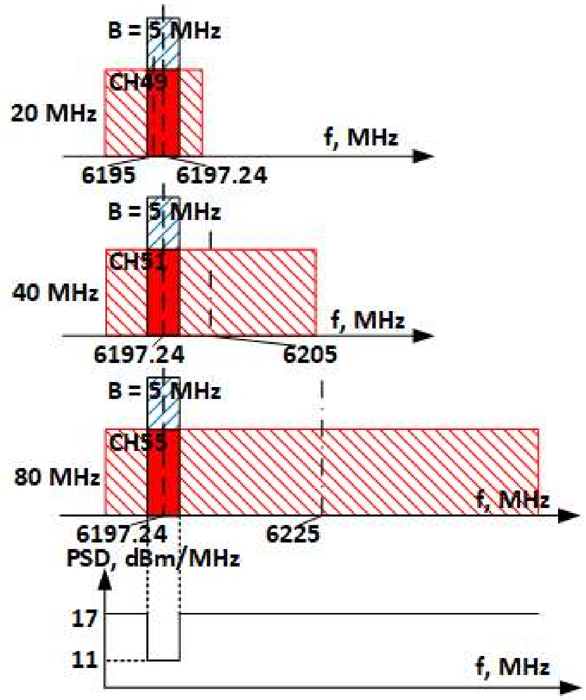

Fig. 4. Channel layout with F_c = 6197.24 MHz and B = 5 MHz

TABLE III. WI-FI CHANNEL EIRP VALUES OF TWO POWER ALLOCATION SCHEMES FOR VICTIM WITH F_c = 6197.24 MHZ AND B = 5 MHZ

Wi-Fi channel	$EIRP_{PSD}$, dBm	$EIRP_{Ch}$, dBm
CH49 (20 MHz)	24	30
CH51 (40 MHz)	27	30
CH55 (80 MHz)	30	30

Fig. 3 shows the second channel layout with victim channel of 30 MHz and center frequency of 6004.5 MHz. As shown in Table II for both Wi-Fi channels CH9 and CH13 two schemes allocate 24 dBm of EIRP. This result is different compared to the CH1 and CH9 EIRP shown previously in Table I. This is because FDR value for CH9 and CH13 is not high enough due to the large overlapping area with the victim channel. CH11, CH7 and victim channel in Fig. 3 show the scenario 3), where the victim channel is completely included in the Wi-Fi channel. Similar to the layout in Fig. 2 $EIRP_{PSD}$ shows 3 dBm higher power than $EIRP_{Ch}$. The FDR value in case of CH11 and CH7 is less than 3 dB and 6 dB, respectively.

Fig. 4 shows the third channel layout with victim channel of 5 MHz and center frequency of 6197.24 MHz. For each case with CH49, CH51, and CH55 the victim narrow band channel is completely included within the interfering channel showing the scenario 3). According to the results in Table III, $EIRP_{Ch}$ is less than or equal to the $EIRP_{PSD}$. $EIRP_{Ch}$ is assigned the maximum possible EIRP of 30 dBm because FDR in all cases exceeds 6 dB due to small overlapping area. FDR is directly proportional to the bandwidth of interfering channel. $EIRP_{PSD}$ increases by 3 dBm when Wi-Fi bandwidth doubles. As can be noticed, scenario 3) in the channel layout shown in Fig. 4 shows completely opposite results compared to Fig. 3 and Fig. 2, where $EIRP_{PSD}$ is larger than $EIRP_{Ch}$. This shows that the final EIRP level for two allocation schemes depends not only on the interferer channelization, but also on the bandwidth of the victim channel.

V. CONCLUSION

In this paper we studied the impact of channelization of interferer and victim links on maximum power allocation for PSD-based and channel-based power allocation schemes. We considered three different scenarios when 1) when Wi-Fi channel is inside the victim channel, 2) both channels partially overlap, and 3) victim channel is inside the Wi-Fi channel. Three different channel layouts were analyzed to cover all three scenarios. The analysis results show that in case of scenario 1) both $EIRP_{PSD}$ and $EIRP_{Ch}$ result in the same power level. In case of scenario 2) the overlapping area plays the crucial role in difference between two schemes. Small overlap leads to the outcome with $EIRP_{PSD}$ much less than $EIRP_{Ch}$. The difference depends on the power quantization level. On the other hand, when overlapping area is big both schemes show the same EIRP results. Finally, in case of scenario 3) both channel bandwidth of interferer and victim are important. The analysis also shows that careful selection of the power allocation scheme is required due to the differences in some of the scenarios in order to avoid unwanted interference.

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