Technical Appendix

Benefits of increased EIRP for standard-power operations in 6 GHz subject to AFC

Author: Douglas Goedken, Fabiano Chaves, Prakash Moorut

Nokia Mobile Networks, Bell Labs & CTO

1 Introduction

This document presents examples of RF link budgets for the 6 GHz band. We use the term "U-NII devices" for 6 GHz unlicensed devices generally. The deployment models, propagation models and device antenna patterns are described.

The FCC Report and Order and Further Notice of Proposed Rulemaking [1] for Unlicensed Use of the 6GHz Band provides a maximum EIRP of 36dBm and 23dBm/10MHz EIRP power spectral density (PSD) for the Standard Power Access Point. With 5G, the assumption is channel bandwidths greater than 20MHz will be likely. This study presents five scenarios to illustrate the difference of using a fixed total EIRP (independent of channel bandwidth) versus a fixed power spectral density for case where the channel bandwidth is greater than 20MHz.

2 RF Link Budget Scenario and parameters

2.1 RF Link Budget description

In this study, a theoretical approach leveraging an RF Link Budget is used to compare the maximum allowable path loss for different deployment scenarios. It applies specific product capabilities for the base stations or access points and user equipment or client devices, along with other assumptions to arrive at a maximum allowable path loss for both the downlink and uplink. The maximum path loss can then be used in a propagation model to estimate the range between the base station and user equipment.

2.2 RF Link Budget scenarios

In the context of this study, the base station (downlink) uses a transmit power according to the proposed U-NII Standard-Power Access Point Maximum EIRP limits.

Five different deployment scenarios are considered.

Scenario 1: The first deployment scenario is considered as the base line. In this scenario, a carrier with 20MHz bandwidth is considered. The base station has 36 dBm Total EIRP for the 20MHz channel, or 23dBm/MHz. For comparison purposes, a DL edge throughput of 5 Mbps was arbitrarily selected.

Scenario 2: This scenario is similar to Scenario 1 with the exception of using an 80MHz bandwidth carrier. This results in the EIRP dBm/MHz value to be reduced by 6 dB. The DL edge throughput remains at 5 Mbps.

Scenario 3: This scenario is also similar to Scenario 1 with two exceptions;

(1) The carrier is 80MHz bandwidth, resulting in the EIRP dBm/MHz value reduced by 6 dB.
(2) The DL edge throughput increases to 20Mbps, an increase of 4 times to correspond to the 4x increase in channel bandwidth.

Scenario 4: This scenario is similar to Scenario 2 (80MHz Channel Bandwidth) with the difference being the total EIRP value is increased by 6dB to maintain the same 23dBm/MHz PSD EIRP as Scenario 1.

Scenario 5: This scenario is similar to Scenario 4 with 23dBm/MHz PSD EIRP but with a higher DL edge throughput resulting in the same cell range as Scenario 1.

2.3 RF Link Budget parameters

Table 1 provides the RF link budget settings used for the five different scenarios which were considered.

The uplink edge throughput has been set at a low level, so as to focus on the downlink across the different scenarios.

Table 1: RF Link Budget examples for Unlicensed 6GHz

Scenario	1		2		3		4		5	
Channel bandwidth [MHz]	20		80		80		80		80	
DL/UL subframes ratio	4:1		4:1		4:1		4:1		4:1	
Parameter	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
Total output power [dBm]	30	23	30	23	30	23	36	23	36	23
Tx Antenna gain [dBi]	6	0	6	0	6	0	6	0	6	0
Effective EIRP [dBm]	36	23	36	23	36	23	42	23	42	23
EIRP [dBm/MHz]	23		17		17		23		23	
Rx Antenna gain [dBi]	0	6	0	6	0	6	0	6	0	6
Cell-edge user throughput [Mbps]	5	0.2	5	0.2	20	0.2	5	0.2	25	0.2
Receiver sensitivity [dBm]	-90.6	-102.3	-90.0	-102.3	-85.5	-102.3	-90.0	-102.3	-84.5	-102.3
Interference Margin [dB]	1.86	2.6	0.4	2.6	1.3	2.6	0.4	2.6	1.8	2.6
Shadowing margin [dB]	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Maximum Allowable Path Loss [dB]	115.7	122.7	116.5	122.7	111.1	122.7	122.5	122.7	115.7	122.7
Cell range [m]	149		157		110		232		149	

The UL receiver sensitivity assumes 15 physical resource blocks with 30kHz sub-carrier spacing and therefore is not impacted with a 20 or 80MHz channel.

The maximum allowable path loss is used with the 3GPP Urban Micro (street canyon) non line-of-sight model defined in 3GPP TS 38.901 with the base station antenna at 9m and user device at 1.5m.

3 RF Link Budget Observations

3.1 General

The observations are made with respect to comparison of Scenario 2 through 5 with the Scenario 1 base line.

3.2 Scenario 2: 80MHz BW, 36dBm EIRP

With scenario 2, the total EIRP is maintained at 36dBm. The channel bandwidth is increased from 20 to 80MHz., resulting in the power spectral density decreasing from 23 to 17 dBm/MHz. Scenario 2 keeps the edge DL throughput the same at 5 Mbps. The larger channel bandwidth (80MHz) allows for a lower SNR, thus the increase to bandwidth and the reduction to the SNR results in the downlink receive sensitivity to be about the same at - 90dBm. The lower power spectral density also benefited Scenario 2 such that the downlink maximum allowable path loss is 0.8dB better. This results in a 5% increase to the cell range, though the spectrum efficiency at the cell edge has been reduced.

3.3 Scenario 3: 80MHz BW, 36dBm EIRP, higher throughput

Scenario 3 is similar to scenario 2 in that the total EIRP is maintained at 36dBm, the channel bandwidth is increased from 20 to 80MHz, and the power spectral density is decreased from 23 to 17 dBm/MHz. The difference introduced with Scenario 3 is the edge DL throughput is increased by a factor of 4 to correspond to the increase in channel bandwidth. To achieve the higher downlink throughput, a higher Modulation and Coding Scheme (MCS) will be used which in turn requires a higher SNR. This higher SNR results in the downlink receive sensitivity to be about 5dB higher. This results in a cell range approximately 25% smaller than the Scenario 1 baseline to maintain a similar cell edge spectrum efficiency.

3.4 Scenario 4: 80MHz BW, 23dBm/MHz PSD EIRP

Scenario 4 differs from Scenario 1, in that the total output power is increase by 6 dB to compensate for the 4 times increase to the channel bandwidth. The PSD EIRP between the two scenarios remains the same at 23dBm/MHz. Scenario 4 keeps the edge DL throughput the same at 5 Mbps. The larger channel bandwidth (80MHz) allows for a lower SNR, thus the increase to bandwidth and the reduction to the SNR results in the downlink receive sensitivity to be about the same at -90dBm. The 6dB additional Tx power, along with small improvement due to spreading the throughput across a larger channel benefits Scenario 4 such that the downlink maximum allowable path loss is 6.8dB better. This results in a 50% increase to the cell range.

3.4 Scenario 5: 80MHz BW, 23dBm/MHz PSD EIRP, higher throughput

Scenario 5 is similar to scenario 4 in that the EIRP PSD is maintained at 23dBm/MHz, the channel bandwidth is 80MHz., and the total power is increased by 6dB. The difference introduced with Scenario 5 is the edge DL throughput is increased to the point where the resulting cell range corresponds to Scenario 1. The result is that with similar cell range as Scenario 1, Scenario 5 could provide 5 times increase to the cell-edge user throughput.

4 Field Results

The results of the RF link budget study for Scenario 4, where transmit power was increased to compensate for the larger channel bandwidth, but not exceeding the 23dBm/MHz PSD EIRP, showed a 50% increase to the cell range. A field test was performed to demonstrate the gain. A walk test was performed at a site (located in upper right corner of Figure 1) for two cases. The first is with the total transmit power at the site set 21 dBm and the second with the transmit power increased by 6 dB to 27 dBm. The results show approximately a 30% increase to the range of site. This is lower than the extent of range increased suggested by the RF link budget, assumed to be due to the local clutter (buildings, trees, etc.) and also the assumed propagation model used in the RF link budget study not tuned to match the real world environment at this site. Still, the increase of 30% in range is significant.

Figure 1: RSRP Comparison

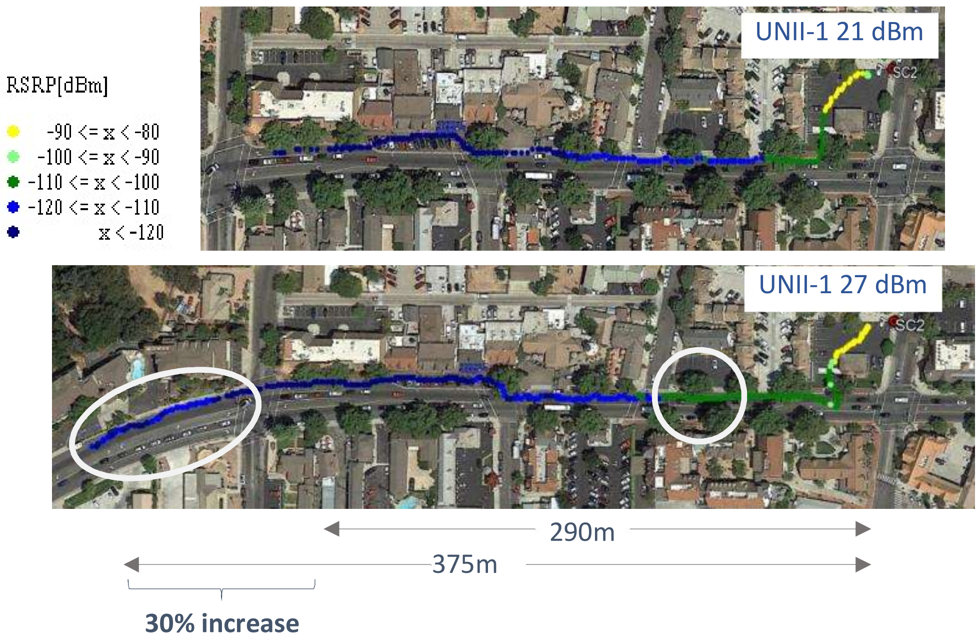
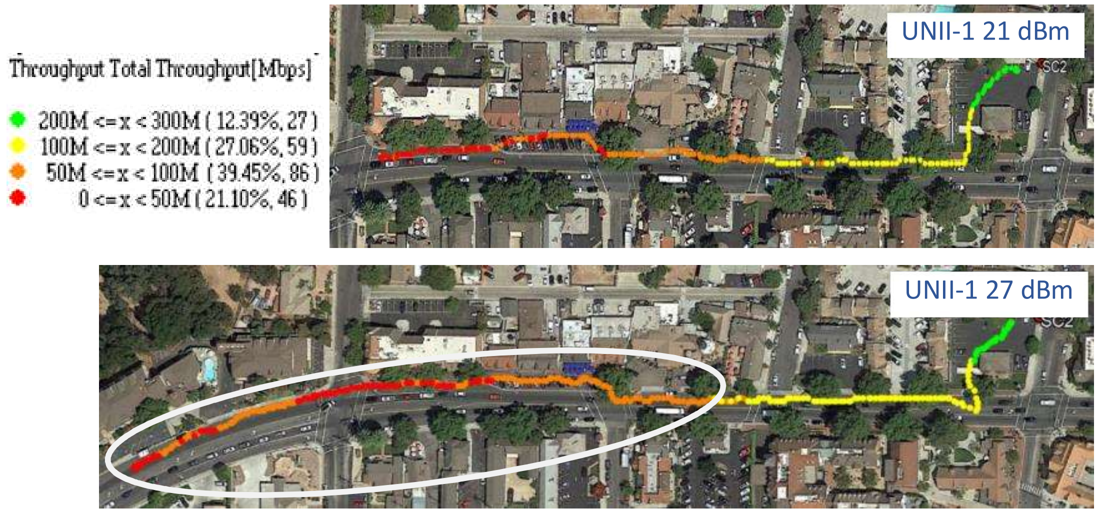


Figure 2 shows the comparison of the SINR. The extended range is observed as well as improved SINR along the path as the source signal is improved by 6dB.

Figure 2: SINR Comparison

Figure 3 shows the comparison of the downlink throughput. Here it can be observed the extra 6dB allows for the site to extend further and provide improved user performance.

Figure 3: Downlink Throughput Comparison



5 Conclusion

As the expectation for 5G is to have channel bandwidths larger than 20MHz, various RF link budget scenarios were considered with regards to the EIRP and PSD EIRP for the Standard Power Access Point. One approach was to fix the Total EIRP power to 36dBm independent of channel bandwidth, such that when the channel bandwidth is considered wider than 20 MHz the PSD EIRP proportionally decreases from the 23dBm/MHz limit. The second approach was to allow the total EIRP to increase, but not allow the PSD EIRP to go above 23dBm/MHz.

- Maintaining the same Total EIRP: an increase to the channel bandwidth will result in the cell edge not being as spectral efficient.
- Maintaining the PSD EIRP at 23dBm/MHz: changing the maximum EIRP to reflect an increase of channel bandwidth provided benefit to the cell range or cell edge throughput, dependent on how one wanted to take advantage of the EIRP increase.

Based on this study, we recommend the Commission consider specifying the Standard Power Access Point maximum EIRP value as 42dBm, thus allowing for higher EIRPs with larger channel bandwidths, while maintaining the 23dBm/MHz PSD EIRP.

6 References

[1] Unlicensed Use of the 6 GHz Band, Report and Order and Further Notice of Proposed Rulemaking, WT Docket No. 18-295 & GN Docket No. 17-183, FCC 20-51, ¶ 1 (rel. Apr. 24, 2020) ("Report and Order"), errata (rel. May 15, 2020).