July 5, 2016

# Comparison of 28GHz and 39GHz Spectrum

AT&T

Advanced Wireless Technology Group

AT&T Labs, Austin TX

## 1 Executive Summary

Lately, mmWave spectrum has received a lot of attention as potential candidates for 5G, as the large bandwidth available in mmWave has made these bands attractive candidates for 5G mobile deployments. Of the various available mmWave spectrums the two bands that have received a lot of attention -- particularly in USA, and Korea -- are 28GHz and 37/39GHz. Between these two bands, the industry momentum currently favors 28GHz due to the activity in Korea as related to the 2018 Olympics. From a propagation point of view, 28GHz has better potential given the longer wavelengths as compared to 37/39GHz. But there is significantly more bandwidth available in the 37/39GHz, which makes it an attractive 5G option as well.

There are, however, important performance differences between the two bands that should be considered in licensing and policy judgments regarding use of the bands. These differences are important to understand to foster competitive 5G deployments in the bands and U.S. leadership in 5G development and deployment.

Below, we provide a comparative analysis of the coverage of a 5G small cell in 28GHz vs 39GHz with all else being equal (i.e. same power level, same antenna configuration, and same channel bandwidth). Our conclusion is that a licensee will need somewhere between 44% - 66% more spectrum in the 39GHz band to provide the same cell edge data rate with the same cell radius as compared to 28GHz. Our analysis follows.

## 2 Analysis

The first step in this analysis is to compare the propagation differences between these frequency bands. Currently the best source of propagation data in these frequencies is the 3GPP TR 38.900, "Study Item on Channel Model for Frequencies Above 6GHz". Based on the TR we see than the propagation model in typical micro-cellular scenario is given as

LOS Conditions: $PL = 32.4 + 21\log 10(d_{3D}) + 20\log 10(f_c)$

NLOS Conditions: $$\begin{aligned} PL_{UMi\text{-}NLOS} &= 35.3\log_{10}(d_{3D}) + 22.4 \\ &+ 21.3\log_{10}(f_c) - 0.3(h_{UT} - 1.5) \end{aligned}$$

Using $f_c$ = 28 GHz and $f_c$ = 39 GHz reveals that the propagation loss at 39 GHz is approximately 3 dB higher than the propagation loss in 28 GHz, for both LOS and NLOS conditions. Additionally, if we want to consider in building coverage then we also have to account for the fact that in building penetration loss is roughly 2dB higher in the 39GHz band as seen in the 3GPP TR 38.900. Therefore for indoor coverage the total loss is 5dB higher in the 39GHz.

The next step in this analysis is to determine how the higher propagation loss impacts the amount of spectrum needed at 39 GHz compared to 28 GHz in order to achieve the same cell coverage and same cell edge data rate in both bands. In order to do this analysis we need to pick a target cell edge and a typical system bandwidth. We pick two typical cases:

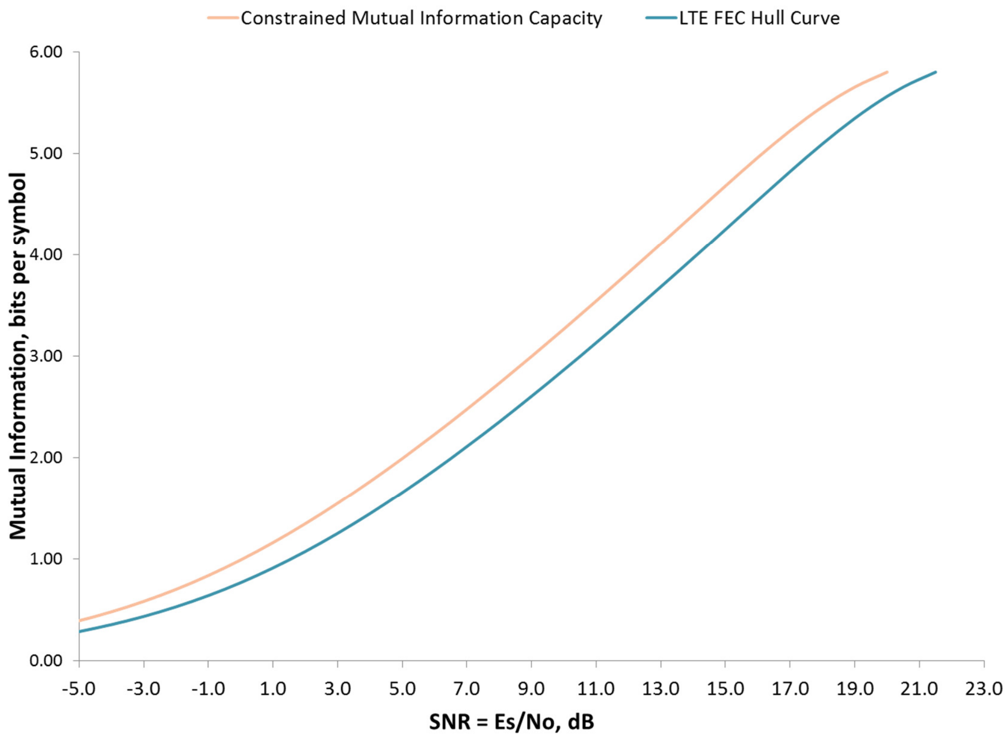
- Case a) In 28GHz we have 200MHz of spectrum and a target cell edge data rate is 200Mbps
- Case b) In 28GHz we have 200MHz of spectrum and a target cell edge data rate is 500Mbps.

From our modeling and analysis we have seen that at the cell-edge mmWave systems are predominantly noise limited rather than interference limited, because mmWave systems are designed with small beam widths (we have seen 8 to 10 degrees) and large system bandwidth with the noise floor proportional to the system bandwidth. As an example, a mmWave system bandwidth 200MHz yields a noise floor 13dB higher than a typical LTE system with a 10MHz system bandwidth. We can therefore show that the difference in the SINR in the two bands is given by

$$\gamma_1 - \gamma_2 = \Delta P + 10\log_{10}\left(\tfrac{1}{X}\right)$$

Where $\gamma_1$ and $\gamma_2$ are the SINR in the 28GHz and 39GHz bands respectively, $\Delta P$ is the propagation loss difference (5dB for indoor and 3dB for outdoor) between the bands, and $X$ is the ratio of the system bandwidth in 39GHz and 28GHz, which we are trying to compute.

In order to compare the bandwidth we need to look at the throughput vs SNR curve for the various MCS levels (modulation and coding). Because the 5G mmWave Forward Error Correction (FEC) scheme has not been determined (nor simulated) the current analysis will be based on LTE FEC. The figure below shows both the theoretical mutual information capacity and the Hull curve for the LTE FEC based on Turbo codes.




This curve shows that for the two cases under consideration (1 bit/symbol for 200Mbps at cell edge and 2.5 bits per symbol for 500Mbps at cell edge), the 28GHz system needs to be operating at 1.5dB and 8.5dB SINR respectively. Based on this we can derive the value of X for the two cases recursively which satisfy the condition

Case a: $1 = (1 + X_a)G\left(1.5 + \Delta P + 10\log_{10}\left(\frac{1}{X_a}\right)\right)$

Case b: $2.5 = (1 + X_b)G\left(8.5 + \Delta P + 10\log_{10}\left(\frac{1}{X_b}\right)\right)$

Where G is the function that maps SINR to spectral efficiency as shown in the figure by LTE Hull Curve, and $\Delta P$ is the difference in propagation between the two bands. For the purpose of these results we use a $\Delta P$ of 3dB which reflects outdoor coverage. Since we do not have a closed form solution for G we solve these expressions numerically and arrive at the following values of X

| | |
|---|---|
| 200Mbps | 0.66 |
| 500Mbps | 0.44 |

<u>This implies that we would need somewhere between 44% - 66% more spectrum in the 39GHz to provide the same cell edge data rate with the same cell radius as compared to 28GHz</u>