

# 5G mmWave and Mobile Virtual Reality Using Pivotal Repeaters and Edge Computing

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The \$1.8 billion global VR (virtual reality) games market, comprising game and headsets, is a small fraction of the \$180 billion games market<sup>1</sup> mostly because VR requires an expensive high-end VR PC, VR headset, and a fast, typically wired, wide area connection such as cable or fiber.

5G mmWave provides a viable wide area connection alternative that, combined with edge cloud computing, will obviate VR PCs. 5G mmWave and edge clouds will dramatically lower entry costs for VR and expand both consumer and business markets, leading to lighter and smaller headsets and glasses. Wide area mobility, in turn, will accelerate the augmented reality (AR) market.



Fig 1 | High end fun – Beat Saber is a VR rhythm game where players use light sabers to slice incoming blocks representing musical beats.

This paper will describe how Pivotal Commware repeaters extended a 5G mmWave signal from a gNB into a hotel room in downtown Los Angeles, where it streamed Beat Saber from PlutoVR's PlutoSphere server at Amazon Web Services (AWS). The purpose of this demonstration was to compare the gameplay and video quality between 4G and 5G mmWave. 5G was a clear winner on both counts and represents a superior, mobile alternative to cable and fiber.

## Pivotal Repeaters Extend 5G mmWave

5G mmWave dominates 4G in capacity and low latency, but its propagation is limited by line-of-site (LOS) and in-building penetration. This is where Pivotal repeaters come in. The Pivot 5G® network repeater, located within LOS of the gNB, uses its donor unit to capture the gNB signal and then passes it via coax to one or two service units (SU). The SU redirects the signal beyond the gNB's LOS; in this case, onto the Nixio patio lounge of the E-Central Hotel. Pivot latency is 40 nanoseconds.

The task of penetrating into the hotel's Figueroa Room, site of the VR demo, was accomplished by Pivotal's Echo 5G subscriber repeater. The Echo was attached within seconds to the inside glass of the Figueroa and plugged into a nearby wall outlet. Echo latency is five nanoseconds. Figure 2 shows the approximate locations in the hotel of the Pivot and Echo repeaters.

<sup>1</sup> Consumer VR Headset and Content Revenue Forecast, 2020-2025, by Omdia, and IDC Data, 2020

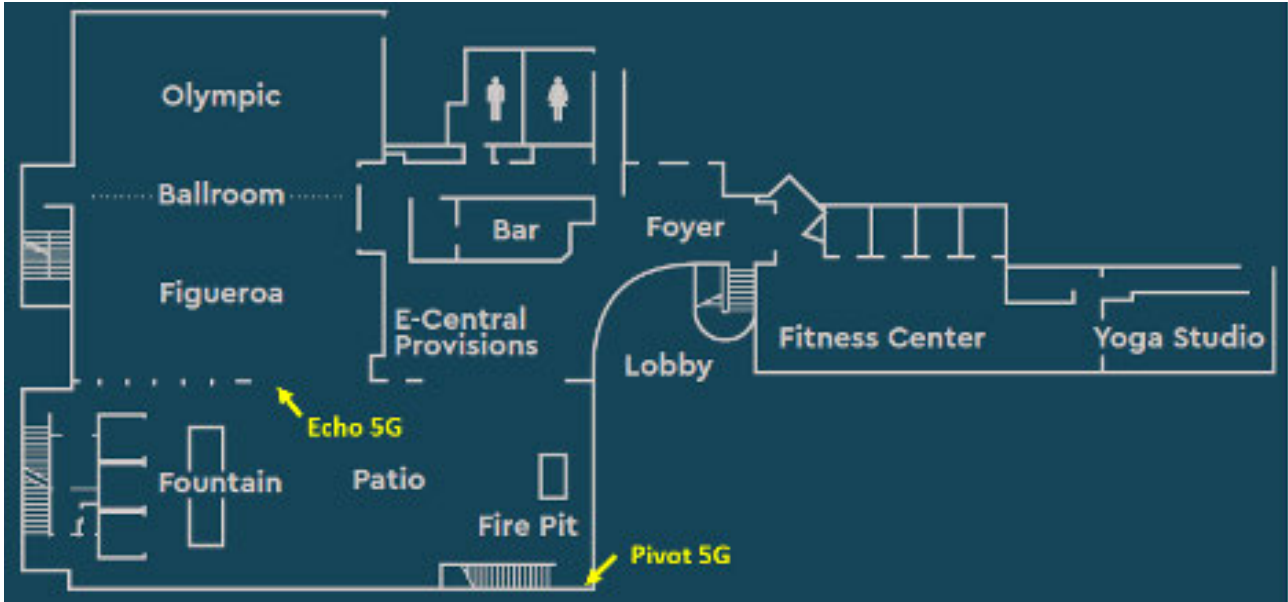


Fig 2 | Pivot 5G extended mmWave signal to lounge patio; Echo 5G brought signal into Figueroa Room

Figures 3 and 4 show the Pivot in situ, flooding the patio lounge with a wide beam of mmWave coverage. Figure 5 shows the Echo helping mmWave to penetrate the Figueroa Room, site of the VR demo.



Fig 3 | DU connected to narrow beam SU #1



Fig 4 | Wide beam SU #2 (DU not pictured)



Fig 5 | Inside glass-attached Echo floods Figueroa Room with mmWave.

Inside Figueroa, a 5G mmWave handset acquired the signal and passed it via WiFi 6, generated by the handset, to an Oculus headset. The outdoor to indoor connection, from Amazon server to VR headset, is shown in Figure 6.

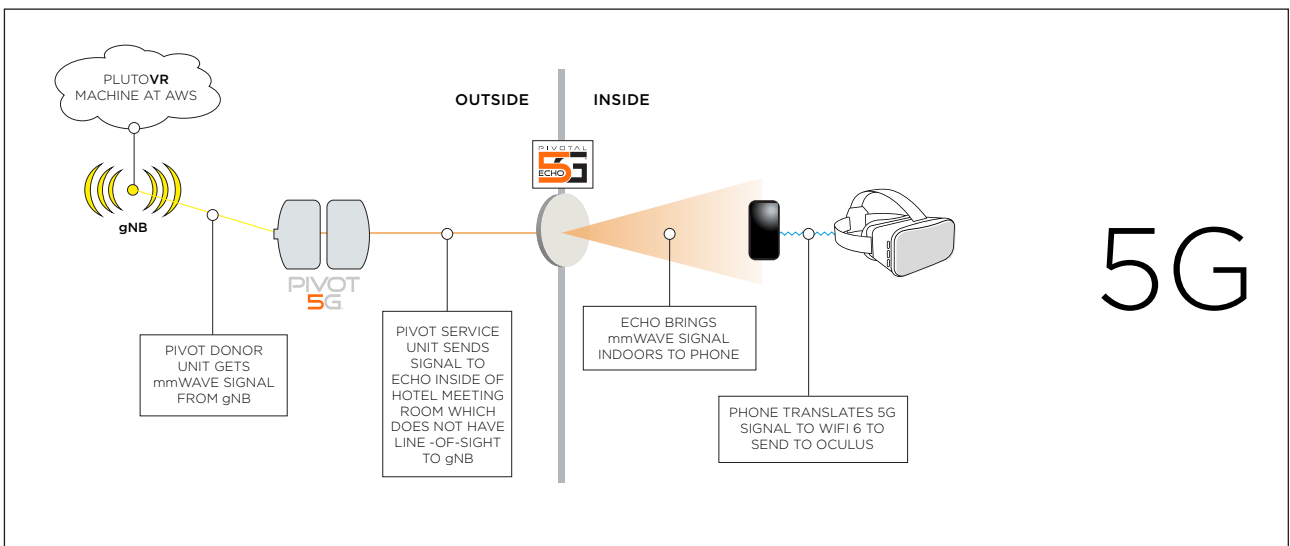


Fig 6 | End-to-end connection for VR demo driven by 5G mmWave.

## VR Demo Using 5G Versus 4G

The Beat Saber play experience was repeated on the ambient 4G network – same handset (in 4G mode), same WiFi hotspot, but with the Pivot and Echo repeaters turned off. See Figure 7.

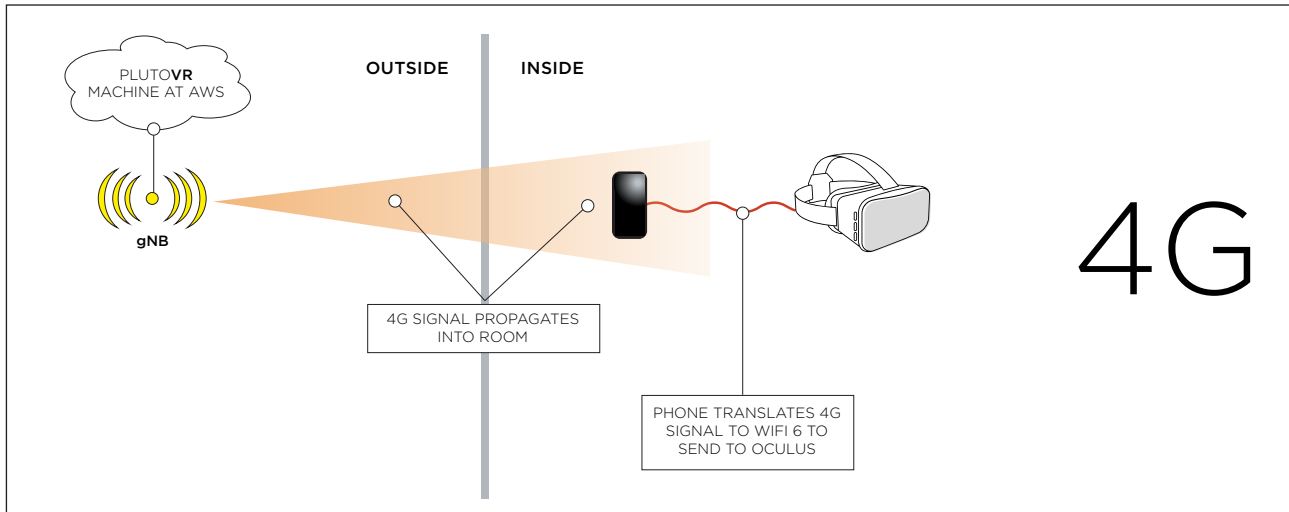


Fig 7 | End-to-end connection for VR demo driven by 4G. Pivot and Echo repeaters turned off.

The player experience between 4G and 5G mmWave was dramatically different. “The game is not playable [on 4G],” said one experienced user. “The sabers are more like ropes than solid objects due to long delay between physical and virtual movements. The game video quality is significantly degraded to compensate for a very bad connection. When casting to a monitor the video quality is even worse with pixilation and frequent lagging.” By contrast, on 5G “The game functions smoothly. Everything moves as expected with no delay.” The 4G vs. 5G experience is summarized by Figure 8 and Table 1.

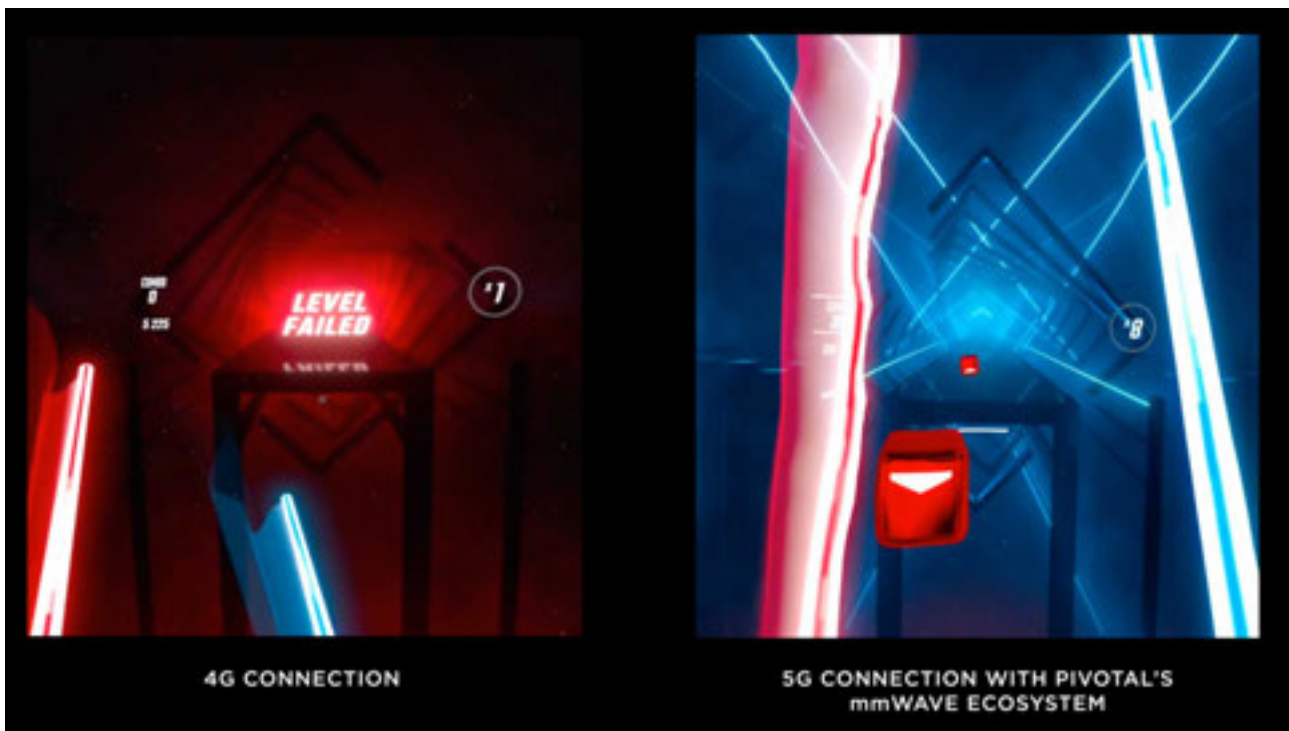


Fig 8 | Prepare to lose on 4G (left).

CONNECTION	DOWNLINK (Mbps)	UPLINK (Mbps)	LATENCY (ms)	GAMEPLAY	VIDEO QUALITY
4G	119	37	21	BAD	BAD
5G mmWAVE on Phone	2,000	100	8	EXCELLENT	EXCELLENT
5G mmWAVE on Oculus	1,200	25	12	EXCELLENT	EXCELLENT

Table 1 | 5G mmWave experience rated Excellent due to faster speed and lower latency. 5G mmWave Oculus experience limited by WiFi 6.<sup>2</sup>

## Summary

Mobile VR/AR streaming will take off as 5G mmWave coverage and 5G edge compute expand. The pace of that expansion will be driven by 5G mmWave network deployment speed and cost. Pivotal repeaters were developed to accelerate deployment and minimize network costs. Pivots require no fiber and install in less than four hours. Echos self-install in seconds. In the meantime, as this demonstration showed, 4G as a wide area connection alternative to 5G mmWave, just won't do.

<sup>2</sup> Virtual reality sickness is caused between the lag in head movement and simulation refresh rate. Opinions vary, but If the simulation refresh rate can be brought down to 13 milliseconds or less of our body's movement (from on average 18 to 22 milliseconds today), then sickness from refresh rate will be reduced or eliminated.