If You Build It, Will They Connect?
6 GHz WiFi in a Stadium

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***Abstract*—The opening of the 6 GHz spectrum promises substantial capacity gains for dense WiFi deployments, yet real-world performance depends critically on configuration choices rather than spectrum availability alone. This paper presents a measurement study of a large-scale outdoor WiFi 6E deployment at Brigham Young University's LaVell Edwards Stadium, combining two years of operational data with targeted measurements during football games. Despite the RF advantages of 6 GHz, capacity-based configuration preferences result in only modest performance improvements compared to 5 GHz. While 6 GHz achieves 3.4× higher median throughput (28 Mbps vs 8 Mbps) and 90% lower channel utilization (3.1% vs 31.4%), both bands fall well below expected performance levels. More critically, client adoption remains the dominant limiting factor: automated Passpoint steering redirects ∼50% of stadium clients, an estimated 20% of whom are 6 GHz-capable, exclusively to 5 GHz, while WiFi chipset-level association decisions prevent manual band selection. Historical data reveals that migration to OWE transition mode increased 6 GHz adoption from near-zero to 21% of non-steered clients.**

***Index Terms*—IEEE 802.11ax, Opportunistic Wireless Encryption (OWE), Hotspot 2.0 / Passpoint, Network measurement study, Dense wireless networks, Multi-band operation, Spectrum utilization**

I. INTRODUCTION

In dense WiFi deployments, such as stadiums and arenas, wireless spectrum is often the limiting factor in network performance [1]. In 2020, the United States Federal Communications Commission (FCC) opened the 6 GHz spectrum to unlicensed use for WiFi systems, and in 2024, finalized the requirements for the use of outdoor Standard Power (SP) devices. This change opened roughly 1.2 GHz of previously allocated spectrum, of which 850 MHz is available for use in outdoor environments. To minimize the impact of this expansion on previously established incumbent links, the use of SP networks relies on an Automated Frequency Coordination (AFC) [2] controller to determine the power limits and channel availability for each individual access point (AP).

Fig. 1. Brigham Young University's LaVell Edwards Stadium.

As the number of devices capable of using the new 6 GHz band continues to increase, outdoor deployments in large-scale venues are increasingly adopting AFC-regulated WiFi systems to reduce traffic congestion across the current 5 GHz infrastructure. With wider channel availability and reduced interference, 6 GHz deployments are widely expected to deliver substantial RF performance improvements over legacy 5 GHz networks. The new 6 GHz spectrum also introduces additional protocol requirements, including stricter security measures via opportunistic wireless encryption (OWE) [3] for open networks and the mandatory use of WiFi Protected Access 3 (WPA3) for secured networks.

This paper analyzes Brigham Young University's LaVell Edwards Stadium, pictured in Fig. 1, which was recently upgraded to support WiFi 6E, to assess how deployment configuration and operational constraints affect user adoption and user-level performance in a large-scale WiFi 6E deployment. Our paper evaluates the performance of the 6 GHz spectrum as it compares to the 5 GHz spectrum, with respect to average signal strength, link speeds, channel utilization, and station counts. We then compare our results with another measurement campaign of the Notre Dame Stadium [4], assessing configuration choices of both stadiums and their impact on user results. We provide historical data showing improvements in user adoption when network configuration changes are made. Additionally, we publish our stadium measurement data on Github as a growing public dataset and a service to those in the development of 6 GHz deployments [5].

II. RELATED WORK

Many studies have been done to measure the WiFi performance at large scale venues. However, most of these studies have narrow focuses on characteristics such as application

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This research was supported by the National Science Foundation under Grant No. 2440881.

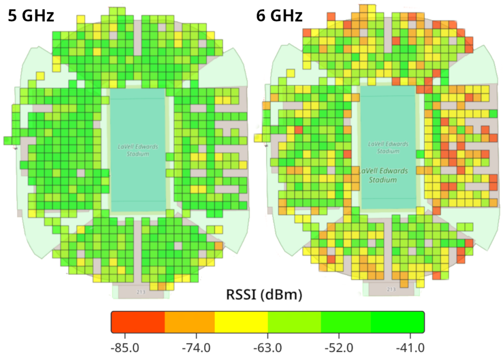

Fig. 2. A heatmap of average RSSI across the stadium. While the 5 GHz performs uniformly across the bowl, 6 GHz has high spatial variance.

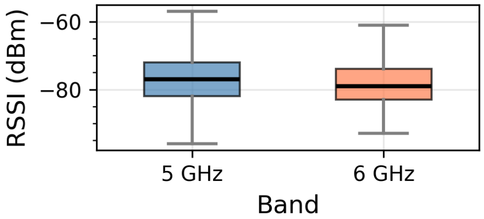

Fig. 3. The RSSI distribution across the 5 GHz and 6 GHz bands during two football games while the stadium was full.

layer performance [6], channel widths [7], and the effects of channel bonding [8]. Others have measured the wireless characteristics of indoor and outdoor WiFi 6E deployments [4], [9]. Most notable is the study done by Dogan-Tusha et al. to evaluate the outdoor wireless characteristics of the Notre Dame football stadium during multiple games in 2024–2025 [4]. Their paper presents a measurement campaign assessing the performance and interaction of Low Power Indoor (LPI) and SP 6 GHz WiFi systems. Their paper provides excellent insights into how indoor (LPI) and outdoor (SP) WiFi deployments affect each other and gathers a large dataset of WiFi statistics in both the 5 GHz and 6 GHz frequency ranges.

Despite these contributions, comparatively little attention has been given to how configuration choices in both hardware and software, as well as operational constraints, influence whether potential RF gains materialize as user-level improvements. Sui et al studied the effects of AP density on WiFi performance [10], and Miao et al studied how venues should consider DHCP usage, user behavior, and AP density in new deployments [11]. Our paper provides critical missing context for new deployments by building on the work done by Dogan-Tusha et al. with a similar set of measurements on the 6 GHz spectrum. Such a study helps to identify trends common to both stadiums and analyzes the unique deployment details of each stadium to assess which configuration choices were most impactful.

TABLE I
SSIDS USED IN LAVELL EDWARDS STADIUM

Year	SSID	Spectrum	Security
2024	BYU Cougars WiFi	5 GHz	Open
	BYU Cougars WiFi 6GHz	6 GHz	OWE
	VerizonWiFiAccess	5 GHz	Hotspot 2.0
2025	BYU Cougars WiFi	5 GHz	Open
	BYU Cougars WiFi	6 GHz	OWE
	owe BYU Cougars WiFi 9a4a	5 GHz	OWE
	VerizonWiFiAccess	5 GHz	Hotspot 2.0

III. ENVIRONMENT AND METHODOLOGY

A. *RF Configuration*

In 2023, LaVell Edwards Stadium was retrofitted with WiFi 6E–capable APs, enabling the stadium to leverage 6 GHz spectrum. There are 1,010 AP5050U/D access points provided by Extreme Networks placed throughout the bowl. While each radio is required to contact nearby AFC controllers to determine the power requirements for their 6 GHz spectrum usage, BYU is not in the range of any significant incumbent signals, and therefore, the radios are given no restrictions beyond the standard maximum allowed power in their spectrum bands. The stadium's dense, unrestricted coverage allows our analysis of LaVell Edwards Stadium to eliminate AFC constraints as a confounding factor in performance, leaving configuration decisions as a dominant factor in adoption and RF performance gains.

To better characterize this coverage, Fig. 2 presents a heatmap of the maximum received RSSI as measured across the stadium, while Fig. 3 shows the distribution of received RSSI values across both bands. The median RSSI for 5 GHz is -78 dBm, while 6 GHz shows -79 dBm. While neither band achieves particularly strong signal strength, the 5 GHz band exhibits slightly more even coverage across the bowl. In contrast, the 6 GHz varies slightly, with the southern and eastern sections showing weaker coverage, likely due slight differences in the chipsets contained in the various smartphones used. A comparison of the empty vs. occupied stadium reveals minimal differences, with empty stadium measurements showing an average signal strength of -77 and -78 dBm for 5 GHz and 6 GHz, respectively, and game-day measurements showing an average increase of 1.0 dBm for both bands. When the stadium is empty, devices report an average of 269.9 beacons in range, while a full crowd reduces the count to an average of 52. The reduced beacon reception count during occupied conditions focuses the measurements on nearby, stronger APs, such that the WiFi coverage during game day is stable and adequate throughout the stadium. Thus, access to a strong WiFi signal is not a limiting factor in the stadium's network performance.

B. *Network Configuration*

Networks that wish to support open 6 GHz WiFi are permitted to do so through the use of OWE, which encrypts traffic without authentication and provides open accessibility. Normally, if a 6 GHz network shares an SSID with a 5 GHz counterpart to assist in network selection, the OWE requirement is added to the 5 GHz SSID, preventing legacy devices without OWE support from connecting. LaVell Edwards uses three SSIDs to solve this compatibility issue, summarized in Table I. The first is an open 5 GHz network named “BYU Cougars WiFi”, the only network visible to users. This SSID broadcasts an OWE Transition Mode Element which advertises a hidden, OWE-enabled 5 GHz SSID called “owe_BYU Cougars WiFi_9a4a”, allowing capable devices to automatically transition to the encrypted connection and satisfying the OWE requirement imposed by the 6 GHz, OWE-enabled SSID broadcast under the same “BYU Cougars WiFi” name.

A fourth SSID is used in the bowl for a 5 GHz private network for Verizon Wireless clients, named “VerizonWiFi-Access”. This SSID uses Passpoint, also known as Hotspot 2.0, to use operator information in beacon frames to automatically connect any Verizon Wireless customers to the network, *without* giving users a notification. As discussed later, Passpoint’s automatic steering has significant implications for 6 GHz adoption rates, as Verizon clients are steered directly to 5 GHz spectrum regardless of capability.

C. Data Collection

The measurement campaign relied primarily on SigCap [12], a tool developed to collect WiFi and LTE performance data. SigCap connects directly to Android’s WifiManager API and records data about each BSSID in range by passively reading through beacon frames as it scans across all available WiFi channels. Simultaneously, it collects data about the network the device is currently connected to. The data, which includes RF metrics such as RSSI, channel utilization, and transmission power as well as protocol data such as advertised link speeds and station counts, is packaged in five-second increments along with the current GPS location.

SigCap also provides several integrated tools that allow for real-time protocol testing. One such tool is iperf3, a tool for measuring point-to-point throughput on IP networks. We used iperf3 during both empty stadium testing and game-day recordings to compare advertised PHY-layer data rates with actual measured throughput. We configured iperf3 to send to an off-campus endpoint at maximum throughput over TCP for 60 seconds per test. Because the stadium has a 100 Gb/s backhaul, we assume that our off-campus endpoint did not constrain the measurements, and that such an endpoint represents a realistic picture of client-side WiFi performance during use at a game.

The data from this campaign is separated into two groups: empty and occupied stadium conditions. Empty stadium measurements established device performance baselines and characterized RF performance. Occupied stadium measurements were taken during two games, and identical devices covered the same locations to isolate network performance changes from device variance. We performed iperf3 tests at fixed locations throughout the stadium to capture single-connection performance representing the average seated user. We also performed mobile tests traversing the bowl to assess network stability and continuity.

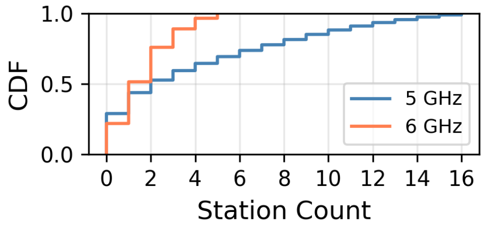

Fig. 4. CDF comparison of BSSID STA counts on 5 GHz and 6 GHz bands. Station counts are based solely on per-BSSID reports instead of aggregate channel measurements or per-AP counts.

Along with the measurement campaign data, Brigham Young University’s OIT provided historical reports generated by Extreme Networks from the deployed wireless access points. These reports include total client counts, aggregate traffic volumes, and usage statistics, and also enable analysis of SSID adoption and configuration trends over the two-year lifetime of the WiFi 6E deployment. Together, these datasets allow us to characterize the temporal evolution of 6 GHz spectrum adoption within the stadium network and quantify client-associated rates as a function of configuration choices.

D. Device Performance

Our measurement campaign used 6 smartphones to record SigCap data. Phones were selected based on availability, but all have the ability to use both 5 and 6 GHz spectrum. A set of measurements was taken with each phone while the stadium was empty to characterize differences between devices that might be mistaken for configuration effects. The phones were placed side by side and measured beacon frames simultaneously, enabling RSSI calibration and baseline link speed benchmarking for each device. Analysis of SigCap snapshots taken by multiple devices at the same time allows us to measure an RSSI bias and reveals that RSSI measurements proved highly consistent across all devices, with Samsung devices averaging only 1 dBm lower than Google devices. However, the connected link speeds varied by up to 33.1% across devices. Because our tests are only interested in configuration effects, we performed all iperf3 throughput measurements on a single device, the Galaxy S24 FE, to eliminate inter-device variance from performance analysis, while RSSI and spatial coverage data were safely aggregated across all devices.

IV. RESULTS

We present a detailed analysis of the collected data as a performance comparison of the 5 GHz and 6 GHz bands. These performance results inform a subsequent comparison with the Notre Dame study, highlighting common trends in large-scale wireless deployments. Despite the clear theoretical benefits of

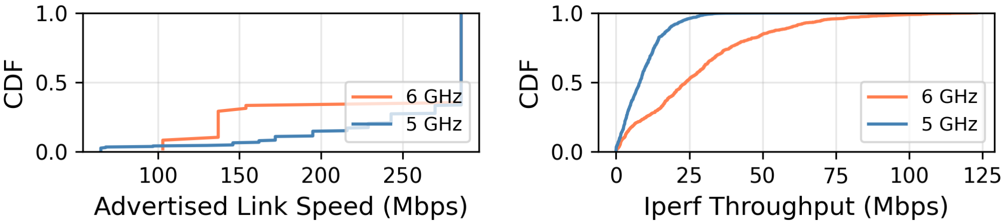

Fig. 5. Left: CDF of access point's advertised data rate while connected to Cougar WiFi. Right: CDF of measured throughput as measured by iperf3 testing.

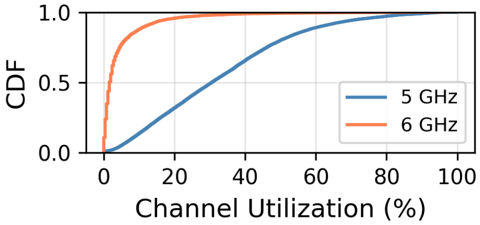

Fig. 6. CDF of the channel utilization, separated by 5 and 6 GHz. It is clear that the 6 GHz spectrum is very underutilized in comparison to the 5 GHz band.

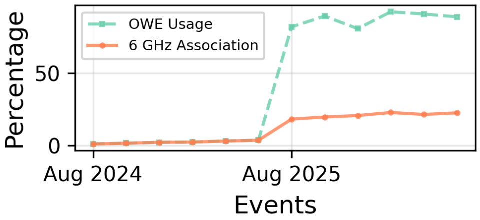

Fig. 7. Estimated percentage of devices associated with the 6 GHz of Cougar WiFi band, along with the percentage of OWE adoption across stadium events over the last two years.

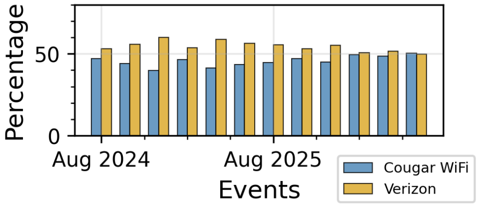

Fig. 8. Percentage of devices on "BYU Cougars WiFi" vs. "Verizon WiFi Access" across stadium events over the last two years. This includes football games as well as large events held in the stadium.

WiFi 6E in both RF performance and protocol enhancements, our findings suggest that increased spectral availability **does not automatically translate into proportional gains in end-user performance**.

A. RF Performance Results

Our results reveal a large difference in the level of adoption of the 5 and 6 GHz spectrum. Fig. 4 illustrates the observed BSSID station counts, showing that the 6 GHz spectrum remains largely unused. 5 GHz BSSIDs serve on average four times more clients than 6 GHz (5 GHz/6 GHz mean: 4, 1), and because each AP broadcasts two 5 GHz BSSIDs (Verizon and Cougars WiFi) per one 6 GHz BSSID, the ratio of clients associated to each AP is around 8:1. Such a drastic difference in client count and contention is directly correlated to lower latency and higher average throughput [13]. In large sporting venues where users simultaneously access ticketing, concessions, social media, and streaming services, such performance differences improve user experience during peak demand periods.

Fig. 5 depicts the comparison in link speed between bands. While both 5 GHz and 6 GHz advertise high PHY-layer link speeds (5 GHz/6 GHz median: 216.0 Mbps, 137.0 Mbps), the actual measured goodput of application-layer data between the AP and client remains substantially lower (median: 8.26 Mbps; 28.12 Mbps). The advertised PHY-layer data rates were obtained from connected APs during iperf3 testing, while goodput was measured directly by iperf3.

Studies of WiFi 802.11n/ac deployments indicate that PHY-layer advertised rates overestimate actual transport-layer throughput due to protocol overhead and shared channel behavior, with TCP goodput typically achieving 50–70% of the PHY rate [14]. In dense deployments, goodput can fall to 20–30% of advertised rates due to high contention and channel utilization. The 6 GHz band achieves 20.5% goodput efficiency, approaching the lower bound of typical dense network performance. In contrast, 5 GHz manages only 3.8% goodput. A study of channel utilization across bands, shown in Fig. 6, demonstrates the same qualities. The median channel utilization for 5 GHz channels reaches 31.4%, while 6 GHz channels remain nearly idle at just 3.1%, representing a 90% reduction in channel occupancy. Despite its superior interference characteristics, the under-utilization of the 6 GHz spectrum reveals a hidden challenge of balancing automatic steering and client adoption with performance and band prioritization.

B. Driving Configuration Factors

Before the 2025 season, LaVell Edwards used two independent SSIDs for 6 and 5 GHz (see Table I), requiring users with capable clients to manually choose the 6 GHz SSID. As shown in the first half of Fig. 7, the new spectrum was available, but almost entirely unused. Almost all users would have already

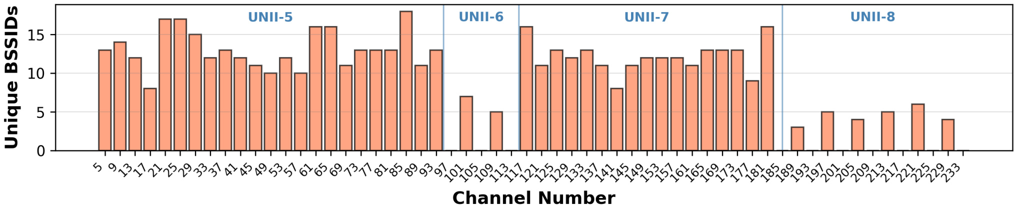

Fig. 9. A list of many of the 6 GHz BSSIDs on the western side of the stadium, separated by channel. UNII bands 6 and 8 are reserved for indoor use only, which are in use by some of the box-seat APs on the western side of the stadium.

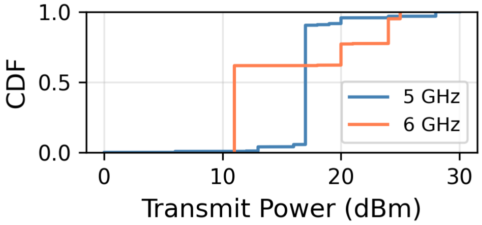

Fig. 10. A CDF of the advertised TX broadcast power as reported by APs in beacon frames.

associated with WiFi prior to the installation of 6 GHz, and new users would still have had to notice there was a 6 GHz band available and opt in. However, as shown in the second half of Fig. 7, the introduction of OWE transition mode led association to the 6 GHz band to jump immediately to around 21%. Further testing also revealed that client devices use certain WiFi chipset measurements to automatically determine whether to associate a device to the 5 GHz OWE hidden SSID or the 6 GHz OWE SSID, regardless of the device's most performant capability or the AP's preferred target. These configuration choices are decisions that LaVell Edwards Stadium currently faces—whether to require users to authenticate directly to a 6 GHz band, or associating them automatically at the cost of certain devices rejecting the opportunity during association.

Despite the benefits of automatic association presented by OWE transition mode, about half the guests are still not taking advantage of the new spectrum. Fig. 8 shows the percentage of association to the two networks used in the stadium over the last 2 years. We find that throughout the stadium's 6 GHz deployment, Verizon WiFi's Passpoint authentication has continuously accounted for over 50 percent of devices at nearly every event. In consequence, all capable clients who associate with Verizon WiFi are unintentionally redirected away from available 6 GHz capacity. We can estimate the percentage of clients steered away from 6 GHz by assuming devices on Verizon WiFi have the same rate of 6 GHz capability as those on Cougar WiFi. This would suggest *an estimated* 10.5% *of the total stadium population, and half the capable client devices, are being automatically steered towards 5 GHz-only connectivity*.

Even with the disparity in usage, both the 5 GHz and 6 GHz spaces are configured to handle a large number of clients. Both bands are configured to use the maximum number of 20 MHz channels available to them, 25 channels for 5 GHz and 42 outdoor channels for 6 GHz. Fig. 9 provides a visual example of the spread of BSSIDs across a section of the stadium, as reported by the Galaxy S24 FE. While not all 59 of the available 6 GHz channels are allowed for outdoor usage, LaVell Edwards Stadium effectively uses the remaining 42 channels to minimize the overlap between APs and maximize client density in a given area. Perhaps in part because its spectrum is spread so evenly, the stadium does not have to broadcast at nearly the maximum rated power for standard power APs, around 30 dBm. Fig. 10 shows the CDF plot of the average transmit power across the bowl, separated by band. The 5 GHz APs transmit at an average power of 17.25 dBm, while the 6 GHz APs transmit even less at an average of 13.41 dBm. Additionally, these transmit powers are consistent whether or not the stadium is occupied. The lower 6 GHz transmit power, despite greater channel availability, suggests a deliberate reduction in power to shrink AP cell size. This configuration works well with the under-seat omnidirectional antennas and prioritizes increased client capacity, since the reduced effective range of the APs increases the channel's ability to be reused. However, because the channels broadcast at so low power, it may also be potentially limiting some of the more impressive throughput options that WiFi 6E offers. Thus far, BYU's deployment decisions have reflected a conservative approach in the development of this recent 6 GHz stadium installation, where the goal is to increment performance gains over time while maintaining a baseline of stable, predictable coverage across diverse client populations.

C. *Configuration comparison of LES and NDS*

To better contextualize the findings in this study, we compare LaVell Edwards Stadium to Notre Dame Stadium, studied by Dogan-Tusha [4] in a similar measurement study focusing on the interactions between indoor and outdoor APs. While their study focuses on the 6 GHz indoor/outdoor coexistence rather than configuration details, the differences they report—particularly in channel widths, transmission power, and client band-steering decisions—offer a contrasting approach to stadium WiFi design. Examining these differences further highlights the impact of configuration design choices on client adoption and performance outcomes.

One unique trait of Notre Dame Stadium is the lack of client steering present in their 6 GHz configuration. While LaVell Edwards steers around 50% of their clients automatically, Notre Dame Stadium is not equipped with Passpoint. The only SSID that would be capable of automatically associating clients, "eduroam", is disabled during game-day events. This means that Notre Dame Stadium's network grants all the capable clients equal access to the 6 GHz spectrum. Because of this lack of steering mechanisms, Dogan-Tusha reports a 14% 6 GHz adoption rate, compared to LaVell Edwards Stadium's 21% adoption among non-Passpoint clients (approximately 10.5% of total stadium clients).

Another significant difference between Notre Dame Stadium and LaVell Edwards is Notre Dame's decision to use 80 MHz channels. Unlike LaVell Edwards Stadium's 42 channels across 6 GHz, Notre Dame's configuration uses 14 total 80 MHz channels on 6 GHz, only 9 of which are available for outdoor use by SP APs. These wider channels provide significantly higher throughput availability, with their maximum advertised link speeds showing link speeds upwards of 1 Gbps, whereas LaVell Edwards, a more modest configuration, maxes out at 286 Mbps, the highest data rate available on 20 MHz WiFi 6E channels. This increase in throughput comes at the cost of greater power usage; Dogan-Tusha reports a mean transmit power of 27 dBm. This higher transmit power is not without consequences, as while it does stay below the AFC requirement in their area, the Dogan-Tusha study also finds the aggregate interference to incumbents could exceed protection thresholds even when individual APs comply with AFC limits. This comparison illustrates the fundamental tradeoff in configuration decisions: LaVell Edwards prioritizes client capacity through narrow, low-power channels, at the cost of absolute performance, while fewer, higher-performance channels reduce capacity, increase the likelihood of AP spectrum collisions, and have higher aggregate interference risk.

V. CONCLUSION

The 6 GHz band has the potential to massively increase the average throughput and client capacity for large-scale venues like LaVell Edwards Stadium. However, these benefits do not come from the passive capacity of the spectrum itself, but rather a coordinated effort in hardware, security, and configuration decisions. While the 6 GHz band in LaVell Edwards Stadium shows promising potential to increase speeds and spread users more evenly, many of these benefits are muted by the standard protocol decisions and automatic network steering. In contrast, Notre Dame Stadium chose a high-performance design with wider channels and fewer, more powerful APs, increasing interference risk while providing clients with larger potential spectrum gains. Such a contrast reveals a fundamental tension in large-scale 6 GHz deployments: decisions that optimize RF performance can actively undermine principles related to the core need to serve clients using that spectrum. The choice to improve automatic association and overall WiFi adoption rates through the use of Passpoint inadvertently steers the majority of clients away from 6 GHz entirely. We conclude that rather than optimizing for RF performance entirely and expecting adoption rates to rise, successful deployments must prioritize designing client steering mechanisms that allow users to easily interact with the new spectrum. Without this, the additional spectrum provided will remain underutilized and fail to improve user experience, despite technical superiority.

ACKNOWLEDGMENT

We would like to thank Brad Parker and Extreme Networks for their help collecting data, and Justin Durfey at BYU for allowing us access to the football games to collect the data.

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