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SUMMER 2019

STADIUM TECH REPORT™

WI-FI HITS 31+TB AT FINAL FOUR

WI-FI 6: THE FUTURE FOR VENUE NETWORKS

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STADIUM TECH REPORT™

Welcome to the second issue of our SIXTH year of STADIUM TECH REPORTS, the Summer 2019 issue! These quarterly long-form reports are designed to give stadium and large public venue owners and operators, and digital sports business executives a way to dig deep into the topic of stadium technology, via exclusive research and profiles of successful stadium technology deployments, as well as news and analysis of topics important to this growing market.

Our profiles for this issue include a recap of the 31-plus terabyte Wi-Fi weekend at this year's Final Four, with a close-up look at the temporary network installed near the court at U.S. Bank Stadium. We are also debuting our "MSR Research" initiative with a white-paper type look at why the new Wi-Fi 6 standard is important to large public venues. Plus, we have an in-person visit profile of the new Allianz Field in St. Paul, and a recap of the new Wi-Fi network at Chesapeake Energy Arena in Oklahoma City!

We'd like to take a quick moment to thank our sponsors, which for this issue include Mobilitie, JMA Wireless, Corning, Boingo, MatSing, Cox Business/Hospitality Network, ExteNet, Neutral Connect Networks, Atomic Data, Oberon, and American Tower. Their generous sponsorship makes it possible for us to offer this content free of charge to our readers. We'd also like to welcome readers from the Inside Towers community, who may have found their way here via our ongoing partnership with the excellent publication Inside Towers. We'd also like to thank the SEAT community for your continued interest and support.

As always, we are here to hear what you have to say: Send me an email to kaps@mobilesportsreport.com and let us know what you think of our STADIUM TECH REPORT series.

Paul Kapustka, Founder & Editor
Mobile Sports Report

IN THIS ISSUE:

Don’t Sweat the Big Stuff

Reliable network coverage and capacity for your visitors on game day is a big deal. After all, passionate fans – who are focused on the action at midfield – have their devices in-hand, ready to share the next big play with the world.

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COMING YOUR WAY: MORE RESEARCH, MORE ANALYSIS

BY PAUL KAPUSTKA

Twenty-four terabytes of Wi-Fi data at the Super Bowl, another 31 TB during Final Four weekend. When it comes to the demands placed on large public-venue wireless networks these days, there is apparently no top end yet in sight. And just to make the game harder, everything an IT professional knows about stadium networks is on the cusp of huge change. With Wi-Fi 6, 5G and CBRS on the near horizon, how do you figure out what's the best next step to take?

While we here at Mobile Sports Report can't design your network for you, what we can do is try to offer some more help when it comes to separating reality from hype. Starting with this issue of our Stadium Tech Report series, MSR is going to add in more forward-looking research and analysis of technical and business topics confronting the stadium networking marketplace. Our first effort is a white paper/PowerPoint dive into the key components of the new 802.11ax Wi-Fi standard, also known as Wi-Fi 6, with a clear focus on what it means specifically for large public-venue networks. And there's more on the way.

In the past, MSR's Stadium Tech Report series has focused mainly on providing profiles of successful (or not successful) stadium network and technology deployments, under the thinking that says the best way to learn

DIGITAL-DEVICE HAPPY U.S. OPEN FANS SHOW WHY VENUE NETWORKS ARE UNDER GROWING PRESSURE. CREDIT: FOX SPORTS

about something is from someone who's already done it. According to many of the readers who contact me about our publications, these profiles are the most popular thing we do and by no means will we be letting up in this area. In fact, we'd like to increase the number of profiles we do, so rest assured our stories about network, display and other stadium technology deployments will continue apace.

AN INCREDIBLE INFLECTION POINT

That being said, in the middle of 2019 the industry finds itself at an incredible inflection point, with many possible paths to choose when it comes to near-future technology and business strategies. With Wi-Fi 6 gear already arriving in the market and CBRS close behind – and 5G cellular not far behind that – venue operators and owners, teams, schools and all other associated users of venue technology are going to be called upon to pick winners without much in the way of established history. And that's just on the technology side of things.

Changes are also imminent to the business models behind stadium wireless networks, from how things like distributed antenna systems (DAS) are funded, and whether or not the current models will still be viable as carriers move to the multiple-spectrum versions of 5G. Will the third-party neutral host model of network building hold up going forward, or will more teams and venues need to take on more responsibilities – and how will the carriers play in a Wi-Fi 6 world? As always we will try to report on the early movers in all the technology and business categories, but it also seems to make sense to provide as much forward-looking information as we can, to help stadium network professionals make the best choices for their businesses as well as for their fans.

What you won't see from us is any meaningless drift into "market size" predictions, the kind of "research" that is absolutely worthless to people who have to make technical and business-case decisions. We're also not going to be in the business of rubber-stamping vendor-specific takes, because the last thing this industry needs is another outlet for pay-to-play content.

Our goal is hard, but simple: We want to build a base of material from subject-matter experts and end-user implementers in a way that mirrors the methods we use to write our profiles – in an editorially objective way, and if possible with peer review from multiple contributors and partners. The Wi-Fi 6 report encapsulated in this report is a joint effort between MSR and our friends at AmpThink, something that grew out of conversations about how to bring more forward-looking expertise on topics like Wi-Fi 6 to the MSR reader audience.

While the meat of this report is based on a Wi-Fi 6 presentation and essay developed by AmpThink, MSR helped clarify the material to make it fit into our report format, with the idea that this report would be just a starting point for deeper discussions into each of the relevant features that we think make Wi-Fi 6 a compelling technology for venues to consider.

Going forward this summer and fall, you can look for MSR to explore each of the Wi-Fi 6 features in more detail, with either short essays, podcasts or additional methods, with plans to add in voices outside of just MSR and AmpThink. Again, the idea is not just to promote a single person or company's viewpoint, but to provide information examined and vetted by as many knowledgeable people as possible. And that's where you come in.

Having attended conferences like SEAT (Daytona will be my seventh time!) I know how many smart people there are out there in the stadium networking technology professional world, and now it's time for as many of you as possible to participate in this process. Ideally, such reports like the Wi-Fi 6 one we're running in this issue would be run past as wide a group of potential users as possible beforehand, to help refine and clarify the most pertinent parts and to fill in the gaps that might have been missed. While I'm confident most readers will find great value in the vendor-agnostic material provided by AmpThink and MSR, I also think having more participants going forward will make for an even stronger team. If you want to join in the fun, let me know via email at kaps at mobilesportsreport.com, or find me at SEAT and we can discuss this plan over a cold beverage. Cheers! –MSR–

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TEMPORARY NETWORK FOR FINAL FOUR PART OF

WI-FI RECORD AT U.S. BANK STADIUM

BY PAUL KAPUSTKA

FOUR TEAMS TWO DAYS 31.2 TERABYTES

One of the traditional characteristics of the Final Four is the yearly travel scramble of the fortunate fans and teams who have advanced to the championship weekend. Somehow, with only a week's notice, plane flights, road trips and hotel rooms get scheduled and booked, leading to packed houses at college basketball's biggest event.

On the stadium technology side, a similar last-minute fire drill happens just about every year as well, as the hosting venues reconfigure themselves to host basketball games inside cavernous buildings built mainly to hold football crowds. At this year's NCAA Men's Final Four at U.S. Bank Stadium in Minneapolis, the stadium tech team and partner AmpThink were able to quickly construct a temporary Wi-Fi network to cover the additional lower-bowl seating. The new capactity was part of a record-setting Wi-Fi network performance at the venue, with single-day numbers surpassing those from Super Bowl 52, held in the same building the year before.

The Wi-Fi numbers, both staggering and sobering especially to venues who are next in line for such bucket-list events, totaled 31.2 terabytes for the two days of game action, according to figures provided by the NCAA. For the semifinal games on Saturday April 6, U.S. Bank Stadium's Wi-Fi network saw 17.8 TB of traffic, topping the 16.31 TB used during Super Bowl 52 on Feb. 4, 2018. The Saturday semifinals also set an attendance record for the venue, with 72,711 on hand, topping the 67,612 in attendance for Super Bowl 52.

FACING PAGE: THE CONFETTI RAINS DOWN ON 2019 FINAL FOUR CHAMPION VIRGINIA. CREDIT ALL PHOTOS: PAUL KAPUSTKA, MSR.

During Monday's championship game, U.S. Bank Stadium saw an additional 13.4 TB of data used on the Wi-Fi network, giving the venue three of the top four single-day Wi-Fi numbers we've reported, with this year's mark of 24.05 TB at Super Bowl 53 in Atlanta the only bigger number. Saturday's take rate at U.S. Bank Stadium,

however, surpassed even the most-recent Super Bowl, with 51,227 unique users on the network, a 70 percent take rate.

'LIKE BUILDING AN ARENA NETWORK INSIDE A FOOTBALL STADIUM'

There's no doubt that the temporary network installed by AmpThink and the U.S. Bank Stadium IT team contributed a great deal to the final Wi-Fi totals, with 250 access points installed in the additional seats. Like at other football venues that are transformed into basketball arenas, U.S. Bank Stadium had temporary seating installed on all four sides of the stadium, with temporary risers stretching down over football seating as well as with risers built behind both baskets. More seats were installed on the "floor" of the football field, right up to the elevated court set in the middle. The temporary APs, like the existing ones in the stadium, are from Cisco.

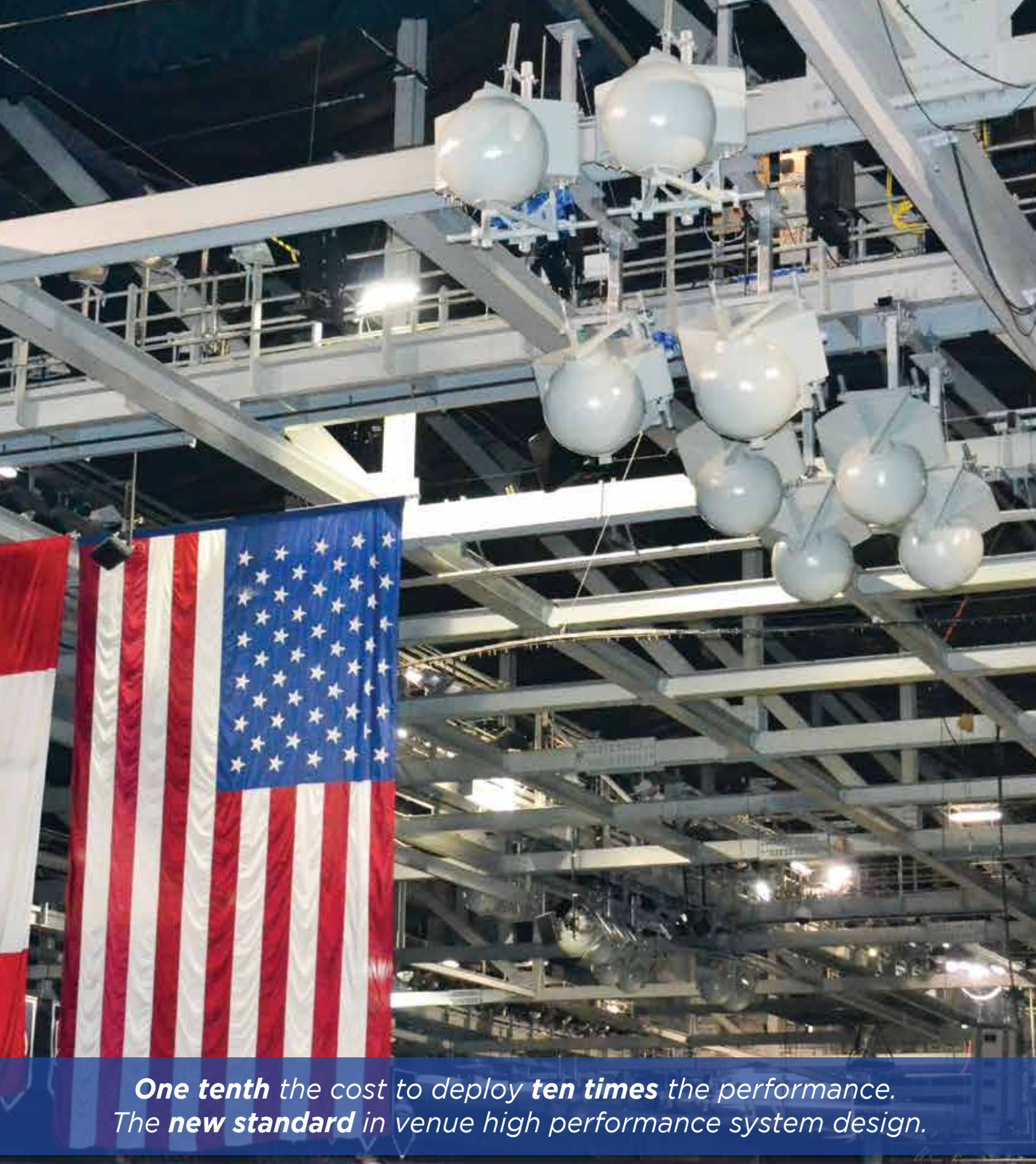
"There are a lot more moving parts to a Final Four than to a Super Bowl," said David Kingsbury, director of IT for U.S. Bank Stadium, describing the difference in providing the networking and technical underpinnings for each event. While planning for the networks was obviously done far in advance, the actual buildout of the temporary Wi-Fi couldn't even begin until the additional seating was in place, a task that finished just five days before the first game was played.

That's when AmpThink deployed a staff of 12 workers to start connecting cables to APs and to switches, while also adding in another 700 wired network connections to the courtside areas for media internet and TV monitor connections. Like it does for every venue network it designs and deploys, AmpThink came to the stadium equipped with a wide assortment of lengths of pre-terminated cables, preparation that made the fast deployment possible.

"If we had to spin raw cable and terminate it on site, we never would have been able to finish in five days," said AmpThink president Bill Anderson.

AmpThink's previous experience in deploying such temporary networks under temporary seating – including

TOP: THE CLOCK COUNTS DOWN TO THE SATURDAY TIPOFF. BOTTOM: FANS WAIT FOR LIGHT RAIL TRAINS AFTER THE GAMES CONCLUDED.



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WI-FI SIGNALS WERE STRONG THROUGHOUT THE STADIUM FOR THE ENTIRE WEEKEND, ALLOWING FANS TO SHARE AND CONSUME RECORD AMOUNTS OF DATA.

at the previous year's Final Four in San Antonio – taught the company that it would also need protection for under-seat switch deployments, to fend off the inevitable liquid spills from the seats above. That requirement was potentially even more necessary at U.S. Bank Stadium, since this year's Final Four was the first to allow in-venue sales of alcoholic beverages.

With some of the temporary seating installed over existing seating, there were 95 APs in the existing handrail-enclosure design that had to be turned off for the Final Four, according to Kingsbury. The 250 new APs added were all installed under the folding chairs, in enclosures that simply sat on the floor.

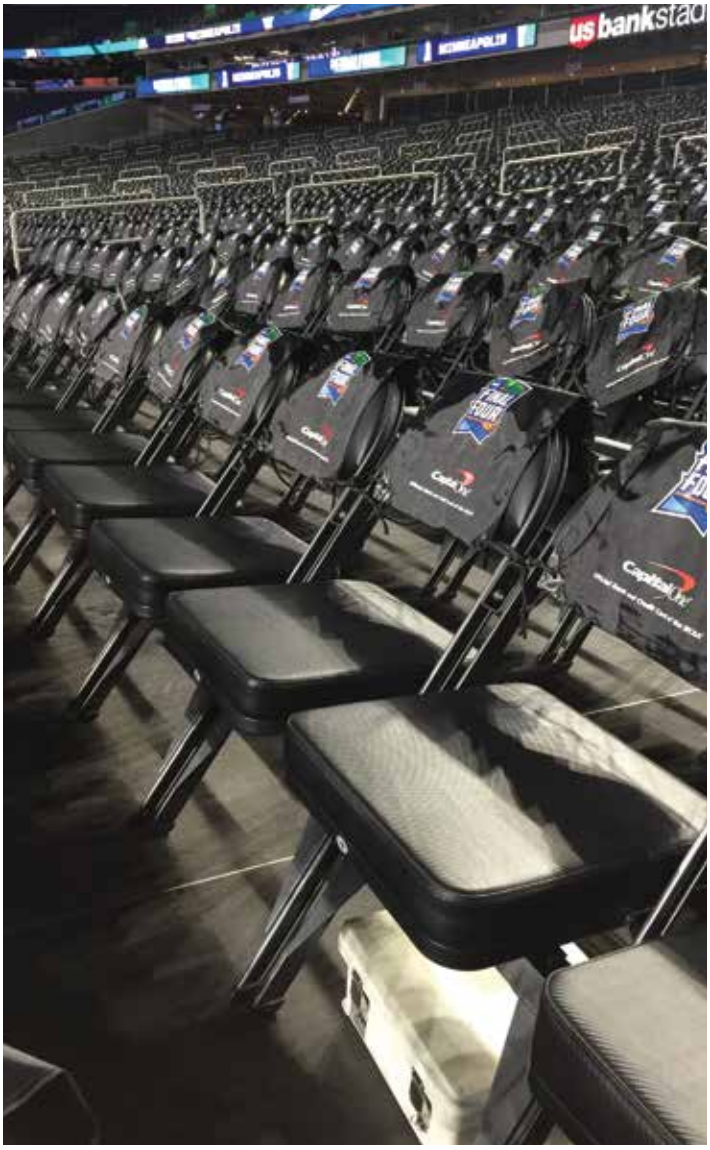
According to AmpThink's Anderson, the company did learn a lesson at U.S. Bank Stadium – that it will, at future events, need to secure the actual enclosures since during the weekend curious fans opened a few of the boxes, with one AP disappearing, perhaps as an interesting IT souvenir.

In San Antonio, AmpThink had zip-tied the enclosures to chairs, which led to increased labor to detatch the devices during the post-event breakdown. While having no such measures at U.S. Bank led to a fast removal – AmpThink said it had removed all the temporary network elements just seven hours after the championship game confetti had settled – for next year's Final Four AmpThink plans to at least zip-tie the enclosures shut so that fans can't attempt any ad hoc network administration.

MORE APS FOR BACK OF HOUSE OPERATIONS

Another difference between the Final Four and the Super Bowl is the fact that four, not two, teams are in attendance for a full weekend, necessitating the need to set up temporary "work rooms" adjacent to each school's locker room area. The media work center for the Final Four is also typically larger than that of a Super Bowl, again with more cities and their attendant media outlets on site thanks to there being four, not just two, teams involved.

CLOCKWISE FROM TOP LEFT: A SWITCH UNDER THE STANDS; A RAILING AP ENCLOSURE; A SOLID SATURDAY SPEED TEST; WHAT A FULL HOUSE LOOKS LIKE; COURTSIDE WIRING; AN AP UNDER A TEMPORARY SEAT; AND WI-FI AND DAS COVERING THE CONCOURSE.



CLOCKWISE FROM LEFT: UNDER-SEAT ENCLOSURES BROUGHT WI-FI TO THE TEMPORARY SEATS; A COURTSIDE MEDIA TV MONITOR; SOCIAL MEDIA STARS ON THE STADIUM DISPLAYS

"We had to cover a lot of places in the stadium that we don't normally cover" with wireless and wired network access, Kingsbury said, saying that an additional 30 APs were needed for team rooms and the main media workspace, which were located on the field level of the stadium in the back hallways. An interesting note at U.S. Bank Stadium was that the yards and yards of fabric used as curtains to cover the clear-plastic ETFE roofing and wall areas was actually benefical to Wi-Fi operations, since it cut off some of the reflective interference caused by the transparent surfaces.

According to Kingsbury the final count of active APs for the Final Four was 1,414, a number reached by adding in the temporary APs while deducting the ones taken offline. Not included in the official NCAA traffic numbers was an additional 3 TB of traffic seen during the free-admission Friday practice sessions, when 36,000 fans visited the stadium, with 9,000 joining the Wi-Fi network.

From the official stats, the peak concurrent user number from Final Four Saturday of 31,141 was also an overall record, beating Super Bowl 53's mark of 30,605. (Super Bowl 53 had 70,081 fans in attendance for the Feb. 3 game between the New England Patriots and the Los Angeles Rams.) The Wi-Fi network numbers for Monday's championship game (won by Virginia 85-77 over Texas Tech in overtime) saw big numbers itself, with 13.4 TB of total data used, and 48,449 unique connections and 29,487 peak concurrent users (out of 72,062 in attendance). Monday's game also produced a peak throughput number of 11.2 Gbps just after the game ended.

None of those totals could have been reached without the temporary network, which AmpThink's Anderson compared to "building a 10,000-seat arena network inside a football stadium." Next stop for a similar temporary Wi-Fi network is Mercedes-Benz Stadium in Atlanta, where the 2020 Final Four awaits. –MSR–

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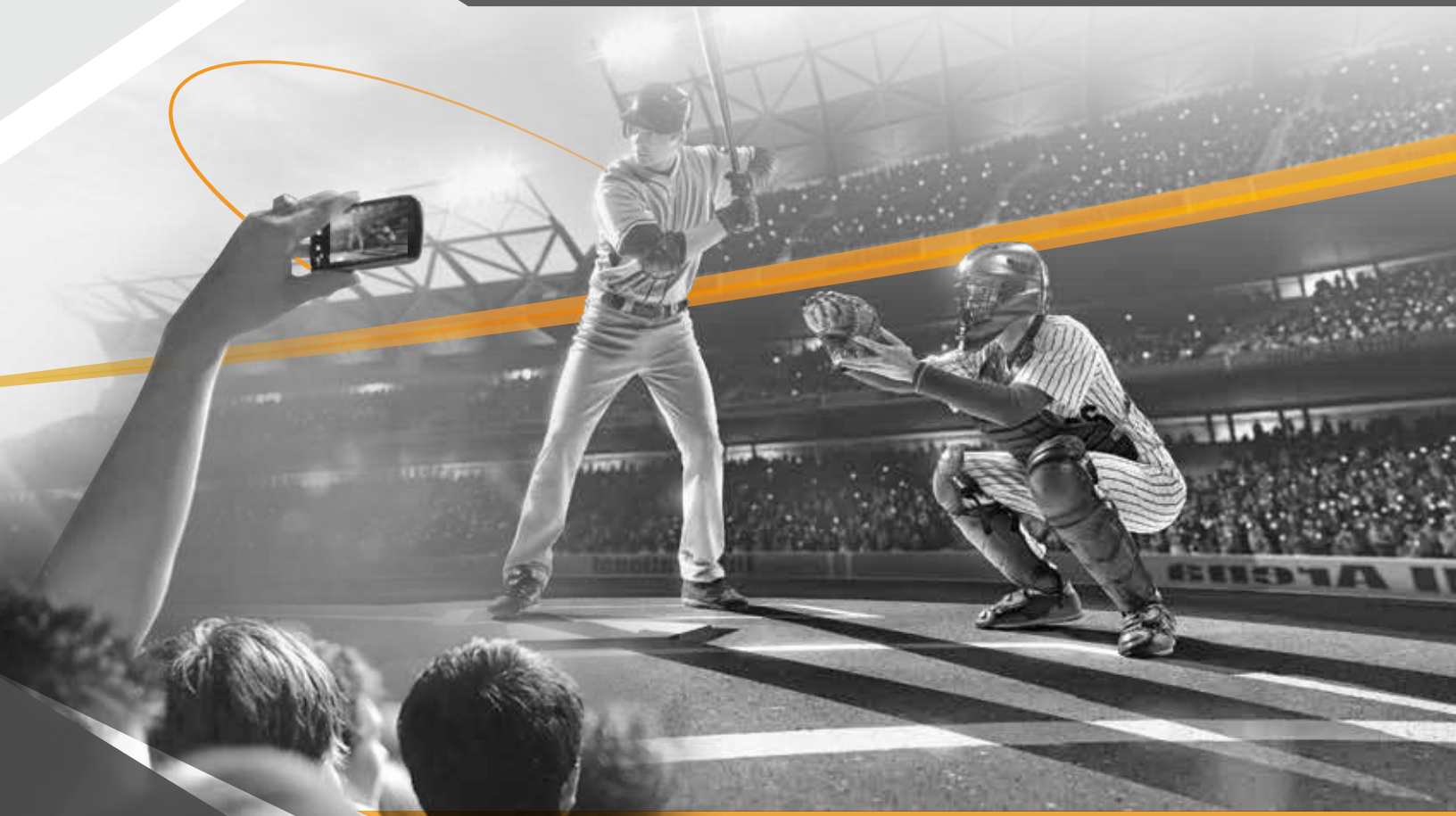

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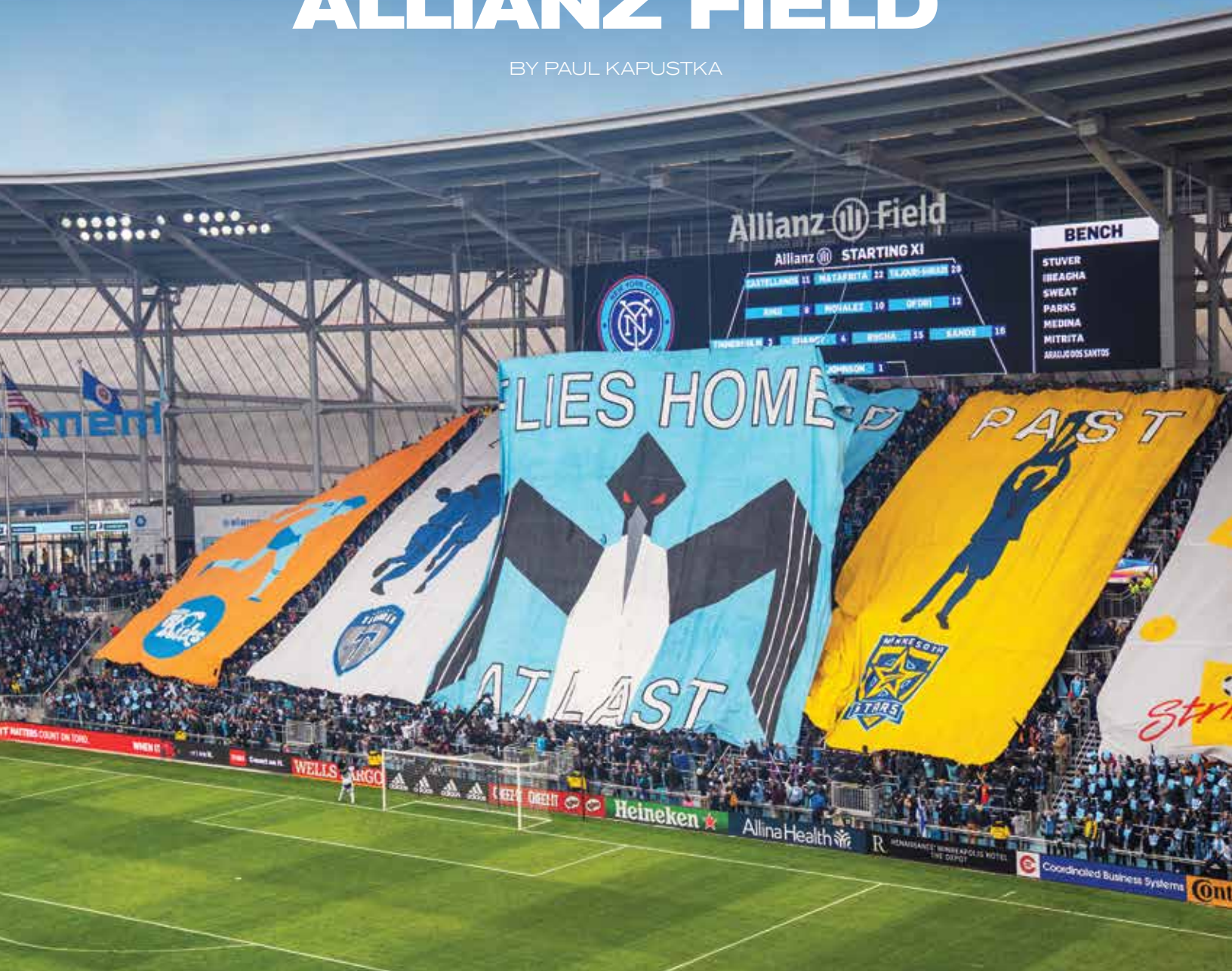
SMALL COMPANY DELIVERS BIG WI-FI FOR MINNESOTA UNITED AT NEW ALLIANZ FIELD

BY PAUL KAPUSTKA



FACING PAGE: OPENING DAY AT ALLIANZ FIELD, WHICH (BELOW) CAN HAVE A COLORFUL OUTSIDE. CREDIT BOTH PHOTOS: MINNESOTA UNITED

FANS AT THE NEW **ALLIANZ FIELD** IN ST. PAUL ARE THE BENEFICIARIES OF A BIG PROJECT DONE BY A SMALL COMPANY TO BRING SOLID FAN-FACING WI-FI TO THE NEW 19,400-SEAT HOME ARENA FOR THE MINNESOTA UNITED FC MLS TEAM.

The striking new $250 million facility, opened in April just off the highway that connects Minneapolis to St. Paul, is a looker from first sight, especially at night if the multi-colored lights in its cursive outside shell are lit. Inside, the clean sight lines and close-to-the-pitch seating that seems a hallmark of every new soccer-specific facility are accompanied by something that's not as easy to detect: A solid fan-facing Wi-Fi network with approximately 480 Cisco access points, in a professional deployment that wouldn't seem out of place at any larger facility, like an NFL stadium.

Actually, the Wi-Fi network inside Allianz Field is somewhat more conspicuous than many other deployments, mainly because instead of hiding or camouflaging the APs, most have very visible branding, letting visitors know that the Wi-Fi is "powered by" Atomic Data.

Who is Atomic Data? Though perhaps better known for their data center and enterprise business managed-services prowess, the 215-person Minneapolis-based firm also has a developing track record in stadium technology deployments, including a role as part of the IT support team for the launch of U.S. Bank Stadium two years ago. In what is undeniably a unique arrangement, Atomic Data paid for and owns the network infrastructure at Allianz Field, providing fan-facing Wi-Fi as well as back-of-house connectivity as a managed service to the team as well as to internal venue vendors like concessionaires.

WHILE A ROBUST WI-FI NETWORK WAS NOT PART OF THE ORIGINAL PLAN, ATOMIC DATA AND THE TEAM FOUND A WAY TO MAKE A MORE DIGITAL-FOCUSED FAN EXPERIENCE HAPPEN.

LOCAL PARTNER EARNS TEAM'S TRUST

While most new stadium builds often look for network and technology firms with a bigger name or longer history, Atomic Data was well known to the Minnesota team, having been a sponsor even before the club moved up to MLS. Chris Wright, CEO of the MNUFC, credited a longtime relationship with Atomic CEO Jim Wolford, a company Wright had known from his days with the NBA Timberwolves and WNBA's Lynx.

"They [Atomic Data] are a very strong local company and we knew of their work, including at U.S. Bank Stadium," Wright said. "Jim has also been a huge advocate of the [soccer] club, even before they moved to MLS. Their history is solid, and they [Atomic Data] have an incredible reputation."

As the team prepared to move into its under-construction home, Wright said that originally having a high-definition wireless network wasn't in the cards.

"The original plan was not to have a robust Wi-Fi network," Wright said, citing overall budget concerns as part of the issue. But when he was brought in as CEO he was looking for a way to change the direction and have a more digital-focused fan experience – and he said by increasing Atomic Data's partnership, the company and the team found a way to make it happen.

As described by both Wright and Atomic Data, the deal includes having Atomic Data pay for and own the Wi-Fi network components, and also to act as the complete IT outsourcer for the team, providing wired and wireless connectivity as a managed service.

"When you look at the demographic of our fans, they're mostly millenials and we wanted to have robust connectivity to connect with them," Wright said. "Over time we were able to negotiate a deal [with Atomic Data] to build what I think is the most capable Wi-Fi network ever for a soccer-specific venue. I think we've turned some heads."

UNDER SEAT AND OUTSIDE THE DOORS

Just before the stadium hosted its first league game, Mobile Sports Report got a tour of the facility from Yagya Mahadevan, enterprise project manager for Atomic Data and sort of the live-in maestro for the network at Allianz Field. Mahadevan, who worked on the U.S. Bank Stadium network deployment before joining Atomic Data full-time, was clearly proud of the company's deployment work, which fit in well with the sleek designs of the new facility.

For the 250 APs in the main seating bowl, Atomic Data used a good amount of under-seat AP deployments, since many of the seats have no overhang. A mix

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THE NETWORK IS SET UP TO PROVIDE SECURE WI-FI CONNECTIVITY TO THE STADIUM'S INDEPENDENT RETAIL AND CONCESSION PARTNERS.

THE STANDING SECTION AT ALLIANZ FIELD. CREDIT: PAUL KAPUSTKA, MSR

of overhead APs covers the seating areas that do have structures overhead, and more APs – which are clearly noticable, including some APs painted white to pop out against black walls and vice versa – are mounted along concourse walkways as well as on the outside of the main entry gates. Since MNUFC is a paperless ticketing facility, Mahadevan said Atomic Data paid special attention to entry gates to make sure fans could connect to Wi-Fi to access their digital tickets.

Wright, who called Atomic Data's devotion to service "second to none," noted that before the first three games at the new stadium, Atomic Data had staff positioned in a ring around the outside of the field, making sure fans knew how to access their tickets via the team app and the Wi-Fi network.

"The lines to get in were really minimized, and that level of desire to deliver a high-end experience is just the way they think," Wright said of Atomic Data.

According to Atomic Data the network is backed by two redundant 10-Gbps backbone pipes (from CenturyLink and Consolidated Communications) and is set up to also provide secure Wi-Fi connectivity to the wide number of independent retail and concession partners. Mahadevan also said that the network has a number of redundant cable drops already built in, in case more APs need to be added in the future. The stadium also has a cellular distributed antenna system (DAS) built by Mobilitie, but as of early this spring none of the carriers had yet been able to deploy gear.

Even the chilly temperatures at the team's April 13 home opener didn't keep fans from trying out the new network, as Atomic Data said it saw 85 gigabytes of Wi-Fi data used that day, with 6,968 unique Wi-Fi device connections, a 35 percent take rate from the sellout 19,796 fans on hand. According to the Atomic Data figures, the stadium's Wi-Fi network saw peak Wi-Fi bandwidth usage of 1.9 Gbps on that opening day; of the 85 GB Wi-Fi data total, download traffic was 38.7 GB and upload traffic was 46.3 GB.

According to Wright, the stadium has already had several visits from representatives from other clubs, who are all interested in the networking technology. Wright's advice to other clubs who are in the process of thinking about or building new stadiums: You should get on the horn with Atomic Data.

"I tell them if you're from Austin or New England, you should be talking to Atomic," Wright said. "They should try to replicate the relationship we have with them." –MSR–

CLOCKWISE FROM TOP LEFT: AN OPENING DAY PROMOTION; ONE OF THE MANY WELL-BRANDED WI-FI APS; AN UNDER-SEAT DEPLOYMENT; THE DAS HEAD END WAITS FOR TELCO GEAR; ANTENNAS IN THE CONCOURSE; AND SIGNAGE TELLING YOU WHO BROUGHT YOU THE WI-FI. CREDITS: FIRST PHOTO, MINNESOTA UNITED; ALL OTHERS: PAUL KAPUSTKA, MSR

JMA Wireless Delivers Premier Wireless Connectivity for DC Baseball Fans

Changing Times at Ball Parks

How the game of Major League Baseball (MLB) is played has basically not changed in the last 150 years, but the fan experience has evolved tremendously across the nation's 30 ballparks. One of the biggest transformations over the last few years has been wireless connectivity to enhance the fan experience as well as to improve park operations. However, not every wireless network is equal as demonstrated on Opening Day by network testing specialists, Global Wireless Solutions (GWS).

At Nationals Park, home of the Washington Nationals, MLB sponsor, T-Mobile, selected the JMA Wireless TEKO™ DAS (distributed antenna system) to meet its mobile communications needs (see Figure 1). The Nationals' wireless network deployed by system integrator, Multipath Communications Group, has readily outperformed those at other MLB ballparks as demonstrated by the OneScore awarded by GWS. The OneScore evaluation process is a measurement of overall performance that takes into account voice, data, video, coverage, and reliability metrics based on customer experience.

"T-Mobile is rightfully obsessed about our customers' experience on the nation's fastest 4G LTE network," said the company's Vice President of National Development, Bob Vorlicek. "JMA Wireless checked off all of the boxes for us with their turnkey DAS network offering – and deployed it in a very timely manner."

Figure 1: Nationals Park Network Details

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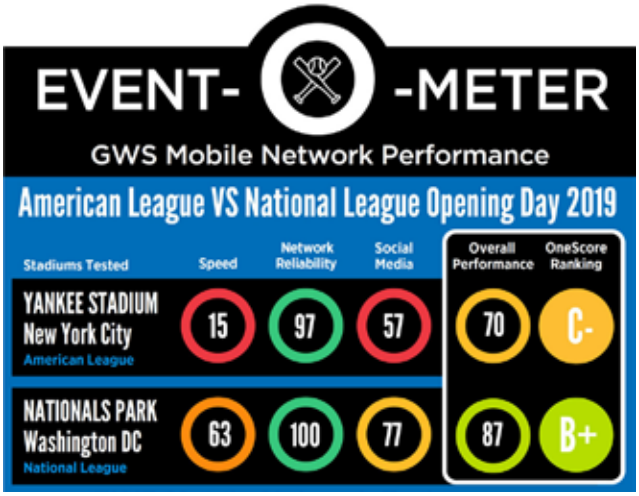
Loaded Network, No Problem

The widespread sharing of videos, social media posts and calls made can result in fans consuming terabytes of data during a single game. On Opening Day, GWS brought league rivalry to the forefront by demonstrating how well the wireless network at Nationals Park vs. the one at American League Yankees Stadium supported fans' data needs. The wireless network at the American League stadium received a GWS OneScore of 70, which equals a C-. However, the JMA Wireless TEKO DAS earned the National League a OneScore of 87 or a B+ (see Figure 2). In fact, the OneScore of 87 at Nationals Park is the highest GWS Event-o-Meter scored ever delivered to date.

Figure 2: JMA Wireless TEKO DAS at Nationals Park Outperforms the Competition



GWS testing specialists experienced the following on Opening Day in Washington, DC and in New York City:

- 100 percent of calls made at both stadiums were completed successfully.
- Data-related tasks, like web browsing and uploading posts to social media, saw success rates of 98 percent in New York and a perfect 100 percent in Washington, DC.
- Video uploads took about six seconds in Washington, DC and a whopping 33 seconds in New York.
- Photos and selfie uploads took about four seconds in DC and 14 seconds in New York.

To learn more about how JMA Wireless solutions can provide the ultimate fan experience at your sports venue, please visit https://jmawireless.com/industries/sports-entertainment/.

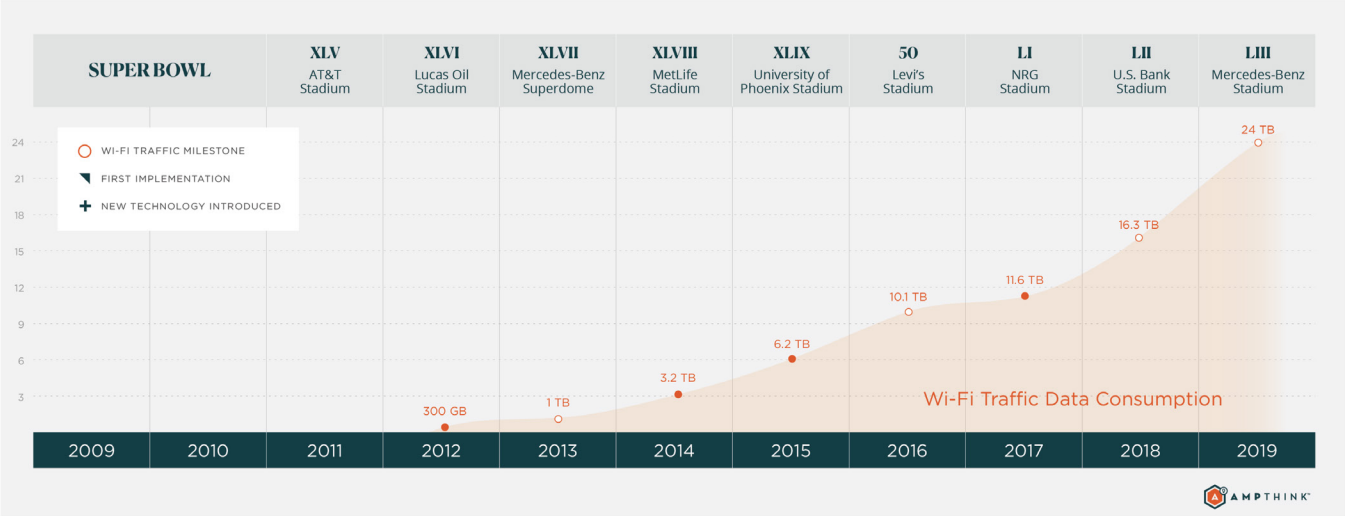
JMA WIRELESS

WI-FI 6

THE GENERATIONAL LEAP IN TECHNOLOGY NEEDED TO KEEP PACE WITH DEMAND

For IT professionals who run Wi-Fi networks inside large public venues, there is both excitement and fear when the latest data traffic numbers are reported from the biggest sporting events. The excitement comes in part from seeing the ever-increasing totals of data used at bucket-list events like the Super Bowl, as they stretch the boundaries of network performance. The fear kicks in when you start wondering whether the networks – including your own – have run out of room to grow.

High Density Wi-Fi



Over the past 8 years, traffic consumption at the Super Bowl has grown from 300 gigabytes to 24 terabytes, a staggering 87% compound annual growth rate ("CAGR"). If consumption continues to grow at the same rate, we can predict that demand at next year's Super Bowl will exceed 40 TB.

Over the same period, there have been incremental gains in technology that have enabled the growth in consumption. The migration of devices from 2.4 GHz to 5 GHz (802.11b to 802.11a) allowed access to new spectrum. Improvements in modulation techniques and chipset capabilities (802.11g to 802.11n to 802.11ac) improved effective data rates. Antennas specifically developed for high density deployments were introduced, reducing cell sizes thereby increasing channel re-use. Combined with year over year refinement of deployment techniques, stadium Wi-Fi capacity has successfully grown to meet the increasing demand.

- Speeds up to 10 Gbps
- 3-5x increase in network capacity
- 5G-like before 5G is available

8x8 MIMO

Increased capacity by providing the ability to Tx/Rx to multiple clients at the same time

OFDMA

Reduce over-the-air collisions and latency with scheduled MAC

Make Wi-Fi predictable

1024-QAM

Increased data rate

Better modulation

1.25x greater throughput

BSS Coloring

Improved spatial re-use

Avoid unnecessary packet processing in client devices

Target Wake Time (TWT)

Improved battery life by scheduling radio wake time

But operators of the networks at both Mercedes-Benz Stadium and U.S. Bank Network will tell you that at big events like the Super Bowl and the Final Four, their Wi-Fi systems are now spectrally constrained – meaning, that they are already using all the available depth of unlicensed spectrum to service the fans' data demands. Such signs seem to indicate that without the release of new spectrum or another generational leap in technology, current Wi-Fi technology will be insufficient to meet growing demand.

Fortunately for the stadium Wi-Fi community, there is an answer: The new 802.11ax standard, which is now known by the new marketing title of "Wi-Fi 6." Wi-Fi 6 is the generational leap in technology that will enable Wi-Fi systems to keep pace with demand. Coupled with the potential expansion of the available unlicensed spectrum incorporating significant portions of the spectrum between 5.8 GHz and 7 GHz, Wi-Fi 6 has the potential to realize a wirelessly connected venue without constraints.

With a wide range of technical improvements, Wi-Fi 6 will greatly advance the entire Wi-Fi ecosystem, for all types of uses. But for venue networks the new features are especially important, since Wi-Fi 6 will allow network operators to significantly improve each of the three main things that matter when it comes to in-venue network performance: it will increase the amount of available spectrum and number of channels; it will increase the average data rate for clients; and it will increase the ability to re-use channels in your space. Let's explore some of those features in detail.

HOW WI-FI 6 ADDRESSES CAPACITY CONSTRAINTS

Wi-Fi 6 directly addresses the capacity constraints inherent in the prior Wi-Fi standards in 5 key areas:

- Migration from OFDM to OFDMA
- The addition of BSS Coloring
- The introduction of 1024 QAM modulation
- The expansion of 4x4 multi-user, multiple input, multiple output (MU-MIMO) to 8x8 MU-MIMO
- The incorporation of Target Wake Times

OFDMA

The most important addition to the Wi-Fi 6 standard is orthogonal frequency division multiple access (OFDMA). Wi-Fi 5 relied on orthogonal frequency division multiplexing (OFDM) which only allowed a single device to communicate on a given channel at a given time. OFDMA, however, allows for concurrent conversations to traverse the same airwaves by segmenting a channel into sub-channels.

Why is this better? To use a simple traffic analogy, OFDMA turns what used to be a single lane of traffic that is as slow as the car in front of you (OFDM) into a multi-lane highway, where any car can pass the traffic and more cars can use the same road at the same time.

Sub-channels allow for the integration of a scheduler. The scheduler's job is to efficiently pack data to or from multiple end devices into a single combined channel. The scheduler is described in the 802.11ax standard. However, the implementation of a scheduler is left up to the manufacturer. The scheduler is the manufacturer's secret sauce.

For venue networks, the bottom line on OFDMA is huge: It allows Wi-Fi 6 networks to accomodate more clients and more traffic over the same amount of spectrum.

BSS COLORING

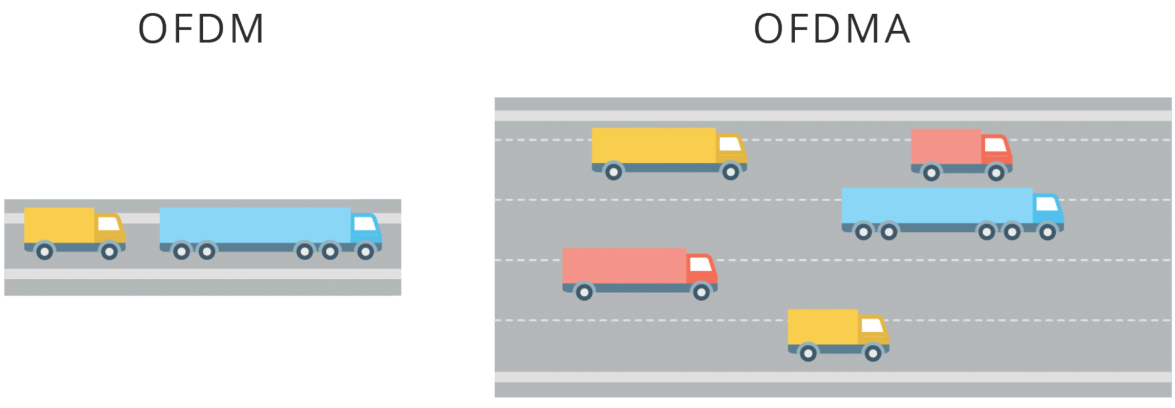
A key limitation of Wi-Fi 5 is the multiple access mechanism. The assumption is that when two devices communicate concurrently on the same channel, the result is a collision and the outcome of a collision is data corruption. In stadium bowls this situation can be problematic, since even with good design and interference plans, it's often still possible for client devices to "hear" APs across the bowl instead of the one they are closest

OFDM - Orthogonal Division Multiplexing

- Only one device can talk on a channel at a time

OFDMA – Orthogonal Frequency Division Multiple Access

- One channel can simultaneously transmit small frames to multiple users
- OFDMA networks can support more clients per AP



OFDMA ALLOWS WI-FI 6 TO ACCOMMODATE MORE CLIENTS AND MORE TRAFFIC OVER THE SAME AMOUNT OF SPECTRUM

to. Even if it's a non-optimal link, when a device hears communications ont he channel it's using, under Wi-Fi 5 it has to wait for that communication to be over before it can transmit.

With Wi-Fi 6 and BSS Coloring, such spatial re-use issues are directly addressed. When packets are "colored," devices that are not participating in the conversation can transmit and will transmit using their own color to differentiate their communications from neighbor conversations. By allowing two separate conversations to occur on the same channel between discrete end point pairs, each channel may be re-used more efficiently with less separation between individual micro-cells. By allowing for smaller micro-cells, the number of potential micro-cells within a stadium deployment can be increased, improving channel re-use.

Bottom line, especially for venue networks: Increases in channel re-use increase the system capacity of a high density network.

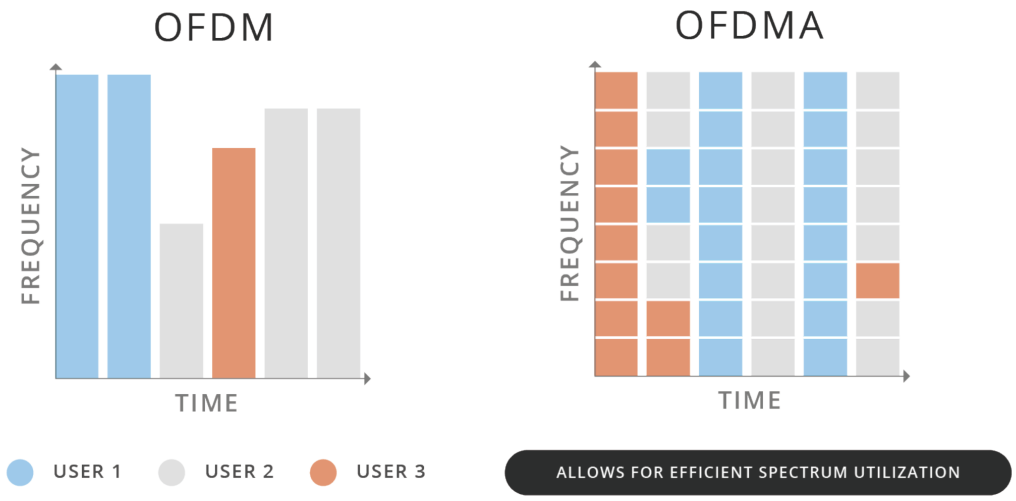
1024 QAM

QAM (quadratic amplitude modulation) refers to a technique used to embed data onto a given Wi-Fi channel. Prior iterations of the Wi-Fi standards were based on less data dense modulation techniques.

QAM is a signal in which two carriers (two sinusoidal waves) shifted in phase by 90 degrees (a quarter out of phase) are modulated and the resultant output consists of both amplitude and phase variations. These variations form the basis for the transmitted binary bits, atoms of the digital world, that results in the information we see on our devices.

Scheduling - The Key to OFDMA Performance

- Now that we can have small bits of data bundled into RUs or big data segments that use all available RUs (the entire channel), we need to schedule which data gets folded into each bundle.
- The scheduler is described in the 802.11ax standard. However, the implementation of a scheduler is left up to the manufacturer. The scheduler is the manufacturer's secret sauce.



Modulation techniques are used to optimize throughput and range. The number of points in the modulation constellation determines the number of bits conveyed with each symbol.

While not all devices will achieve 1024 QAM, the significant improvement from Wi-Fi 5 to Wi-Fi 6 is simple math: With 256-QAM, Wi-Fi 5 could transfer 8 bits per symbol; with Wi-Fi 6, the potential increases to 10 bits per symbol – a 25 percent increase in potential overall data rates.

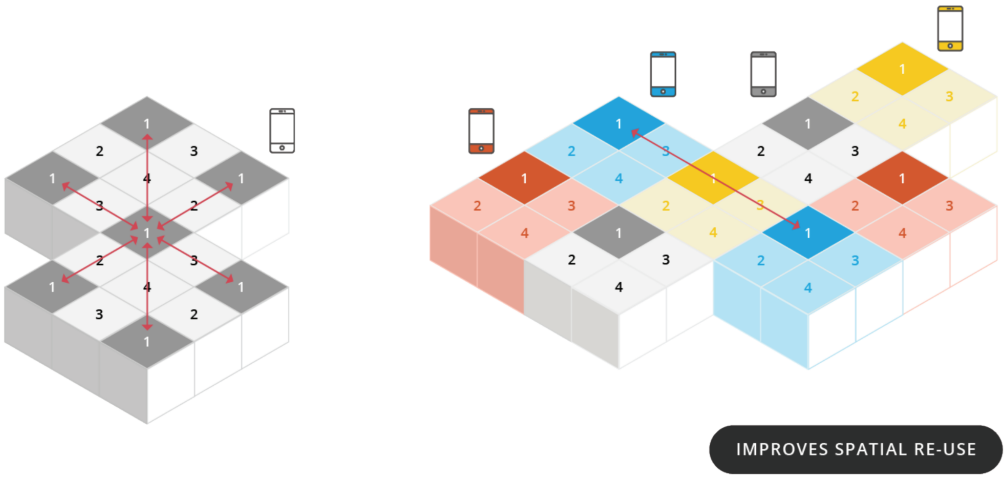
The bottom line for venue networks: 1024 QAM provides the ability for Wi-Fi 6 networks to carry more data over the same period of time.

8 X 8 MIMO, OR 'MASSIVE MIMO'

Wi-Fi 5 first introduced the idea of a radio chain. Prior to the introduction of the first version of Wi-Fi 5, an individual radio within an access point was the combination of a single transmitter and single receiver that could be attached to one or more antennas (antenna diversity), allowing for each radio to communicate with a single device. In a Wi-Fi 5 access point, the single transmitter/receiver pair was broken into multiple transceiver pairs with a maximum of 4 transmitters and 4 receivers per radio, each coupled with their own antenna.

Multi-user MIMO was introduced in Wi-Fi 5 wave 2. Using beam forming techniques, MU-MIMO allowed a single access point to direct multiple streams of data across a given channel concurrently. Within the Wi-Fi standard, a 4x4 access point could support concurrent communication with up to 3 client devices over a single

- Before 802.11ax - when a device heard communications on the channel it was using, it had to wait for that communication to end before it could transmit
- BSS Coloring identifies the communicating pair with a color
- If a device hears communications from a different color it can ignore it and possibly transmit anyway
- This improves - "spatial re-use" where spatial re-use is the ability for multiple pairs of radios to use the same channel concurrently



IMPROVES SPATIAL RE-USE

channel. Wi-Fi 6 builds on the MU-MIMO capabilities by increasing the number of supported transmit/receive pairs within an access point from 4 to 8, doubling the number of concurrent conversations that can take place over a given channel.

And while Wi-Fi 5 MIMO only worked for download traffic, Wi-Fi 6 8x8 MIMO adds support for bi-directional traffic, an important feature for stadium networks since much of the big-game data totals are from fans uploading data like pictures and video to social media networks. Though the benefits of 8x8 MIMO may be delayed somewhat until client devices and other gear mature to support the feature, it is a great tool to have to support future data demands.

Bottom line: Venue Wi-Fi 6 networks using 8x8 MIMO can have greater capacity by serving more devices simultaneously.

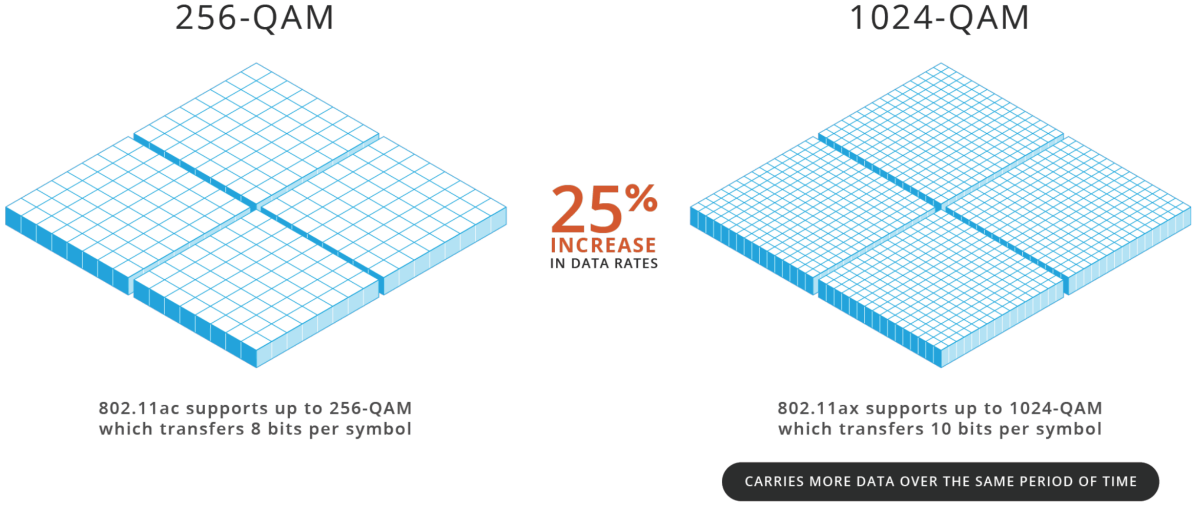
TARGET WAIT TIME (TWT)

Anyone who has watched their device battery drain as it keeps seeking a Wi-Fi connection can figure out the obvious benefit that Target Wait Time will bring to Wi-Fi 6 networks. The simple premise is that with TWT, an AP and a client can set up agreed "wake times" for communications, limiting the number of times a client device has to wake up.

This feature will be extremely useful for networks using Wi-Fi 6 for Internet of Things (IoT) communications, since devices can potentially negotiate very long sleep times, like hours, or days. This feature is perfect for IoT devices that only need to communicate once in a while, like water meters.

The bottom line for Wi-Fi 6 networks: Target Wait Time brings more cellular-like performance to networks, reducing spectrum contention and preserving device battery life.

- QAM is a signal in which two carriers (two sinusoidal waves) shifted in phase by 90 degrees (a quarter out of phase) are modulated and the resultant output consists of both amplitude and phase variations. These variations form the basis for the transmitted binary bits, atoms of the digital world, that results in the information we see on our devices.
- Modulation techniques are used to optimize throughput and range. The number of points in the modulation constellation determines the number of bits conveyed with each symbol.



Conclusion: Wi-Fi 6 is the generational leap in technology that will enable stadium Wi-Fi systems to keep pace with demand

Even as stadium network professionals contemplate which technologies and which business models make sense for their venues' wireless futures, it's hard to see any one with the potential to play a bigger role than Wi-Fi 6. Even as it takes time for all the features to be realized as the device and gear ecosystem matures from Wi-Fi 5 to Wi-Fi 6, the backwards compatibility of the standards-based 802.11 environment assures that even as venues move forward, older client devices won't be left unconnected.

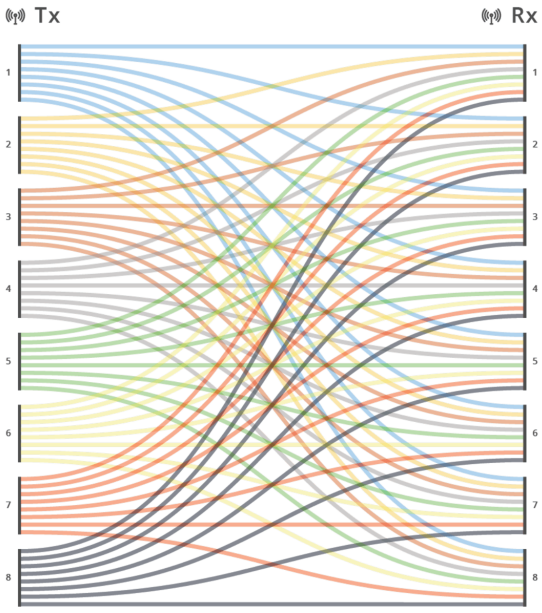
Even more potential for stadium Wi-Fi networks is on the near horizon as the cards continue to fall in the favor of more unlicensed spectrum becoming available in the 6 GHz region, a potential windfall of 1,200 MHz of new spectrum – far more than the 150 MHz currently being used in the 5 GHz unlicensed bands.

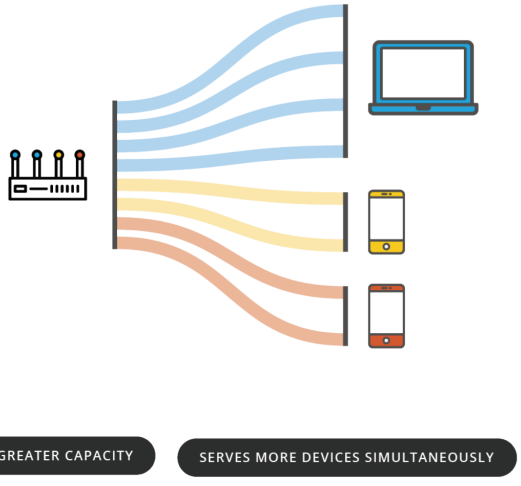
Though competition from other players from the cellular and CBRS spaces will no doubt make the rulings around 6 GHz an interesting political development to watch, the ability for Wi-Fi 6 to make Wi-Fi networks as efficient and powerful as licensed cellular networks should ensure that a good portion of the new airwaves are set aside for unlicensed use.

For venue networks that are already seeing spectrum constraint, the new technology in Wi-Fi 6 and the potential of more new spectrum could be the now-arriving answers to the question of how stadium networks will keep up with data demands.

(Analysis and slides provided to MSR by AmpThink)

- "Massive MIMO"
- 802.11 AC (Wi-Fi 5) supports up to 4x4 MIMO
- Increase capacity by providing the ability to transmit to and receive from to multiple clients at the same time





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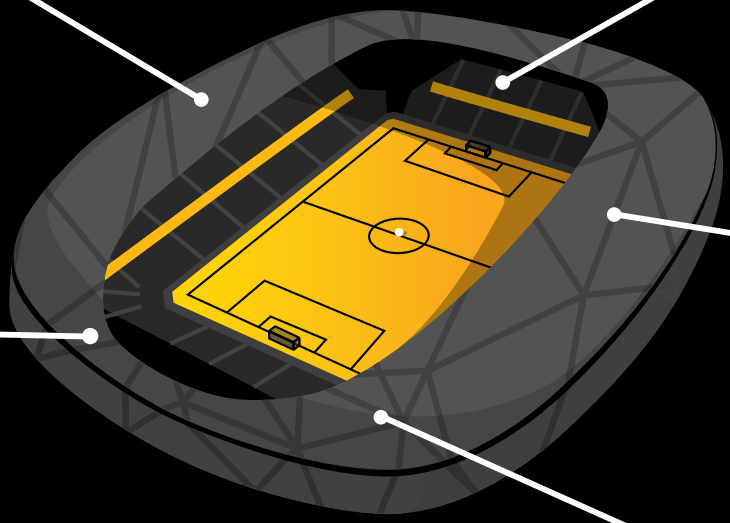

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TOP-DOWN APPROACH BRINGS WI-FI TO

CHESAPEAKE ENERGY ARENA

BY PAUL KAPUSTKA

FACING PAGE: CHESAPEAKE ENERGY ARENA, HOME OF THE NBA'S OKLAHOMA CITY THUNDER. THIS PAGE: AN AP POINTS DOWN FROM THE CATWALK. CREDIT ALL PHOTOS: OKLAHOMA CITY THUNDER

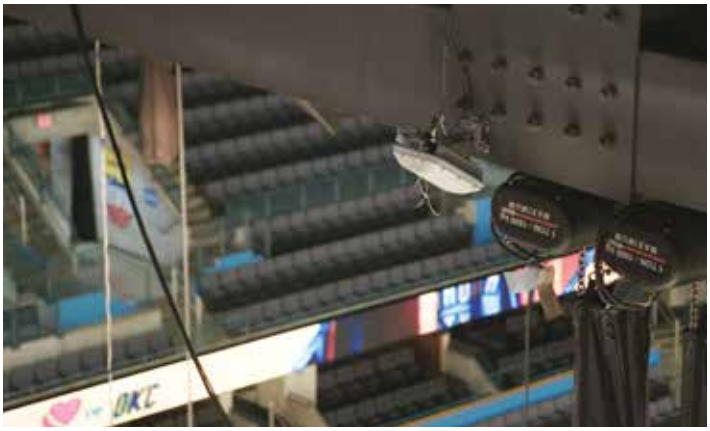
If there's one sure thing about stadium Wi-Fi deployments, it's that pretty much no two networks are ever exactly the same. So even as there is a growing large-venue trend for putting Wi-Fi access points under seats or in handrails, sometimes the traditional top-down method is still the one that works best.

Such was the case for the first full fan-facing Wi-Fi network at Chesapeake Energy Arena in Oklahoma City, home of the NBA's Thunder. With a large amount of retractable seating in the 18,000-seat venue, an under-seat approach to Wi-Fi would prove too costly and disruptive, leading the team to look for connectivity from above.

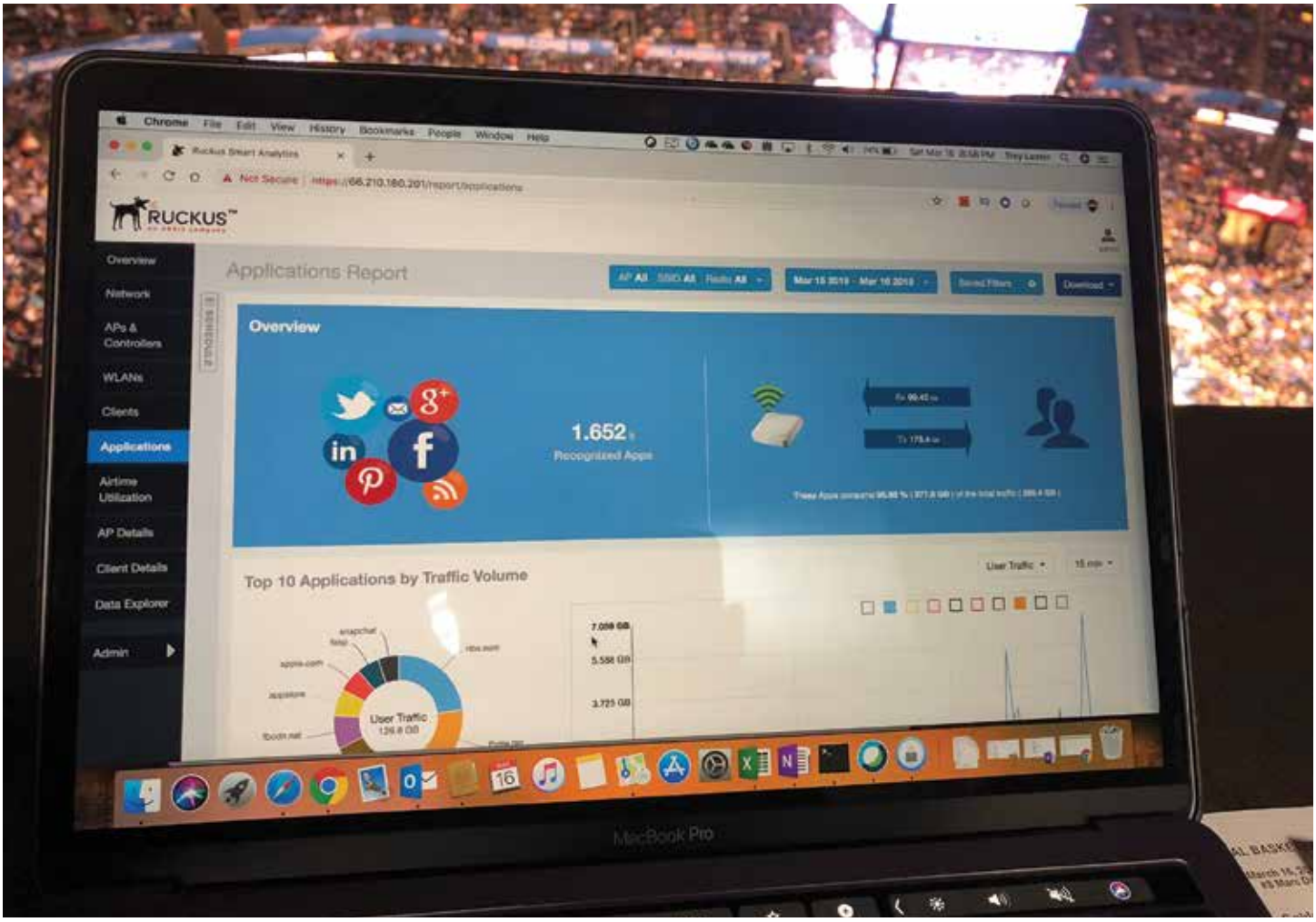
While a solid in-building cellular distributed antenna system (DAS) had done a good job of keeping fans connected the last few years, the team's desire to have more mobile insight to fan activity as well as a switch to a Wi-Fi-centric point of sale system led Oklahoma City to finally install fan-facing Wi-Fi throughout the venue.

Chris Nelson, manager of information technology for venue manager SMG, and Tyler Lane, director of technology for the Thunder, spoke with Mobile Sports Report about the recent Wi-Fi deployment at Chesapeake Energy Arena, which went live during the most recent NBA season.

Though the venue looked at all options, Nelson said that going under-seat with APs would have been "very costly" to do, given the large number of retractable seats in the arena.



CLOCKWISE FROM TOP LEFT: APS POINT DOWN FROM ALL SPOTS IN THE RAFTERS, INCLUDING OFF BEAMS AND CATWALKS. BELOW: ARENA IT ADMINISTRATORS HAVE A CLEAR LOOK AT STATISTICS INCLUDING APPLICATION USAGE.



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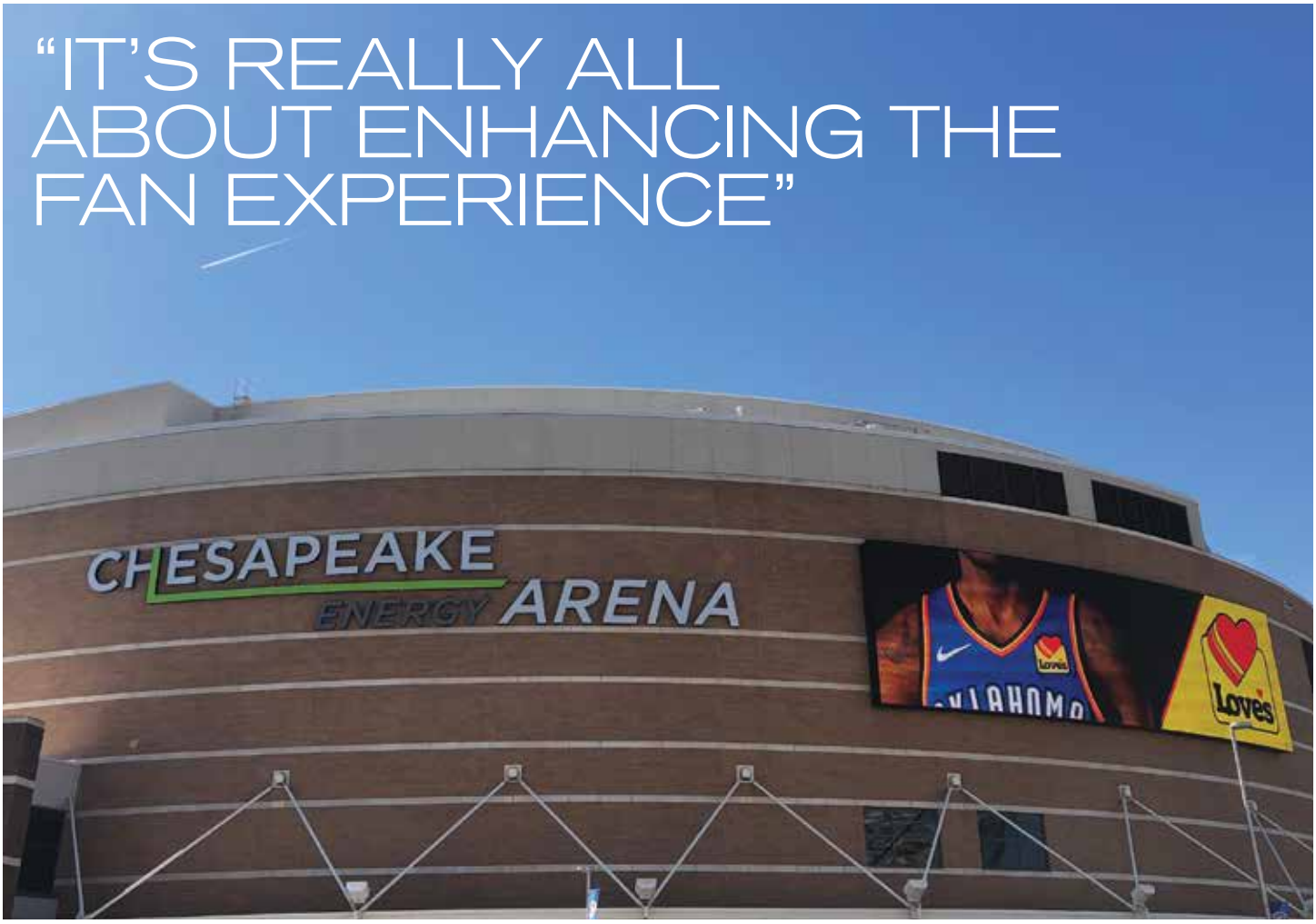

WI-FI WAS BROUGHT IN TO HELP IMPROVE THE FAN EXPERIENCE AT CHESAPEAKE ENERGY ARENA.

"We wanted to hang them [APs] from the top if we could," Nelson said.

After testing the top equipment brands available, the Thunder settled on Ruckus gear, for what they said was a simple reason, one involving the 96 feet in air space from the catwalk to the arena floor.

"Ruckus was the only one whose gear could reach down all the way," Nelson said.

ADDING TO THE FAN EXPERIENCE

According to the team the deployment saw 410 total APs used, with 350 in the arena proper and another 60 deployed across the street at the Cox Convention Center. According to the Thunder's Lane, the team rolled out the service slowly at first, with some targeted testing and feedback from season ticket holders.

"We got some good feedback and then when we went to a full rollout we had signage in the concourses, communications via ticketing services and announcements over the PA and on the scoreboard," to tell fans about the system, said Lane.

According to statistics provided by the team, the Wi-Fi was getting good traction as the season went on, with a March 16 game vs. the Golden State Warriors seeing 589.3 gigabytes of traffic, from 2,738 clients that connected to the network. Lane said the team employed Jeremy Roach and his Rectitude 369 firm to assist with the network design; Roach in the past helped design networks at Levi's Stadium and Sacramento's Golden 1 Center.

Now that the Wi-Fi network is in place, Lane said the Thunder is starting to increase the ways it can add to the fan experience via digital means, including app-based features like showing press conferences live and by having an artificial intelligence chatbot to help provide fans with arena information.

"It's really all about enhancing the fan experience," Lane said, with an emphasis on driving digital ticketing use in the YinzCam-developed team app. Lane said that the system also drives a lot of mobile concessions traffic, and added that "Ruckus did a fantastic job of asking all the right questions for our food and beverage partners." –MSR–


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