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WHITEPAPER

Delivering on the Promise of **Smart Stadiums**

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Executive Summary

The current technology deployed in stadiums is just beginning to scratch the surface of possibilities. Today's wireless systems have already enhanced the traditional fan experience and are changing the way stadiums operate. As venues become smarter, more data and analytics are being captured than ever before.

These properties are now starting to function like mini cities. Mobile devices can now be used to pre-order food and beverages or check concession lines. Cameras throughout the venue are integrated into the network to deliver real-time multiple angle replays. Connected security robots roam today's stadiums to identify suspicious activity, which is communicated instantly to the command center. These kinds of capabilities will increase as massive IoT further alters environments.

According to Gartner, the 8.4 billion connected things around the world today will steadily grow to over 21 billion by the year 2020. And, 5G will be the enabler, supporting up to 1 million connected devices per .38 square miles, compared to around 2,000 connected devices per .38 square miles with 4G.[1]

In this paper, we will explore what the 5G promise will make a reality and how wireless networks will evolve to support the technologies of tomorrow.

A Strong Foundation

Smart stadiums are complex environments and connectivity is key (see Figure 1). The wireless connectivity enabling the smart stadium experience must be a foundational element that is part of the venue's architectural plans, similar to how plumbing and electricity are included. When taking connectivity into consideration at this early stage, it can be optimized for cellular demand while still preserving a venue's aesthetics. Nowadays antennas are even being mounted right into the concrete under the Bowl of a stadium, not only guaranteeing powerful wireless connectivity, but also helping to ensure the venue's aesthetics are maintained.

These connectivity needs are expanding as a stadium is no longer just a stadium, but it includes restaurants, shops and other businesses. Furthermore, stadiums are often only one building on an entertainment campus that is comprised of additional restaurants, hotels, lounges and parking. Wireless connectivity for the entire area must be considered at the initial development stage.

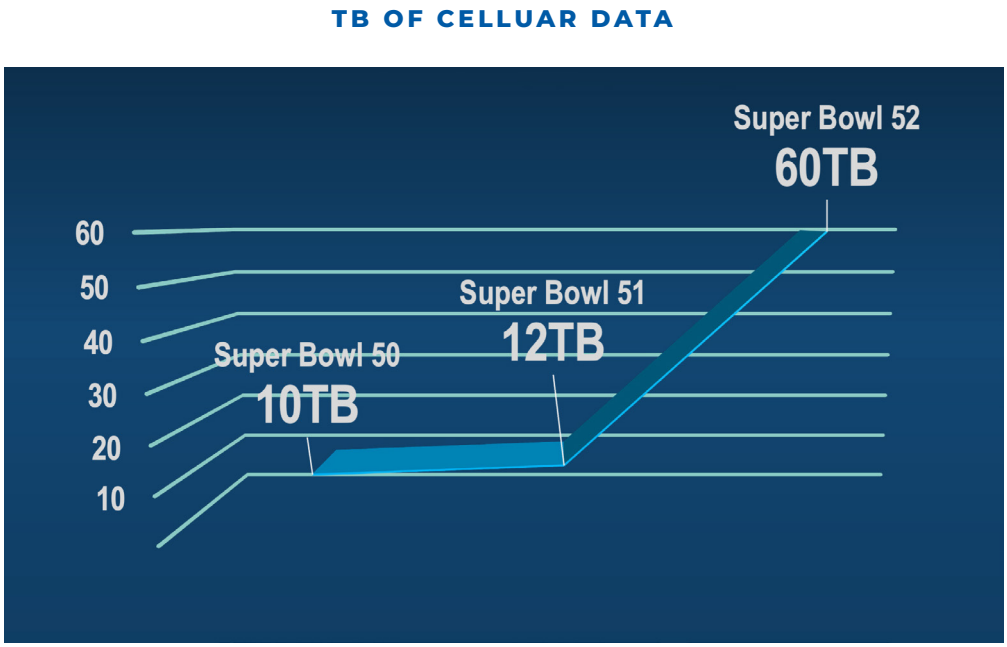

Figure 1: The demand for wireless connectivity continues to grow year after year as illustrated by the data transported over cellular during the last three Super Bowls.

A 360-Degree View

Now that connectivity is part of the initial plan for a stadium, a technology vendor must take a 360-degree view when considering how to utilize it for a sports venue. The pyramid in Figure 2 illustrates the different levels, with connectivity being that foundational element that provides access to increased bandwidth to enable different devices and overall mobility across the venue. However, technology vendors cannot only be concerned about the foundation, but they must be involved at every level.

The next level concerns devices and sensors, which are used to collect and measure not only existing data, but they expand the possibilities with access to new types of information, such as inventory for shops and restaurants, which is not measured today.

The third level of the pyramid manages these devices and aggregates the data before sending it to the Cloud. While the fourth level is the most intelligent, transforming it into actionable insights useful for venue owners and staff. Finally, the top level of the pyramid involves the end users of the network, which includes not only the fans but the venue staff, providing new and enhanced services made possible with wireless connectivity.

WIRELESS CONNECTIVITY PYRAMID

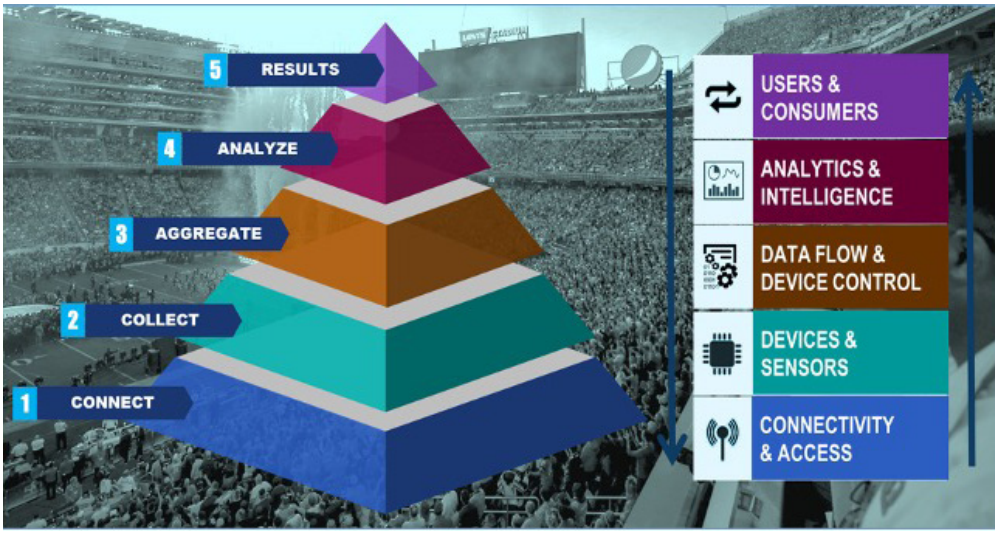

Figure 2: To ensure optimal wireless connectivity, technology vendors should be involved at every level of the pyramid.

The Smart Stadium Vision

Today's smart stadiums require a deeper level of intelligence and data. This means the next generation of smart stadiums must include knowledge not only about people, but machines, usage, space and much more. There will be new services to optimize the fan experience, but also many other areas of operation within the stadium will be impacted.

A common and expanded wireless infrastructure must be deployed to offer greater speed, provide increased intelligence and enable more devices beyond ones directly utilized by humans. The wireless infrastructure necessary for a smart stadium must include a radical increase in sensory and control points.

ON THE FOLLOWING PAGE ARE THE KEY AREAS THAT WILL BE IMPACTED BY SMART STADIUM TECHNOLOGY:

1. Fan Experience
2. Facility Management
3. Operations
4. Retail Sales
5. Safety and Security

1 FAN EXPERIENCE

We live in a world that demands constant connectivity without complication. Fans expect to post, text, upload, call and share their current in-venue experiences. The smart stadium affords fans the ability to engage and share onsite, building a case for going to the stadium versus watching the big game in the comfort of their homes. The wireless connectivity will enable richer engagement by providing player stats and wagering opportunities, game data, unique fan experiences, and location-based offers and promotions.

The fan experience can even be taken to the hyper fan intelligence level. Fans can opt in to share not only their location in the stadium, but also personal Sensors can be used in conjunction with self-driving cars to drop patrons off at the nearest entrance, park in a pre-assigned location in the lot, and even pick them up at the end of an event.

2 FACILITY MANAGEMENT

Wireless connectivity will improve a smart stadium's carbon footprint by enabling technology to control and reduce energy consumption related to lighting or water usage. In addition, waste and recycling will be managed intelligently with receptacles only being emptied when necessary. With sensors, any structural issues can be monitored too.

Parking is one of the biggest reasons why people do not attend sporting events in person. At a smart stadium, the ingress and egress patterns can be monitored and adjusted to ensure optimal traffic flow. Sensors can be used in conjunction with self-driving cars to drop patrons off at the nearest entrance, park in a pre-assigned location in the lot, and even pick them up at the end of an event.

3 OPERATIONS

Smart stadiums also impact operations, making the venue more prepared before and on the big game day. With M2M, machine and vehicle diagnostics will report any issues, helping to ensure equipment is functioning properly prior to an event. Also, these assets will be readily tracked. Furthermore, consumable monitoring will help ensure that restaurants do not run out of popular food items during an event.

4 RETAIL SALES

Shopping is often a component of the fan experience. Smart stadiums will offer more targeted marketing, helping to ensure the ultimate onsite experience as well as generate additional revenue for the venue. Fans can even order and pay for merchandise from their seats, which can be ready for pick up at the end of an event. In addition, the onsite retailer will not only receive shopping analytics, but supply chain information, helping to alleviate any product shortages.

5 SAFETY AND SECURITY

Not only improper fan behavior, but a host of other threats are impacting safety and security in sports venues nowadays. At smart stadiums, data, notifications, and intelligence will be localized to help speed response time to an emergency. Edge based services will make it easier to loop in the proper onsite first responders. Furthermore, the FirstNet initiative in the United States is opening the door to a host of additional public safety applications.

The Evolution of Athletes

Today professional sports is huge business with athletes' contracts worth hundreds of millions of dollars. However, every year 10 percent to 30 percent of these lucrative salaries are wasted unfortunately due to player injuries. For Major League Baseball this can equal up to $700 million being thrown away in a single year.[2] To help alleviate some of these injuries before they happen, sports attire will include hundreds of embedded sensors to provide valuable data, which can be used by medical staff and coaches.

This information can help a doctor determine if a player needs to be taken out of a game before he aggravates an old injury again, which can end up sidelining him for a portion of the season. These sensors not only help prevent injuries, but they also provide player analytics, which not only coaches value, but fans enjoy. For example, it can provide data for a football player regarding how long he held the ball before passing, the release angle, muscle tension, heart rate, leg speed, and the G-force.

Making 5G a Reality

With 5G, increased performance, new services and lower costs will become a reality. Today's standards organizations are addressing many of the requirements for 5G. For example, extremely low latency will be necessary to ensure real-time information is obtained from sensors. New spectrum must be deployed to provide additional capacity for more devices, especially with the advent of massive IoT (Internet of Things). Software based approaches are being addressed for virtualization and optimized infrastructure.

Planning for a 5G Smart Stadium

Today standards organizations may be working to ensure 5G becomes a reality, but venue owners also need to be thinking now about how to make 5G a reality in their stadiums. The stadium environment is going to become increasingly complex and challenging as IoT becomes pervasive, and edge RAN technology enables new services with mobile edge computing (MEC). To support these new services, venue owners must consider how to increase cell density, and how to optimize the placement of antennas. When determining antenna placement, SINR or Signal to Noise Plus Interference Ratio must be considered. Antenna placement and the level of interference are critical to ensuring good SINR. Next, venue owners should plan for the different service layers required to support the many new sensors, which will enable these new smart applications. Some sensors will need low latency while for others this will not be an issue.

Finally, with 5G, new spectrum will be added. It is critical to think through migration plans for these new spectrums as they become available. Stadiums must be ready to take advantage of licensed and unlicensed spectrums.

Bowl Density Must Evolve

In today's stadiums, antennas are often placed behind the zones in the Bowl. And in areas where further enhanced performance is required, antennas are placed under the seats in the Bowl. As mentioned previously, antennas are now even being embedded into the concrete of the Bowl. With this newer design, the antennas disappear yet density and capacity increase in particular zones.

When determining the capacity, often a calculationcalled peak average capacity is used. Peak average capacity is based on all users on a carrier using the wireless system at the exact same time. This does not happen in reality, but it is a good basis to use when determining how to reach the capacity desired. New designs will increase peak average capacity two to three-fold the current rate of 3 Mbps.

These new designs must be constructed with future multi-spectrum needs in mind. Venue owners should not have to rip and replace networks as new spectrum, such as the mid-band CBRS (Citizens Broadband Radio Service) in the 3.5 GHz band, become available for use. The wireless network should be able to overlay these new spectrums and support their functionality with the addition of new modules or by just turning on software. With these types of changes, the peak average capacity will increase another three-fold.

Ultimately, the Bowl density should be designed to support the "Super G Stage" where there are tighter and smaller cells that can support even higher frequencies, such as Millimeter wave technology at 28 GHz. However, this higher frequency brings its own set of propagation challenges that must be overcome. At the Super G Stage, the peak average capacity will increase again another ten-fold (see Figure 3). The end goal is to increase the speed to the mobile devices.

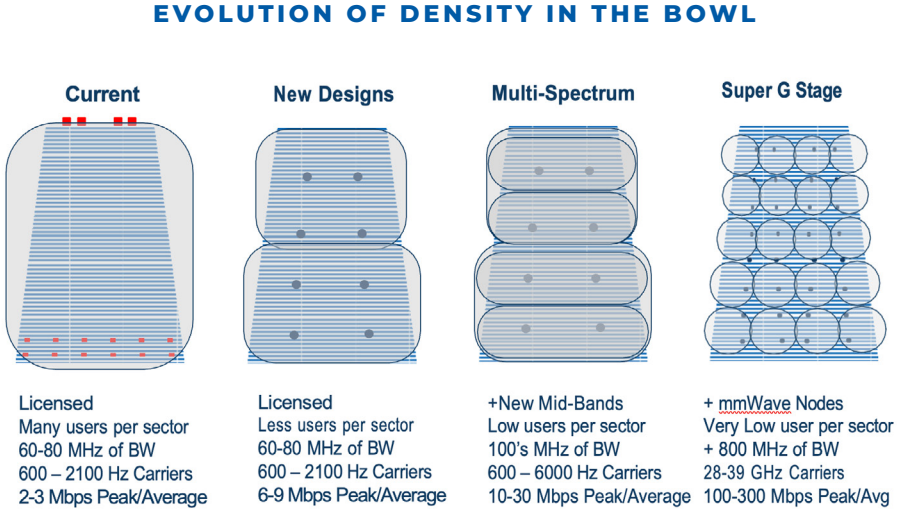

Figure 3: It is critical to think about how a venue's Bowl density must evolve to adequately support 5G.

Spectrum Usage

Currently, the spectrum used includes license bands in the 600 MHz to 2700 MHz range. However, this will be changing as mid-band spectrum such as CBRS becomes available. It will be 150 MHz of spectrum that can be shared by all operators. And, by combining it with currently available spectrum, the peak average capacity can be dramatically increased. Also, the FCC is investigating other spectrum in this mid-band range, up to 500 MHz capacity could come available in the next two to three years.

There are also bands in the Wi-Fi zone that can be used. However, in these zones there is competition with Wi-Fi devices. LAA (Licensed Assisted Access), which is part of LTE, is currently available. In the near future, there will be another band known as LWA (LTE-WLAN Aggregation), also available for use in the Wi-Fi zone. However, to ensure optimal wireless connectivity, a venue owner must coordinate the Wi-Fi plan with each operator's LAA plan and even LWA plans in the future.

Finally, 5G and 28 GHz are going to be addressed by Fixed Wireless. Fixed Wireless is available today with antennas in many residential and business districts, providing broadband service to end-point destinations. However, there is research going on currently to deliver this same type of high capacity to mobile devices, not just fixed end-points (see Figure 4).

5G Challenges

5G will make possible the many use cases mentioned previously and so much more. With IoT, there will be thousands of applications across numerous industries, impacting many different types of devices.

However, the significant increases in capabilities and density will also result in major challenges. Additional capacity will be needed, which is very costly. Already today's wireless systems consume massive footprints, which require much power, cooling and human expertise.

This will be exacerbated further on the head-end portion of the network as venue owner's move to 5G. The footprint for the head-end will grow, consuming even more valuable onsite real estate, which should be used for revenue generating activities, not housing wireless infrastructure.

RAN ON THE MOVE

- Saves **14+ million** kWhs/year
- Saves **3,000 square feet** of head-end space
- Saves more than **$800K** in cooling expenses
- Eliminates **5,000+** coaxial and **1,800** fibers

Saving an estimated $7 Million in three years!

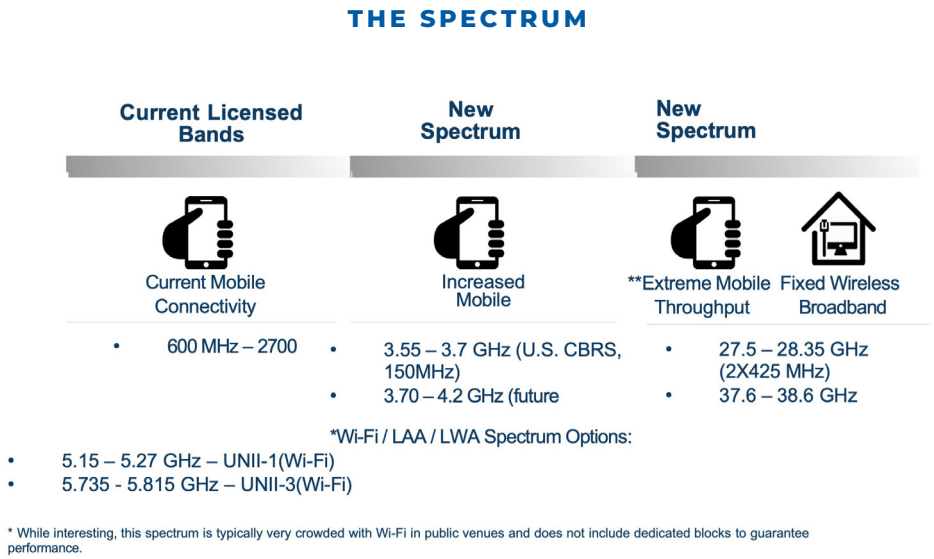

Figure 4: The amount of licensed and unlicensed spectrum will grow dramatically over the next few years to support 5G applications.

Evolution to Software Access Networks

To combat the 5G challenges, wireless networks are evolving to software access networks, which will not require large, on premise rooms filled with complex hardware in need of powering and cooling. Instead, the RAN (radio access network) will become part of a data center, making it simpler, more compact and cost-efficient. Figure 5 illustrates $7 million in savings over a three-year period that a future stadium could experience by implementing a software access network.

By moving to a software-based infrastructure, the RAN can also take advantage of Cloud economics. The software can run on servers in the data center and assets can be placed in the Cloud of the operator. These assets will only be consumed at a stadium as they are needed, resulting in much better RAN utilization (increases from 25-30 percent to 75-80 percent), and a much more cost-efficient model overall.

This type of infrastructure also results in a DevOps architecture, with software development being unified with operations requirements as part of the design process. With this approach, asset utilization can be automated by using algorithms that will draw upon the Cloud assets. For example, as more and more mobile devices enter a stadium on game day the asset utilization will increase. The performance of the software will make your network intelligently elastic – increasing and decreasing wireless coverage as people move around an entertainment campus.

Prepare Your Network Today for Tomorrow's 5G

When thinking about a smart stadium, the venue owner must consider how today's shared nodes will extend into the future and be ready for 5G. The fiber plan, conduit and powering must be reviewed for these nodes so the foundation of the infrastructure does not have to be changed as new spectrum and layers are added. It is key to work with a supplier who places the nodes in the right areas, provides the necessary fiber infrastructure and delivers the capacity needed in a zone, ensuring that more devices can be readily supported in the future. Furthermore, the head-end must be taken into consideration, and how the technology will be extensible to the new 5G data center mentioned earlier.

In summary, it is best to think of this migration path as being comprised of three areas of planning. First, there are the extensible 5G ready flexible zones in the stadium. Next, there is connectivity back to the head-end, which includes an extensible distribution framework covering power, conduit and fiber requirements. Finally, the head-end should take advantage of the virtualized 5G technology and the migration to the data center.

In these data centers, a venue owner will have mobile edge compute services, which will extract intelligence on users, such as location, footfall, etc., and in turn, deliver new venue services. It is key to think about how this virtualized RAN and MEC will evolve over time in a smart stadium.

In Conclusion

With the advent of 5G, a venue owner must think about how an entire Eco system will be impacted in a smart stadium. Wireless must be considered in the initial framework of a smart stadium. Then venue owners should think about the kind of connectivity that needs to be made available and who the different users of it will be – people, sensors, and/or machines. Next, it is important to consider how the information obtained through these different channels flows into back office data to produce valuable intelligence. In closing, a 360-degree view is necessary to determine how to ready infrastructure to support new spectrum and layers, which in turn enables 5G applications and the smart stadium of the future.

Levi's® Stadium is one of the most technically advanced sports venues in the world today.

Sources: [1] "5G - Connection Density - Massive IoT and So Much More", November 2, 2017, CIO.com
Sources: [2] "What is the Real Cost of Injuries in Professional Sport", Stephen Smith, May 16, 2016, Medium.com

About JMA Wireless

JMA Wireless is the leading global innovator in mobile wireless connectivity solutions that ensure infrastructure reliability, streamline service operations, and maximize wireless performance. Employing powerful, patented innovations, their solutions portfolio is proven to lower the cost of operations while ensuring lifetime quality levels in equipment and unrivaled performance for coverage and high-speed mobile data.

JMA Wireless solutions cover macro infrastructure, outdoor and indoor distributed antenna systems, small cell solutions, and virtualized RAN software. JMA Wireless corporate headquarters are located in Liverpool, NY, with manufacturing, R&D, and sales operations in over 20 locations worldwide.

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