Stadium Wi-Fi

Designing Wi-Fi Networks for Stadiums: Challenges & Best Practices

iBwave

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Got Game?

Stadium Wi-Fi Network Best Practices

Commercial scale Wi-Fi networks are becoming as ubiquitous as the devices that access them. It's a trend that only promises to grow not only larger but grow larger at an ever-increasing rate. In fact, at last count 29 of 32 NFL stadiums are equipped with Wi-Fi networks, feeding the appetites of fans who arrive to each event with an increasing appetite for bandwidth and throughput. A robust, high-capacity Wi-Fi network has become as necessary as concession stands and adequate parking. Those sports venues not joining the wireless world stand a high risk of dropping attendance and being relegated to farm team status.

Modeling, designing, and deploying a Wi-Fi network in a standard office complex, warehouse, or conventional retail environment already poses significant challenges to IT professionals. Accomplishing the same feat in a stadium however, can make those appear to be child's play. A stadium is a veritable hodgepodge of architectural styles and constructs which work in perfect harmony to create an ideal sports venue – but for the wireless network it's a minefield of potential transmission, reception, range, coverage, capacity and interference issues.

The stadium carries the Wi-Fi network designer far from the familiarity of horizontal floors and vertical walls and into a realm that demands rigorous modeling, testing, and accepting that no one solution fits all scenarios.

Understanding The Stadium Environment

It's best to think of the arena as a collection of building types amalgamated into one. The various component structures which make up a typical sports venue draw from conventional office buildings, warehouses, retail spaces, and back offices, and all of those seemingly tacked on to a structure which has few parallels in architecture – a vast open area playing field surrounded by a most unconventional bowl-shaped seating area which not only presents a formidable inclined plane, but introduces an RF signal body loss factor unlike any seen elsewhere with the exception of concert halls – with the understanding that most stadiums lead a double life as concert venues.

Concrete dominates the arena structure, and while it alone doesn't play a huge role in the stands or playing field, it can wreak havoc in concession areas, press rooms, team locker rooms, underground parking, back office and other support locations in and underneath the main stadium structure. Heavy concrete has the potential to create an RF attenuation of around 22dBm in the 2.4GHz spectrum and even higher in the 5GHz spectrum. The tendency for arenas to employ a circular perimeter can create special RF signal reflectivity conditions, and then there's the bowl and playing field which will demand a specific approach and considerations that take into account the inclined areas and high potential for co-channel interference (CCI) within and across levels.

Arenas also serve large amounts of users and devices before and after events as spectators move to and from parking and public transit areas – device use can be considerable during these periods, and so it's imperative to determine if you'll cover these areas, and how robust the network should be. Tailgate parties alone, always a big part of the sports event experience, signal the need for adequate capacity and coverage in parking areas.

Those are the immutable architectural factors, and Wi-Fi network functionality issues are only compounded when one includes the relatively high density of users and clients which can present itself sporadically, and either fill the field, as during concerts, or leave it empty during sports events. Next, we'll briefly explore how users and the rapid evolution of client devices can impact capacity and performance and must be considered as major design parameters for any arena Wi-Fi network.

Concrete areas in sports stadium can wreak havoc on wireless coverage

Understanding The User & Client Usage Profile

A decade ago social media was only just getting a toehold, and no one could have foreseen how it would impact both wireless network design and user's expectations of their performance. Smartphones make up the vast majority of connected devices present in any sports venue during an event. Over that same decade they've grown in complexity, storage, and place an endlessly growing demand on the networks they're connected to. Whereas a 2-megapixel camera was once the standard, today smartphones come equipped with not one but up to two 12 to 20-megapixel cameras – meaning uploaded or streamed video and images take up considerable bandwidth. Then there's the advent and proliferation of cloud storage, which means almost everything a smartphone films or shoots is instantly uploaded whether it's shared on social media or not – another heavy user of bandwidth. Add to that the resulting increased file sizes – a 2 MP bitmapped image is one thing, 5 minutes of 1080P video is quite another - and users are going to expect any data they upload to be transferred quickly and without issue. Suffice to say that connected devices of all kinds and their use of bandwidth particularly in the presence of available Wi-Fi networks are going to reach levels we cannot afford to underestimate.

Client use during events can also produce dramatic spikes such as that which might occur at critical points during a game, or the arrival of a celebrity onstage at the start of a concert. Spikes in network demand and the corresponding load on capacity will be as large as they are sporadic and are one indicator that when designing a Wi-Fi network for stadiums, full attendance with heavy client device use should always be anticipated and planned for. Experience has shown that one AP per 100-200 connected client devices will satisfy even the sharpest usage peaks. However, time and continuing device complexity and capability are sure to force a revision of this number.

Nor are spectators the only ones riding the back of the arena Wi-Fi network because stadium operations (security, admissions, maintenance) and event personnel can also tax its capacity and performance. Operational use of the network relies as much, if not more, upon a network with sufficient power and built-in redundancies not only for business, but for the overall safety of a heavily-populated public venue.

Stadium networks absolutely need to be designed with sufficient forethought given to future use and capacity rather than incur the costs and penalties of being forced to play an expensive game of catch up long after the ball has dropped. Anticipate, extrapolate and stay ahead of the game, because users are going to expect connectivity that's sustained, reliable, and robust. Ultimately fans are counting on your Wi-Fi network to enhance their experience. Can you deliver?

Critical points in a game often result in massive usage spikes

Completing The Impossible Play: Arena Wi-Fi Network Design Challenges

Worldwide nearly 1000 stadiums can boast a seating capacity of 30,000 or more, with extreme examples capable of accommodating over 100,000 spectators. Compare than to a typical retail, industrial or warehousing environment and the main difference becomes apparent – capacity and performance demands. As mentioned, these demands can vary wildly and exhibit enormous spikes during events. Plus, the presence of over 30,000 RF attenuating bodies can drain the effectiveness no matter the transmission power, choice of spectrum, or antenna selection – the latter which will prove to be one of the key factors to successful arena Wi-Fi network design and deployment.

But before diving into the game-changing specifics of arena Wi-Fi network design, let's go over some of those challenges that affect almost every large-scale commercial wireless network deployment, including sports venues.

Customer Requirements Preplanning Checklist!

It's a great idea to establish a checklist of all the important considerations any large Wi-Fi network needs to address before beginning the design phase. An easy way to get a basic overview is with a checklist, and here's one to get you started.

Not all of these will apply to every arena or sports venue, but we've built-in a considerable overlap and redundancy in these "must-dos", so chances are your unique scenario will be covered completely.

What to Know

- Evaluate and anticipate the services you'll need to offer over your network. (Voice over Wi-Fi, email, internet access, video streaming, uploading, etc.)

- Evaluate and anticipate the application types you'll be deploying. (Voice, video, data)

- Evaluate the optimal segmentation of data and number of logical networks your setup may need upon launch, and as the demand on the network grows.

- Evaluate the location and architectural parameters

  1) Building materials – presence of concrete, metal, tinted windows, high ceilings, fire-rated doors and any other RF propagation inhibitors)

  2) The immediate vicinity surrounding your arena's location., for example; metallic surfaces in close proximity to an antenna can affect the antenna pattern.

  3) Do you have a digital version of a current floor plan of your location that can be imported into our iBwave Wi-Fi® design software for AP placement and RF predictive modeling? Arena design relies on accurate 3D modeling and is nearly impossible to perform in a timely, cost-effective fashion without it.

  4) Do you foresee high-density areas outside of the seating area that may also need to host many client devices? Concession areas, press boxes, and exterior parking are good examples.

  5) In the case of an existing arena is there already a network infrastructure in place, including legacy or other, and backhaul cabling? Retrofitting a stadium with a state-of-the-art Wi-Fi network and associated infrastructure is a massive undertaking that requires just as much, and at times more planning than doing so for an entirely new structure.

  6) Will existing backhaul cabling restrict the optimal localization of APs along its backbone? It is recommended to use a professional grade Wi-Fi RF design tool like iBwave to best determine AP positioning to ensure proper coverage and capacity requirements.

  7) Is the 2.4 GHz spectrum currently in use at the stadium? It's essential to perform an RF Survey during an event using Wi-Fi spectrum analyzer. This will help determine noise level, another important design parameter.

- Evaluate and anticipate your retail Wi-Fi network's connection and capacity needs.

  1) How many active client devices do you estimate might connect to the network at peak hours? Recent Superbowl statistics indicate that about 1/3rd of all clients are simultaneously connected during peak times during a game. What kind of peaks can you expect during events, and will those peaks differ for sporting vs. musical events? Are there specific areas that will have more connections than others (subterranean levels, back offices, parking)?

  2) Do you know what those peak hours will be? Does the arena host more sports events vs. concerts? (Empty bowl vs. populated bowl affects coverage and can be greatly affected by body loss.

  3) Are you subject to local regulations (FCC, CRTC) governing RF propagation, frequency limitations, maximum allowable transmission power and EIRP (Equivalent Isotropically Radiated Power) or other relevant limitations?

  4) Will you require seamless roaming capability?

  5) Will you build-in sufficient failover ability and redundancies to ensure seamless operation during events where the network is subject to higher stresses?

- Installing stadium Wi-Fi networks is an enormous undertaking, and so redesign and redeployment should be at the longest possible intervals. Evaluate and anticipate your retail Wi-Fi network's backwards and forwards compatibility requirements and then extrapolate as far as possible.

  1) Bearing in mind that only 2-3% of devices utilize 802.11b/g (primarily as ticket scanners at venue entrances) should you invent the effort in assuring full IEEE 802.11-1997 to IEEE802.11ax compatibility, particularly in the seating area?

  2) What's your cut-off for backwards compatibility?

  3) Will you support a wide range of legacy devices?

  4) Do you anticipate the need for PoE (Power over Ethernet) capabilities?

  5) Which protocols will your network need to support? (IPv4/IPv6)

- Evaluate and anticipate your retail Wi-Fi network's security needs.

  1) Will you network require the hiring of a Security Manager that understands your current and future security needs, compliance with security regulations and their integration into the network, and stay abreast of rapidly changing network security technology?

  2) Are you hoping to include a wireless intrusion detection and prevention system for off-limit areas and for those times the sports venue is closed to the public?

  3) Have you factored in the need for preventing unlawful signal interception?

  4) Is there value in hardening your network equipment and infrastructure against present and future vulnerabilities?

  5) What about other security requirements such as captive portals, guest access control, and RADIUS ability (Remote Authentication Dial-In User Service)

  6) Is the network located in an area where intermittent power outages might require that it be equipped with a UPS backup?

- Operationally speaking…

  1) Has a finance manager or CFO made sufficient allocation of funds available for the design, deployment and continued maintenance of a robust retail Wi-Fi network?

  2) Have you weighed leasing versus purchasing a network setup?

  3) Is a project manager entrusted with control and coordination of the myriad of details on which the successful implementation of your new network depends?

This checklist is a great place to start for the design of nearly all large Wi-Fi installations. But arenas are special beasts. It's obvious there are few structures that employ large-scale wireless networks that look like, or function in quite the same way as sports venues. So, what are those particular challenges to arena Wi-Fi network design that can really force a network designer into overtime?

There are 3 primary arena-centric considerations that come into play when designing networks for these structures;

Specific Challenges

Architectural

A stadium's seating area is built in levels. Each level serves a different number of spectators, all seated on an incline. And while there are few if any architectural obstacles to impede RF signals, the selection of antenna types and careful assignment of spectrum channels can make the difference between a well-designed network and having to tear it down and start again. CCI can become a real problem between adjacent levels depending on the antenna type being deployed – and so any 3D modeling for network design is only complete once all the levels are considered as a whole. The playing field, or bowl, is sometimes filled with users and devices, other times only athletes, which means APs will likely be needed to provide it with adequate coverage. Building material is also an important factor, stadiums being largely made of reinforced concrete which has high RF signal attenuation properties, a fact which can have an important effect in lower areas such as concession stands, team dressing rooms, interior parking, service and maintenance areas and back offices, indeed anything that lies beneath the seating areas and bowl. Coupled with a tendency to design arenas on a circular or oval plan, and assuming that shape is carried over to associated corridors and internal transit areas, and the sports venue proves itself to be an entirely unique challenge.

Capacity, Coverage, and Performance

Always, always, always design an arena Wi-Fi network under the assumption of full attendance. Your network should have sufficient APs to assure coverage and be able to handle the relatively high demands on capacity. The average commercial or industrial Wi-Fi network rarely has to cater to 30,000+ users and devices in ultra-high-density conditions with a far higher average number of simultaneous users with a usage profile that favors sharp spikes in demand and enormous strains on throughput.

Interference

As you'll see later, no matter the type of antenna you choose sports venues almost always require a large number of APs in relatively close proximity to one another. Overlapping cells need to be planned for, yet must be organized judiciously so as to avoid the incumbent interference sure to be present when hundreds of antennas are located in a high-density AP environment. This sets the stage for potentially nightmarish CCI conditions, particularly in the 2.4GHz spectrum where for practical reasons we are limited to 3 channels. Avoiding CCI invariably results in coverage holes, so AP selection, and of course antenna type both become crucial decisions to be made.

Then there are the rogues… external Wi-Fi networks and non-Wi-Fi transmitters outside of the control of the one you're designing. The Wi-Fi spectrum is unlicensed, and almost anywhere you plan to install a new one will be subject to competing networks and other RF and non-RF signals of varying strength. It's a fact you'll encounter in almost any urban area – so be sure to plan for a Tx sufficient to compensate for residual noise in the spectrum and any CCI contamination from sources beyond your reach.

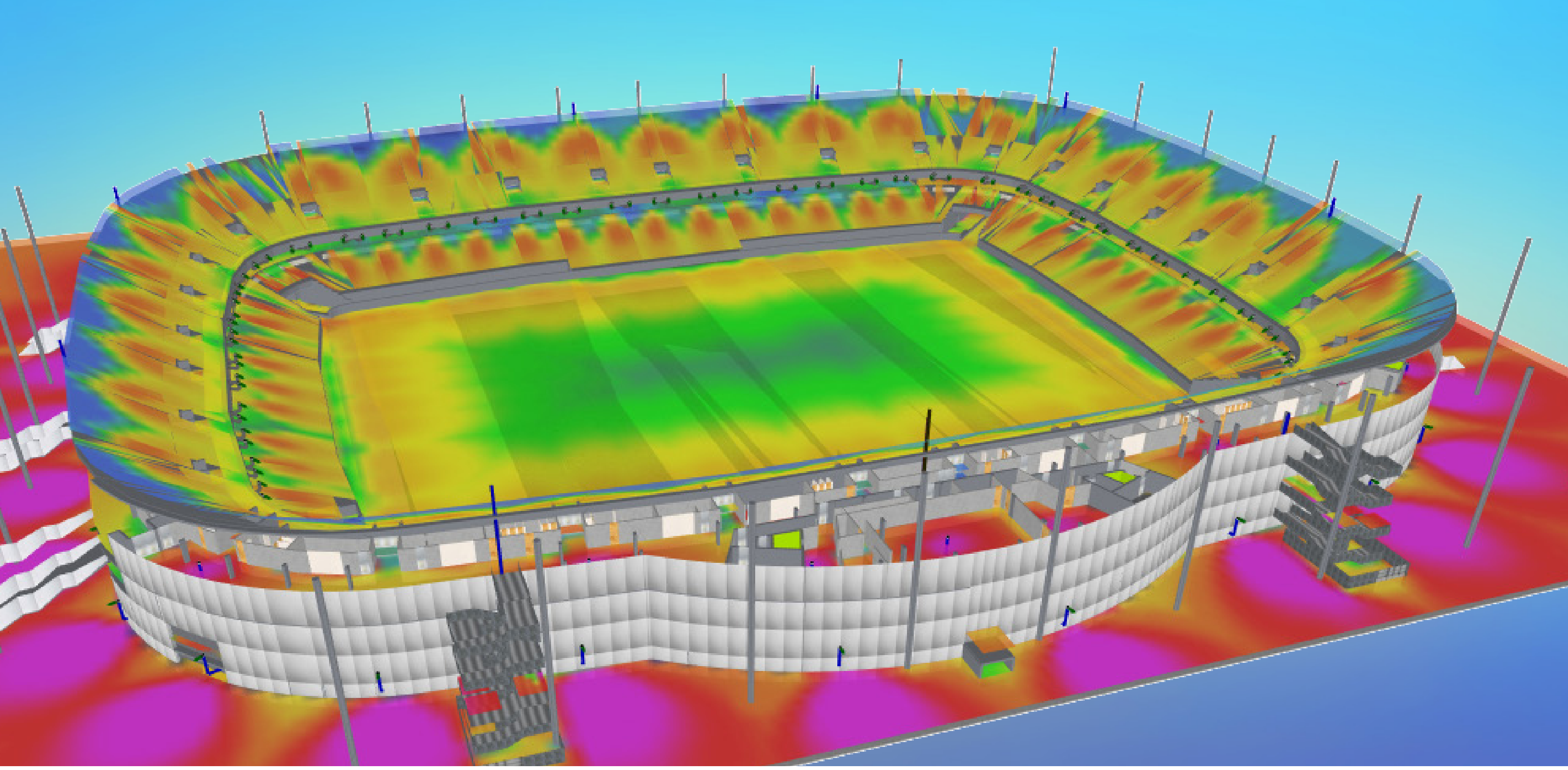
Winning Big

Stadium Wi-Fi Network Challenges

Atypical doesn't begin to describe the stadium environment – a collection of building styles housing a range of facilities that serve many end-uses, all of it built with materials potentially hostile to RF signals and regularly hosting ultra-high-density throngs of equally RF-unfriendly users wielding an army of data-throughput-hungry devices.

Clearly designing a robust, reliable Wi-Fi network for a major sports venue isn't going to be a cakewalk. In spite of these formidable challenges it is still possible to achieve the seemingly unachievable – all it takes it forethought, planning, and meticulous attention to detail.

Designing the ideal stadium Wi-Fi network requires a lot of effort up front, but experience has taught us that for every hour of preparation dozens are saved in rethinking, redesigning, and in the worst-case scenario, reinstalling a massively expensive wireless infrastructure. And it all starts with 3D modeling…

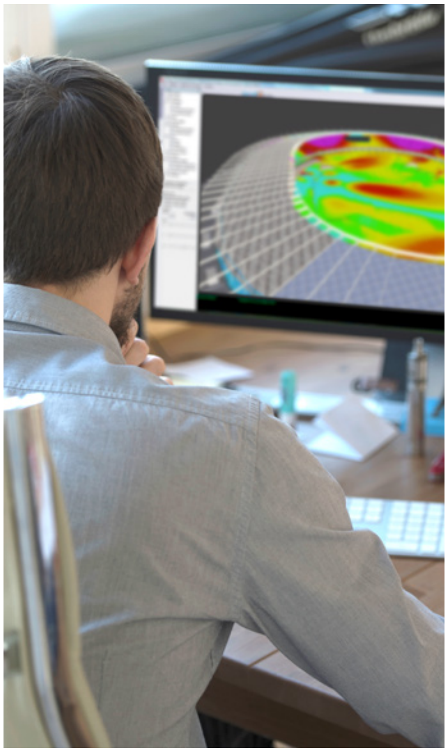


3D Modeling: Building A Case For All Scenarios

Clearly it's far easier to design and deploy a Wi-Fi network in a new stadium than to install one in an older, existing venue where after-the-fact installation of wireless infrastructure, reconstruction and reconfiguration of specific architectural elements and integration or replacement of any existing equipment can be appreciably costlier and more time-consuming.

For that reason, and several others as we shall see, best-case scenarios for stadium Wi-Fi network design rely on planning and development before even a cubic foot of concrete is poured. Creating an accurate 3D model of a future sports venue can lead to accurate predictions of all the RF signal propagation issues a network designer is likely to encounter. Building a 3D model of an arena is time and manpower intensive, but all of that effort is more than made up for at the back end where many times the hours will be shaved off by avoiding redesign and worse still, incorrect equipment purchase decisions or complete tear downs of improperly designed networks.

In the case of an existing sports venue, nothing beats the traditional exhaustive walkthrough and RF survey



Stadium 3D modeling with iBwave Wi-Fi®

along with an intimate knowledge of architectural plans, and reference to any existing network's performance statistics and known RF signal issues. For the sake of practicality, and in recognition that a small majority of new stadium Wi-Fi networks are installed in brand new venues, this eBook will focus its scenarios on buildings in the planning and construction phase, when Wi-Fi network design is easiest to adjust to ideal performance and live up to capacity, coverage and performance expectations.

iBwave Wi-Fi® is the ideal tool for the configuration and virtual testing of almost any type of Wi-Fi network, but is particularly valuable when planning for variable architecture structures like stadiums where fine-tuning and hypothetical scenarios based on variable parameters contribute to covering all the bases and avoiding network issues for as far into the future as possible.

It's All About Antennas…

Designing and deploying a Wi-Fi network in a stadium environment can be best be understood by breaking it into its two main components; the seating area & playing field – and everything else. Not to depreciate the importance of back offices, concession, parking, and other areas that need to be covered, but the big difference between the sports venue Wi-Fi network and almost any other large-scale commercial one is the seating area and playing field. This is where the obstacles lie in wait, and where intensive, exhaustive planning needs to be done – by preference on an accurate 3D model.

And when it comes to creating the conditions for proper coverage, capacity, and avoiding CCI in seating areas and on the playing field, it's purely a question of the right antennas in the right places. But guesswork won't help one iota… this is a task that requires diligence and ultra-accurate modeling.

So, what about antennas?

Antenna Types

The stadium environment poses unique challenges to the stadium Wi-Fi network designer. Because of its unique architecture and the resulting complex geometries, the seating areas and bowl (playing field) comprise an obstacle course of RF signal reflection, absorption and attenuation. In addition, the seating areas usually exist on multiple levels each requiring their own specific configurations based on peak estimated users & connected devices so the risk of serious CCI is high. All of these create challenges, but all can be equally overcome by careful AP location – and perhaps more importantly, antenna type selection.

For our purposes we'll consider the 3 primary antenna types to be overhead, under-seat, and railing mounted. These are the most practical, and applicable to the sports venue environment. Each has its particular advantages and disadvantages, and there simply isn't a "one-size-fits-all" solution. And, as you'll discover, nor is mixing antenna types normally a recommended course of action.

Here's a brief rundown of relevant antenna types:

Overhead Antennas

Overhead antennas are easy to design and simple to deploy. But because they're directional their precise coverage is more difficult to determine and control particularly between stadium seating levels. Back and side-lobe transmission also have to be carefully limited to avoid additional CCI. Lastly, accessing them for maintenance or redeployment can be difficult given their location several meters above floor level.

Under-seat Antennas

Under-seat antennas, while easier to access, are more prone to damage by spectators, and hence need to be of sturdier build. Under-seat antennas can be either omni or bidirectional, but within the arena context omnidirectional is usually preferred. Their range is less than alternative types, which presumes a higher AP count, plus they've got the largest RF signal body loss to deal with – however they do offer the best coverage and CCI control.

Handrail Antennas

Handrail antennas are probably the easiest to install, access and service, but as their name reveals, absolutely rely on the presence of handrails. However, this is almost always a given in stadiums, so it won't be counted as a disadvantage. Directional in nature, they also have to contend with serious amount of RF signal attenuation die to body loss, albeit to a lesser degree than the under-seat variety.

Even under ideal conditions no single type of antenna will eliminate coverage holes and CCI. But dependent on the specifics of the stadium seating area architecture, one type will end up doing the job better, although sometimes only by a fraction, than a competing variety.

We'll explore how each antenna fares in a later section when we set up a Wi-Fi network in a hypothetical new-build stadium setting.

Technology Best-Practices Checklist

Do:

- Use the 20 MHz channels (1,6,11 and/or 1,5,9, 13) exclusively within the 2.4 GHz range. Never use the 40 MHz channels in the 2.4 GHz range.
- Use the 20 MHz and 40 MHz channels within the 5 GHz range. There are as many as 23 to choose from!
- Set the 2.4 GHz and 5 GHz SSIDs as separate networks, giving them similar names (e.g.: Guest_2.4GHz & Guest_5GHz). Create a separate SSID for 802.11b/g devices if they're in use as ticket scanners near the entrance. Disable 802.11b/g in the seating area.
- Choose equipment that supports band steering to dynamically allocate channels.
- Include support for DFS (Dynamic Frequency Selection) channels (52-144) in the 5 GHz range.

Want to know more?: *http://clients.mikealbano.com* has an extensive list of devices that operate in this spectrum.)

- Ensure that all AP equipment also supports DFS.
- Implement DHCP (Dynamic Host Configuration Protocol) so that a range of free and working IP addresses are reserved and assigned in order to assure client devices detect and acknowledge connection. Assigned IP addresses that are not renewed return to the pool of available addresses ensuring a continuous supply for devices seeking connection.
- Think in 3-dimensions when designing your stadium Wi-Fi network. The complex seating area and playing field aside, office spaces are very different from concession areas and the latter in particular can be a tricky place for RF signal propagation. No matter where it's being installed, a network designer must acknowledge the ABCs of the X, Y and Z axes! And the Z-axis plays a major role in the seating area!
- At 5 GHz, use separate channels for APs located on different floors to prevent co-channel interference and avoid impeding network performance. High-density AP zones like the seating area are at a much greater risk of CCI and so the risks associated with improper assignment of spectrum and channels is multiplied.
- Include Wi-Fi network access in elevators and service elevators. This can be accomplished via a shaft-certified cable or using a wireless backhaul.
- Always make good use of monitoring tools to ensure a reliable, seamless experience for connect devices and consumers. Vigilance is key for the proper operation of wired and wireless networks, from the connection to the IP, to server use, backhaul use and reliability, and efficient problem-free RF signal propagation.

Best Practices

Back Offices, Concession & Outside Areas

Offices

Office areas associated with the stadium environment are as vulnerable to performance and security issues as any other part of the network and require the same care and consistency of planning rigor as does the seating area and playing field, albeit the setup will be less complex. Sports venue office areas are often the nerve center and need as robust & reliable a Wi-Fi network as the rest of the stadium.

It's best to provide connectivity at both the 2.4 GHz and 5 GHz level with dual-band interior APs. Because the layout of offices will differ from the seating area the rules that dictate AP use and localization will more closely resemble that of a large shopping mall (see Retail Wi-Fi Network Best Practices: *https://info.ibwave.com/ebook-retail-wifi-networks*).

Voice over Wi-Fi, video, audio, file transfer, email, and real-time inventory and security require multiple APs, and this can engender interference, channel overlap, and countless other potential propagation issues and throughput bottlenecks. The use of additional external direction antennae is a good practice for use in specific targeted locations to avoid signal bleed and potential security lapses. Don't be shy to use enough APs, choosing units that can handle a high volume of concurrent connections and support QoS (Quality of Service) technology that work to prioritize data.

It can be a very bad day indeed if the sports venue office areas lose their Wi-Fi network access and can even trigger an expensive event cancellation.

Concession areas are an odd mix of the two primary stadium environments. While they don't normally present the challenging atypical architecture of the seating area, they can nonetheless have peak activity periods where demand is high, body loss substantial, and so require as careful a selection of antenna type and CCI prevention. Obtaining near complete coverage is difficult, and invariable transmission holes will occur. The trick is to minimize those without creating undue CCI.

Outside Areas

Exterior areas associated with stadiums also need to be able to rely on a stable, secure Wi-Fi network every bit as much as the enclosed office areas and concession stands do. The operational areas of a sports venue go far beyond the seats and spectators into those exterior areas like parking hardware, connectivity, and network capacity.

The first challenge is an obvious one; weather. The elements can spell trouble for the exterior components of your external parking, service, and even playing field Wi-Fi network areas. Cold, heat, direct sunlight, excessive dryness and of course humidity all take their toll on equipment, so ensure that it's protected, and accessible for easy maintenance. It's recommended to opt for APs hardened for outdoor use that meet or exceed NEMA or IP ratings for ingress protection. Most under-seat, handrail and overhead antennas destined for large-scale commercial purposes are weather-resistant, but always double check the product specifications to ensure compliance. Needless to add that exposed cabling should also be weather and UV resistant. Availability of reliable power and backhaul data cabling or meshed wireless backhauls are must-haves.

Certain jurisdictions may regulate the standards of exterior APs, and with the exceptionally high density of antennas used in arena seating areas this is almost sure to become an important consideration. Best be aware of the rules governing Wi-Fi equipment and network installation and use in the area where the stadium is being built. Sports venue Wi-Fi network designers working in countries within the European Union should take note that ATEX 95* and ATEX 137* outline separate safety directives for indoor and outdoor electrical equipment in potentially explosive atmospheres for makers and users respectively.

Harsh climatic conditions create punishing environments for stadium network infrastructure and RF signal propagation. Add to that the increasing number of severe weather events and weather extremes, and the need for hardened outdoor Wi-Fi network components becomes clearer. In many ways, the sports venue is a prime example of large-scale external AP deployment, and any stadium makes a great case study in the many ways to do it correctly, and incorrectly.

* For more of ATEX 95 & ATEX 137 see: *http://ec.europa.eu/DocsRoom/documents/16402/attachments/1/translations/en/renditions/native*

Best Practices: Essential Technologies

It's essential to equip your network with as modern a technology toolkit as possible. Cost is always a factor, with more advanced systems and features invariably being more expensive, both to acquire and to train personnel in its use. But what you invest up front in modernization you save on the other end by being able to keep a system relevant and viable for longer periods. Antenna selection is probably the most important consideration in the stadium environment – they'll make up the bulk of the equipment, so ease-of-installation and long-term maintenance costs will vary depending on whether you opt for overhead, under-seat, or hand rail. Make it a policy to buy the latest technology, and if possible, with a preference for equipment that can be upgraded for one or two cycles before required complete replacement. The first technology to be superseded and deprecated will always be the oldest, and least advanced. Something to think about…

So what should a well-designed arena Wi-Fi network include? What are the must-haves and nice-to-haves of a happy, healthy network? Here's a quick point-form guide to those features that should be seriously considered, plus a checklist of additional important technology best-practices that can add flexibility and resilience to your network design.

Key Technical Features

Captive Portals

Captive Portals can serve a purpose in guiding users to in-house and other proprietary services that can in turn serve to collect data on consumer behavior. However, installing complex captive portals with unwieldy UIs are another story. Simpler is better, and the more likely users will want to make use of it. Bear in mind that spectators at an event probably won't want to waste time logging in – they're there to see the action, not have to be the ones jumping through hoops.

Location-Based Services

An important bedrock of data collection, location-based services provide additional depth & breadth to the precision of the conclusions that can be drawn from the analysis of the raw data compiled. Spectator traffic, network usage, event density patterns, and geofencing data can all be readily determined from the use of location-based services.

Management & Analytics Support:

This is crucial for the efficient and seamless operation of your sports venue Wi-Fi network, the collection of data, and just as importantly, its distillation, analysis and finally the formulation actionable conclusions. No network runs itself! Yet…

Gigabit Ethernet Port Count

Nothing ruins a stadium Wi-Fi network's day like dropped connections during the big game. DoS due to traffic surging over capacity, or the complete lack of essential failsafe redundancies can lead to a lineup at the complaints department. Considering the massive spiked usage of a sports venue network, it's safe to say you can never have enough gigabit Ethernet ports. Devices are going to get faster and exercise a greater demand on network capacity, so you can count on needs eventually meeting and surpassing whatever capacity was initially built into them. Maxing out your gigabit Ethernet port count helps forestall the inevitable.

Power Over Ethernet

IEEE 802.3 standardized power-over-Ethernet in 2003, allowing for the convenience of concurrent data and power transmission over a common Ethernet cabling. It can save on infrastructure costs and time required for installation – plus it can keep a network up and running during shortages if connected to a backup power source. Note that newer technologies such as IEEE 802.11ac/ax require a connection to PoE+. Again… it's another one of those nice-to-have extras that doesn't seem necessary until it is.

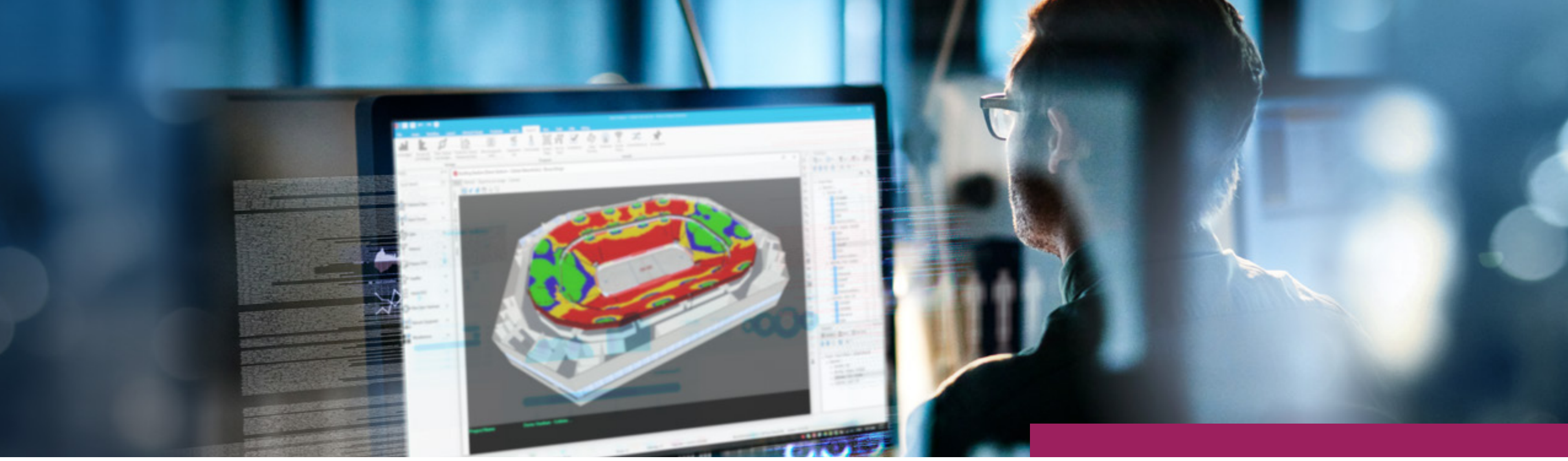
Swimming The IEEE Sea

IEEE 802.11 governs most of the world's wireless networks. It's a comprehensive set of standards, and many of its amendments were established to regulate those systems subordinate to the core Wi-Fi network.

Here are a few:

- IEEE 802.11ac MU-MIMO ((Multi-User Multiple Input Multiple Output)
- IEEE 802.11ax HEW (High Efficiency Wireless)
- IEEE 802.11v Client management
- IEEE 802.11k Radio resource management
- IEEE 802.11w Management frame protection
- IEEE 802.11i Data frame security

Want to know more?
An overview of the IEEE 802.11 standards and its amendments can be found at *https://en.wikipedia.org/wiki/IEEE_802.11*



iBwave Wi-Fi®: Design & Validation

Using iBwave Wi-Fi® For Stadium Wi-Fi Network Design

We've gone over the numerous issues and obstacles facing any sports venue Wi-Fi network and touched upon a few of the many best-practices that go into the planning of a successful deployment and operation. This is dense, demanding material, and a rigorous approach to design isn't merely good thinking, it's absolutely essential.

But a stadium Wi-Fi network can in some ways be seen as organic in nature. It grows, evolves, and must compete against its surroundings and the constant challenge of extinction by obsolescence. In this case driven by the relentless advance of technology. The complex clockwork of what is a functioning, reliable, forward-thinking stadium Wi-Fi network has countless moving parts – and so ensuring its proper design means a myriad of details come into play all of them governed by the uncertainties of locale, regulation, architecture, use, traffic and how these might change over the short and long term. Add to that the massive peaks in usage caused by the sheer number of users that often almost simultaneously draw from its limited resources and it's a no-brainer – trial and error with a live system is simply not a viable option.

It's not comforting to have to consider that the Wi-Fi network approaches the definition of a classic study in chaos theory. What is comforting is that we've developed our network design software with exactly this in mind; the streamlining & simplification of planning, designing, validating, and deploying superior Wi-Fi networks. That's the sole focus of our iBwave Wi-Fi® software. So, what does that look like in practice?

iBwave Wi-Fi® is software that seems almost tailor-made for the inevitable complexities of designing a Wi-Fi network within demanding architectural configurations that can torment the most robust setup. Planning for a reliable network operation in an environment filled with 30,000+ RF-signal-attenuating bodies hungry for high-speed, high throughput is a recipe for disappointment. Arrive prepared.

iBwave Wi-Fi®: Network Design Multitasker

iBwave Wi-Fi® is a 3D Wi-Fi network planning and design software solution. It's hard to think that any high-performance network could be realized without the invaluable assistance of such a tool, determining the right design based on those countless mutable parameters, conditions and limitations discussed in previous chapters.

iBwave Wi-Fi® helps pull it all together; from advanced 3D predictive modeling including inclined surfaces, body loss modeling, radio frequency choice to channel planning, cable routing, AP placement, PoE switches, wireless LAN controllers, and how all of them work together within a defined physical space. It takes a powerful solution to let you explore multiple configurations for optimal RF signal propagation based on network traffic vs. capacity at peak on/off periods, bandwidth consumption estimates, anticipated applications, technology options and allows you to tweak each of those variables ad infinitum and achieve a level of customization and optimization that any ideal stadium Wi-Fi network should enjoy.

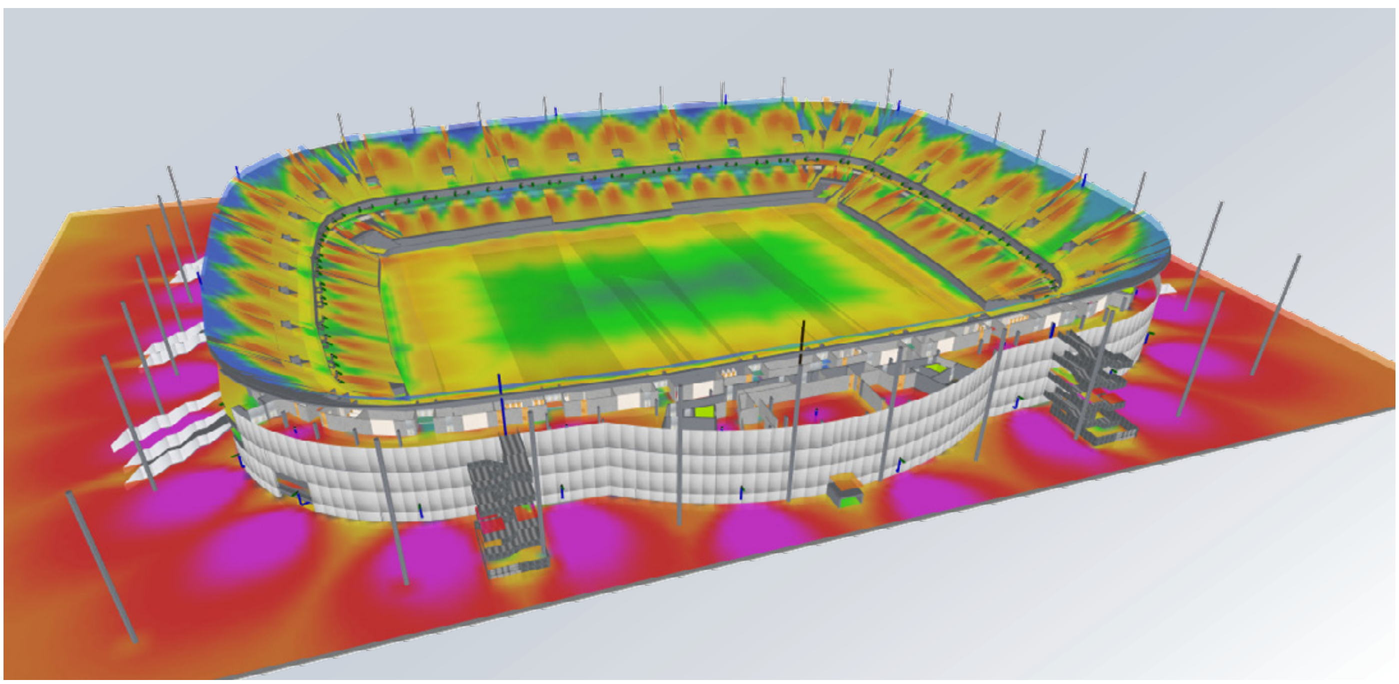
In short, planning with purpose, design that delivers, and validation you can rely upon, every time.

iBwave Wi-Fi®: A Virtual Network Design Sandbox

Picture it. The clean slate that is your new stadium environment – every last architectural detail, materials, exterior and interior areas in easy-to-manipulate 3D. All that's missing are the throngs of paying spectators, and all they'll be missing is a powerful, reliable Wi-Fi network that'll make any event more memorable. That's what iBwave Wi-Fi® makes possible, and it's the time and effort you put into creating a 3D environment that becomes the framework upon which iBwave Wi-Fi® plans visualizations of your network's components. Here in real time you can test each piece of equipment within virtual models of the locales that comprise your stadium design, the tricky seating area and playing field included. It's easy to add network infrastructure, APs, cabling, switches and instantly understand RF signal propagation issues and other potential problems. Stadium seating areas which require hundreds of APs might take uncounted hours more to configure without 3D modeling – similarly, any errors that arise during the design process require human eyes to spot them – usually the same human eyes that created the errors in the first place.

There are volumes that could be written about the advantages of designing with iBwave Wi-Fi® but rather than tell you, we're going to demonstrate the application of 3 different antenna types to a single level seating area of a hypothetical stadium design.

iBwave Wi-Fi®: Wi-Fi Network Design Case Study



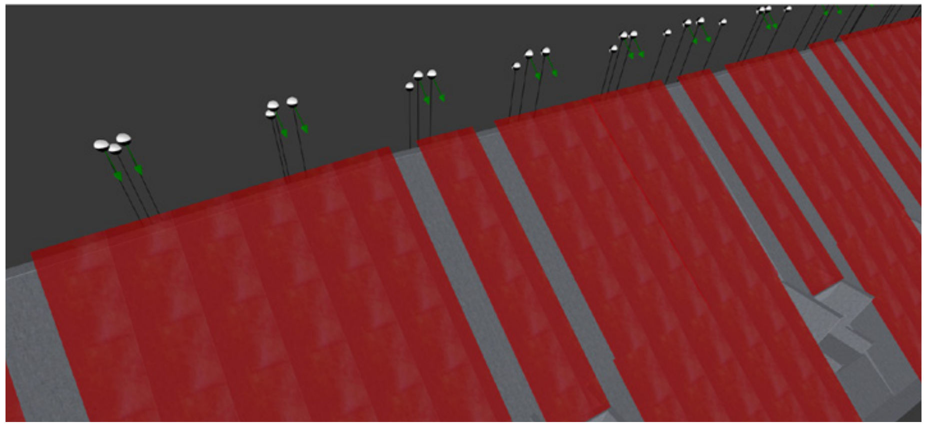
Stadium 3D model

Before we delve too deeply into our hypothetical stadium Wi-Fi network planning and design it's a good idea to reiterate that for the sake of simplicity & clarity, we'll be dealing with only a single seating level. While it will ably illustrate the challenges presented with AP placement and corresponding intra-level CCI, it does not reveal the equally important interference that certain antenna types are bound to create between seating levels. Suffice to say that iBwave Wi-Fi® can just as easily produce a integrated multilevel view that will allow designers to ferret out and eliminate overlapping RF signals between levels. The core principles remain the same.

Scenario 1 – Overhead Antennas

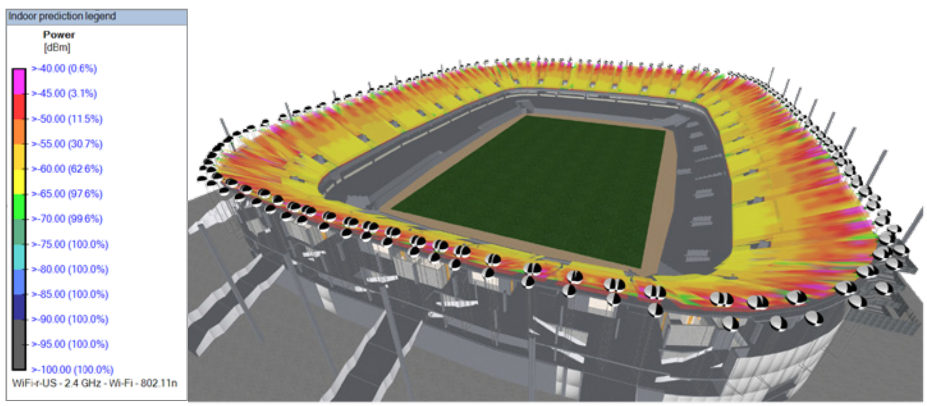
As mentioned on *page 11* of Stadium Wi-Fi Best Practices, overhead antennas are easy to design and deploy, but they will invariable create CCI in some areas along the periphery of their transmission sector. While easy to install, they can be difficult to access and maintain because of the height at which they are mounted.

Placement of overhead antennas in our hypothetical stadium is relatively straightforward – paired 2.4 & 5Ghz units at the top of each seating area section with directional transmission pointed downwards.

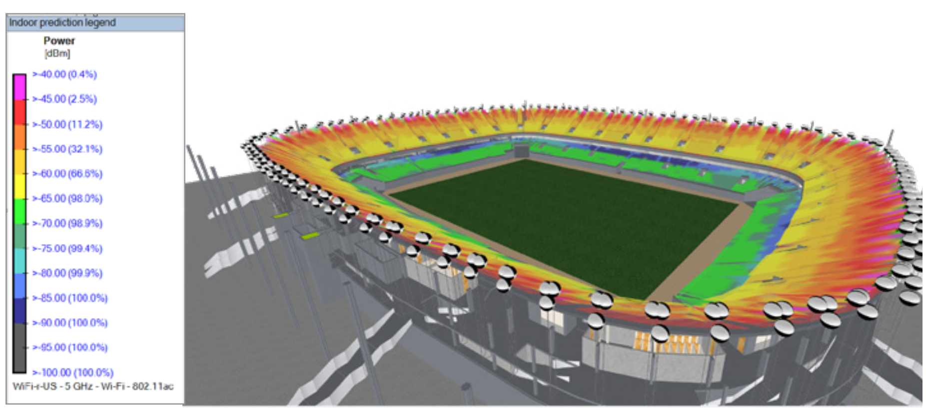


3D stadium single-level seating area model with overhead antenna APs

In the figure opposite, RF propagation simulation shows that coverage at 2.4Ghz is generally good with acceptable dBm levels at point of reception attaining 97.6% of the desired coverage of -65 dBm. Small transmission holes are visible at the top of each seating section, with occasional drop-offs near concrete covered spectator access points. 5GHz coverage is a little more complete at 98% coverage of the target area. Transmission holes appear in roughly the same areas as in the 2.4GHz spectrum.

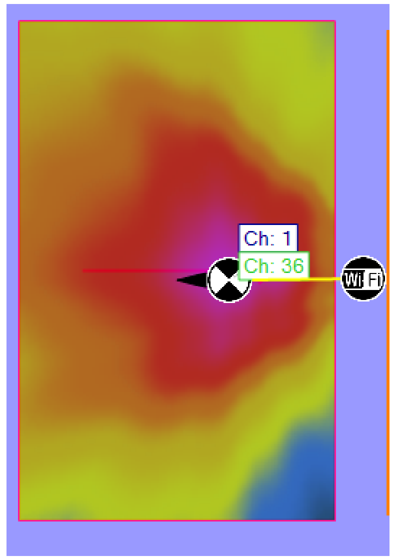


Stadium single-level seating area model (overhead antennas) with 2.4GHz coverage data

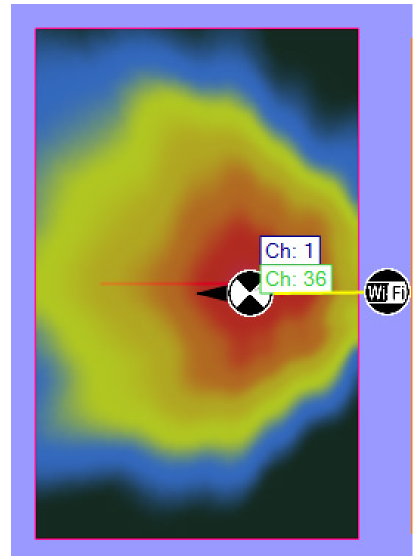


Stadium single-level seating area model (overhead antennas) with 5GHz coverage data

Regardless of the antenna type that is ultimately deployed, RF signal attenuation through body loss will play a major role in stadium Wi-Fi network design, and it's essential to plan for maximum attendance, and hence maximum body loss. Never assume that your network's performance at half stadium capacity will suffice for the big game – it won't. Play big, or don't play at all is the first rule.

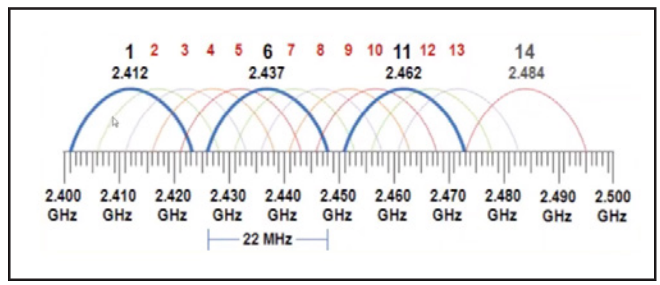


Empty Seats



With body loss

Generally speaking, overhead antennas provide excellent coverage – but because our single-level seating model is going to be above, or below others with separate antenna arrays, CCI is going to be a major problem. We're not going to address inter-level CCI in this eBook, but it will arise – thankfully iBwave Wi-Fi® will determine the problem areas and allow you to adjust AP placement, Tx, and other antenna parameters to reduce it to an absolute minimum. That's the solution. Now let's examine the problem that necessitated it in the first place.

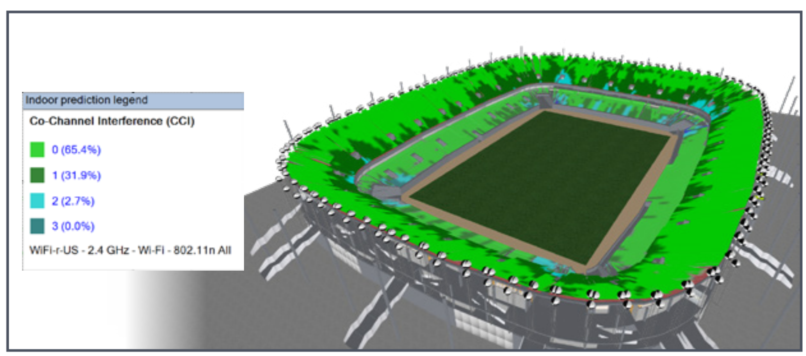


2.4GHz spectrum structure diagram

The 2.4GHz spectrum typically allows antennas in close proximity to each other allow for the use of 3 channels if CCI is to be avoided. The 2.4GHz structure shows us why:

Which means antennas using this spectrum require careful placement – but even with the most meticulous planning CCI areas will crop up. Fortunately, proper planning and deployment in our virtual scenario has limited the effects of CCI to acceptable levels. However, without the right tool, this map might have presented a very different face.

With 19 channels to choose from, CCI in the 5GHz spectrum is not an issue even when it comes to the dense AP environment in our hypothetical stadium design.



Stadium single-level seating area model (with 2.4GHz CCI data)

RF signal attenuation is not as serious a consideration with overhead antennas as most of the Tx occurs above body and connected device prediction height. However, it should still be modeled and examined as stadium inclines, and particularities in their architectural design could bring body loss into play once again.

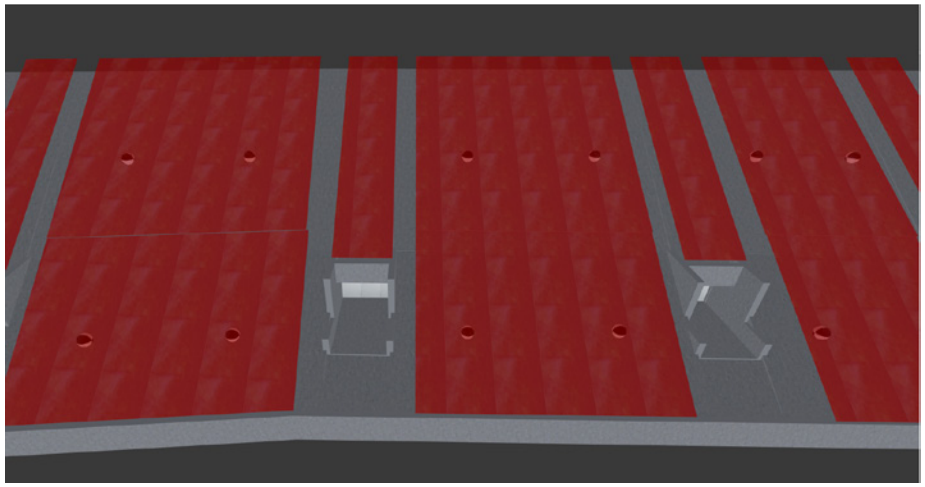
Our 3D model required the installation of 108 APs covering a combined average of 97.8% of the desired target area. It is a viable option for this stadium design.

But we're not done… two other antenna options remain.

Scenario 2 – Under-seat Antennas

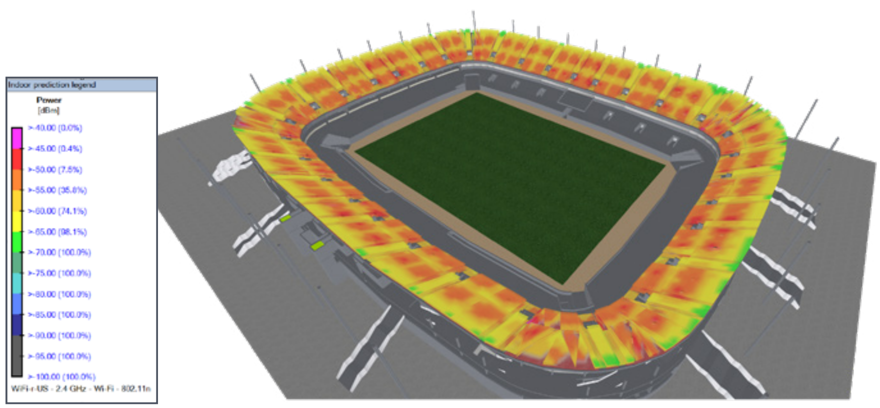
Under-seat antennas have a limited range when compared with their overhead cousins, but because for our purposes they usually function omnidirectionally we obtain a better coverage containment, and so a lower potential for CCI, except of course, in the 2.4GHz range where it remains a fact of life in almost any scenario but particularly so because of the under-seat antennas limited coverage.

Here we've placed 4 under-seat antennas in each seating section. Ironically this sets up the conditions for significant CCI as we have only 3 practical channels to choose from, so our interference map is going to be more active than in the case of overhead antennas.

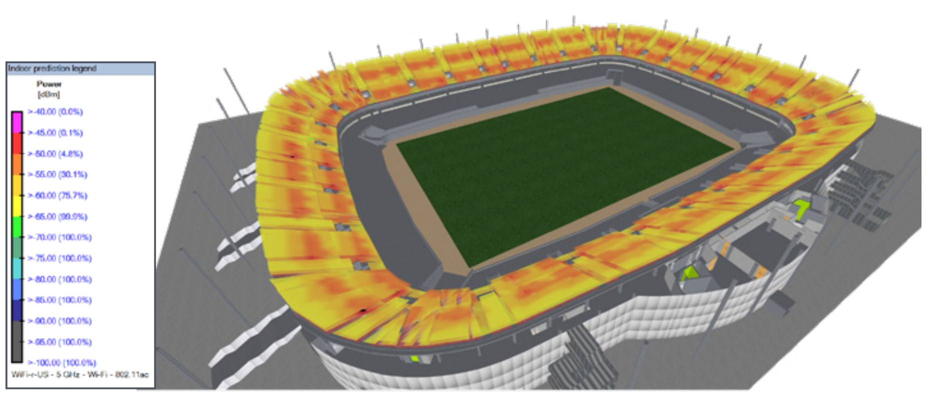


3D stadium single-level seating area model with under-seat antenna APs

Coverage in the 2.4GHz spectrum is excellent at 99.1%, but as expected, signal strength tends to drop off with distance as Tx levels need to be constrained in order to avoid incurring a significant CCI penalty. The 5GHz antenna exhibits a very slightly lower 98/1% coverage but manages to achieve higher Tx levels thanks to that spectrum's 19 available channels and negligible CCI risk.

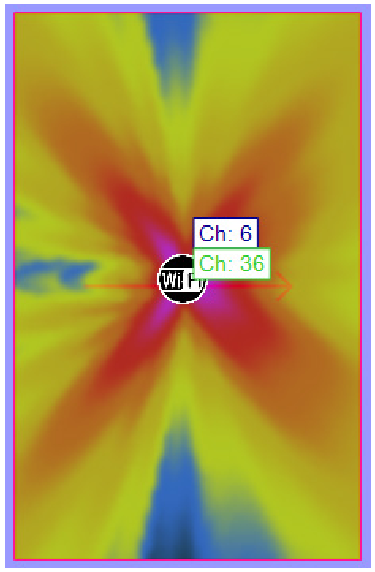


Stadium single-level seating area model with 2.4GHz coverage data (under-seat antennas)

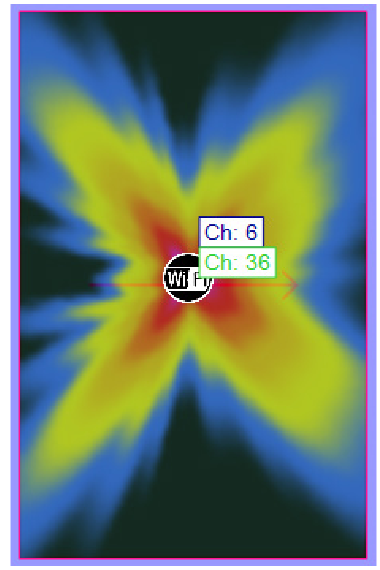


Stadium single-level seating area model with 5GHz coverage data (under-seat antennas)

Under-seat APs' chief handicap is the marked impact of body loss RF signal attenuation. Mounted closely beneath throngs of spectators, their omnidirectional transmission must begin its journey to client devices by first traveling through this challenging attenuation medium. The resulting body loss maps dramatically illustrate this shortcoming.

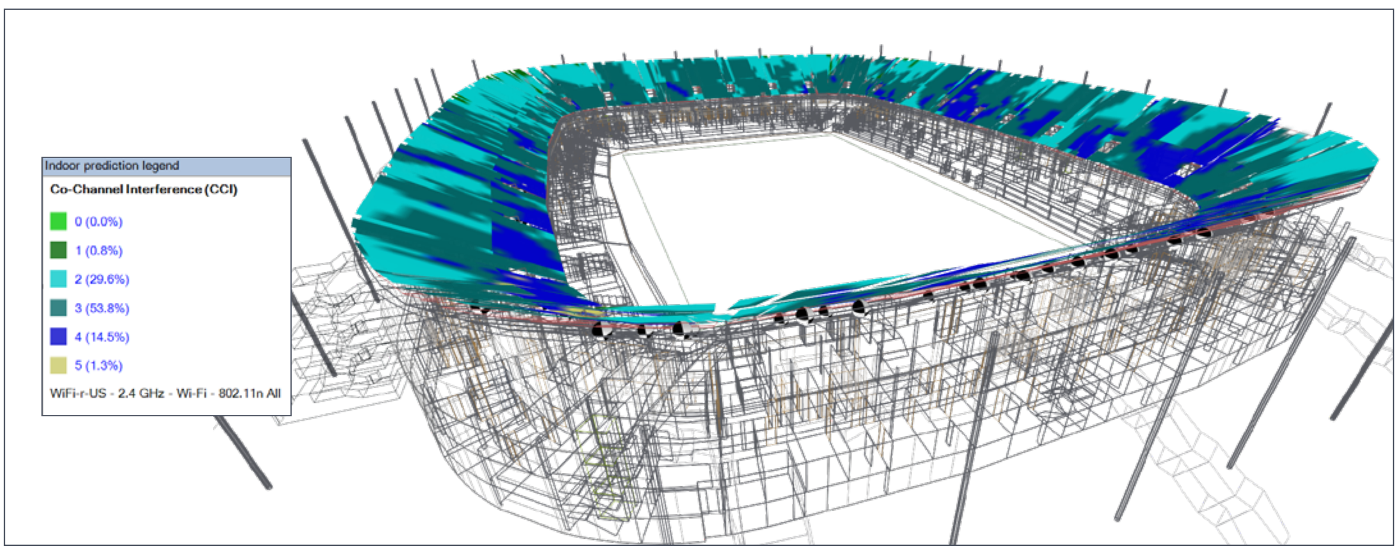


Empty Seats



With body loss

This in no way excludes them from the running, in fact, even taking body loss into consideration the 2.4GHz coverage map still shows acceptable power levels at full stadium capacity and paired with the superior Tx levels and overage in the 5GHz spectrum under-seat APs begin to reveal their potential.



Stadium single-level seating area model with 2.4GHz CCI data

The associated CCI prediction in the 2.4GHz range is higher than for overhead antennas, but because they are transmitting upwards the likelihood of their RF signal contaminating lower seating levels is almost nil. Again, with only 3 channels free for use in this spectrum, CCI will continue to be an issue, nonetheless a manageable one.

Emphasis must remain on planning for full coverage at full attendance with the least possible associated CCI. Careful planning, and tools like iBwave Wi-Fi® make that possible, and cut back dramatically on required manpower hours.

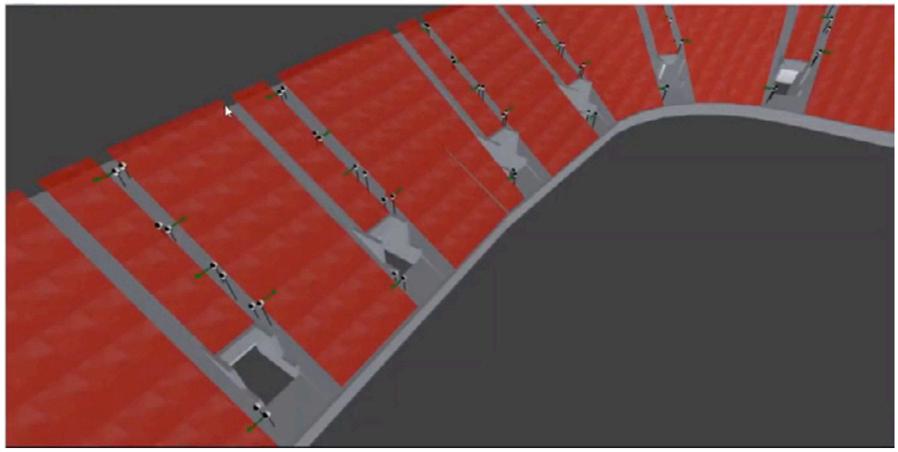
In the end it comes down to do choosing the right balance between sufficient Tx levels and the potential for CCI.

Our virtual stadium required 128 dual-band APs in the under-seat configuration covering a combined average of 99% of the desired target area making it a strong candidate for this particular scenario.

Scenario 3 – Handrail Antennas

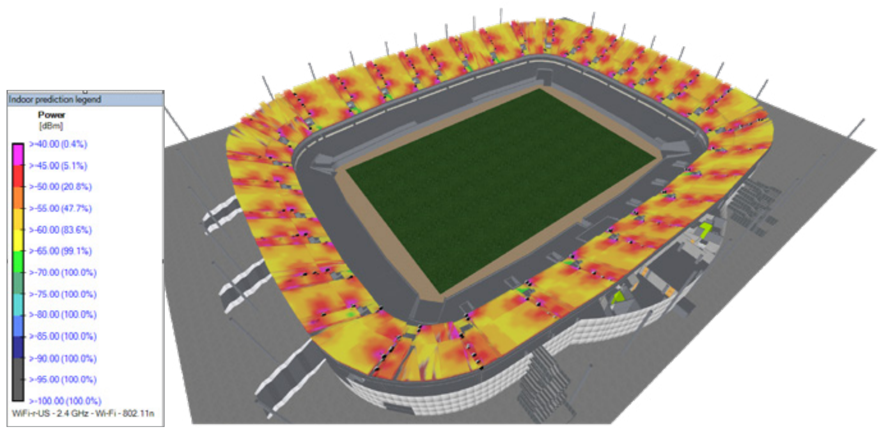
Another suitable approach for setting up an arena Wi-Fi network is the use of handrail antennas. Like the overhead variety they are directional but require the presence of handrails for installation – fortunately this is almost always the default in the stadium environment.

Providing complete coverage necessitates the placement of APs along the handrails that line the stairways that ascend either side of and transmit across each seating section.

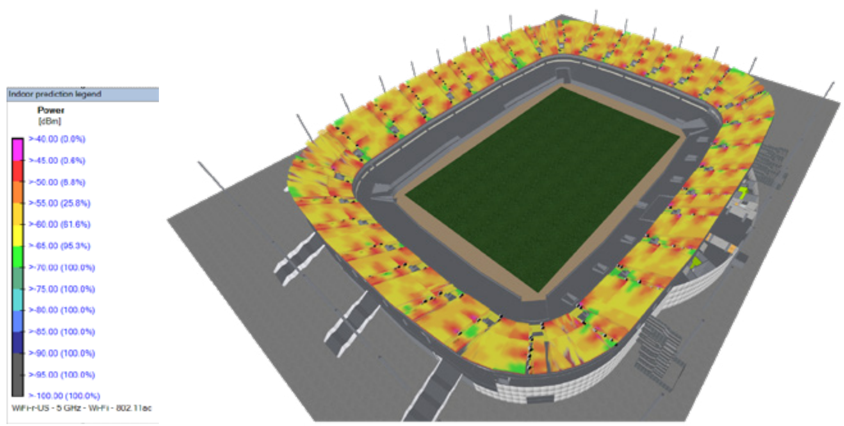


View of stadium single-level seating area model (handrail antennas)

Coverage using in the 2.4GHz spectrum the handrail model is the lowest among the 3 antenna types managing only 95.3% with the most serious signal dropouts occurring at spectator entry points which fortunately are rarely where connected devices and their users lurk looking to stream video or upload their favorite pics of the game. Contrarily the 5GHz spectrum exhibits its best showing at 99.1% with corresponding spectator entry point dropouts but with a considerably smaller footprint.

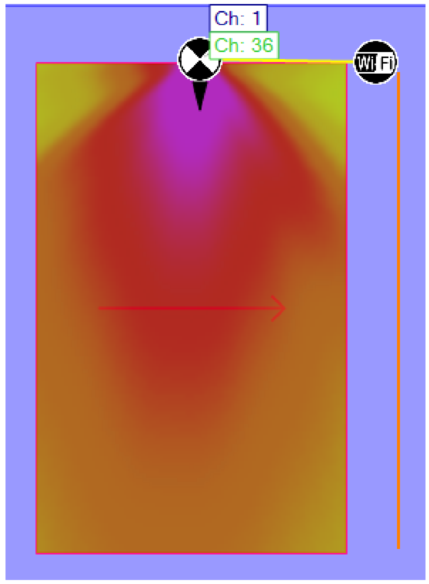


Stadium single-level seating area model with 2.4GHz coverage data (handrail antennas)

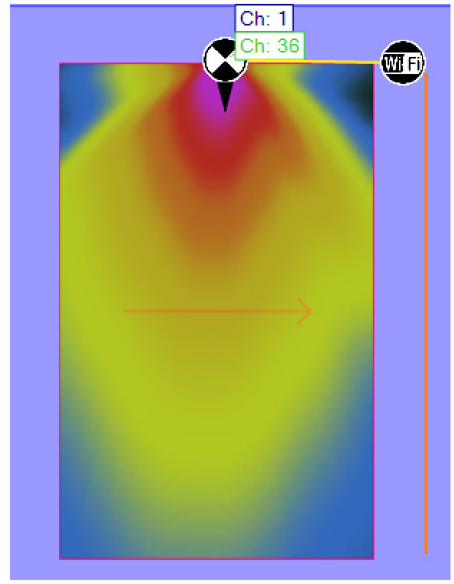


Stadium single-level seating area model with 5GHz coverage data (handrail antennas)

Similar to that seen using under-seat antennas, the handrail model also falls victim to serious body loss RF signal attenuation – and like their under-seat counterpart transmit almost entirely through masses of spectators, leading to a very rapid drop-off of signal. Plan for an average device prediction height of 1.5m, with an average body loss height of 1.85m. No, not everyone is that tall, but to ensure proper coverage assume that your virtual spectators will jump and cheer frequently – so even those under 6ft will occasionally reach the predicted 1.85m body loss height.

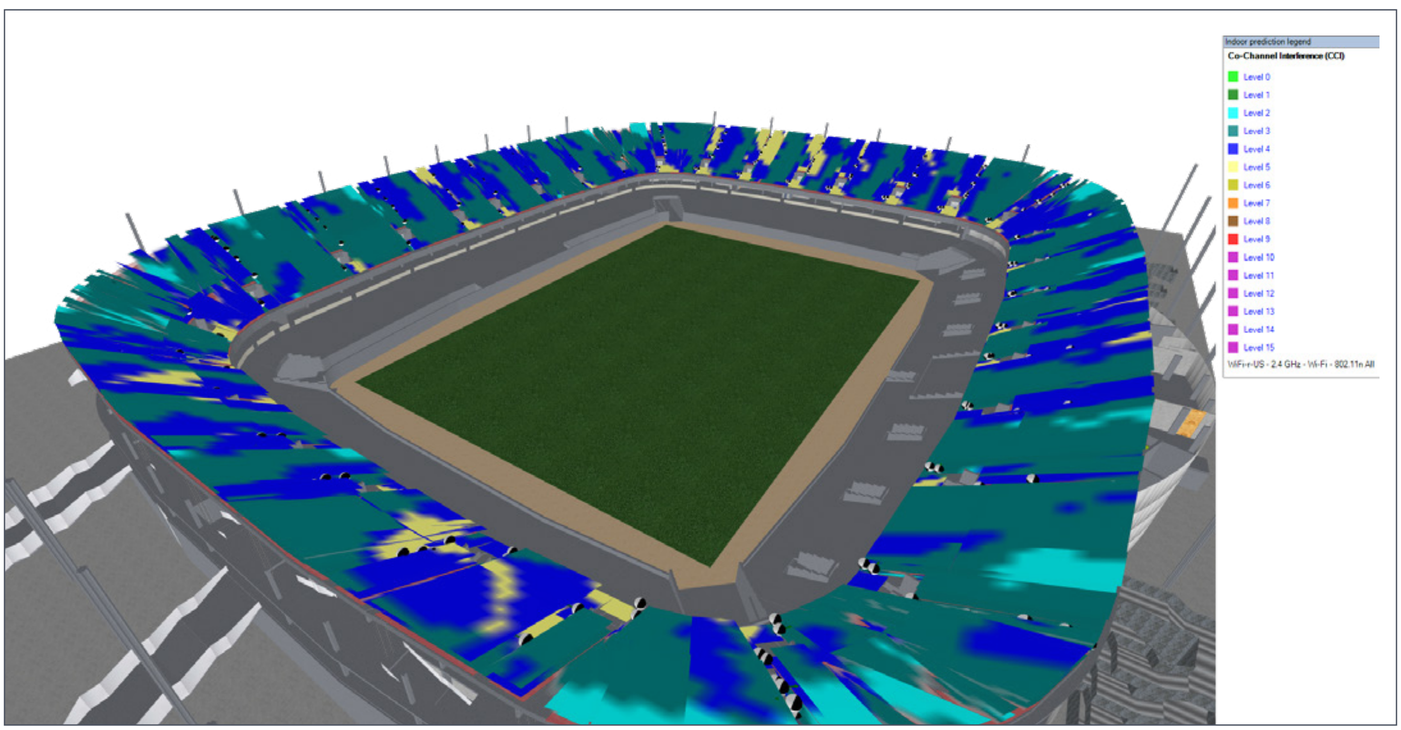


Empty Seats



With body loss

The handrail model CCI prediction map shows the highest CCI count for handrail antennas. Directional antennas that essentially point towards each other will invariably be the source of CCI – it's the nature of the beast. But, also in keeping with the CCI prediction map for under-seat antennas, the severity is limited by the high body loss RF signal attenuation and mitigated by the absence of interference in the 5GHz spectrum and the increasing prevalence of connected devices that use it by default.



Stadium single-level seating area model with 2.4GHz CCI data

Viability of the handrail model for our virtual sports venue is the least impressive of the 3 types. 159 handrail APs were required to properly cover one seating level area and while coverage in the 5GHz range was superior to the others, the cost of installing so many APs puts it out of the running for our chosen scenario.

Summary

No two stadium Wi-Fi environments are the same. Architecture and final spectator capacity will be the deciding factors in any 3D model predicting the efficacy of a given AP type. Unless cost or other specifications demand that overhead, under-seat, or handrail are prerequisites, then all 3 should be applied using iBwave Wi-Fi®.

An important note to those who might think that combining two or more AP types might solve coverage holes. And that note is, yes, but no. Given enough APs and combining types will almost certainly result in 100% transmission coverage… but the resulting CCI prediction map will be nightmarish – sure, everyone will get a signal, but network performance is going to fall well below minimum expectations.

Thanks…

Now that wasn't so hard, was it? However, we're the first to admit that covering a topic as complex as designing a full-coverage, cross-channel-free, seamless, flawless Wi-Fi network in an environment as unique as a stadium is no mean feat and requires software that is in continuous evolution. That's the core idea behind iBwave Wi-Fi®. This is software that is designed to always stay a step ahead of the latest wireless technology and its application to architecture, building ergonomics, and associated commercial applications. And it does.

But it helps to begin your journey pointed in the right direction, and Stadium Wi-Fi Network Best Practices places into context many of those things you'll need to know before you begin planning any large-scale sports venue Wi-Fi network – most importantly before the first concrete is poured beneath the first level of spectator seating. What can go wrong, what's known, what's unknown, what's unknowable, and proposes the best ways to address these, and the countless other issues sure to be encountered during the planning, design, and deployment of a network.

We're here to make life, and Wi-Fi network design a little easier. Thanks for taking the time to read Stadium Wi-Fi Network Best Practices, and here's to seamless Wi-Fi network operation that scores one on body loss RF signal attenuation, defeats CCI and provides gold-medal coverage. We're iBwave, and we design exceptional software, but we're not experts at sports analogies…

ADDENDUM: Handy Tear-Off Planning Checklist

1) What kind of anticipated services are expected to rely on the Wi-Fi network? These can include voice over Wi-Fi, email, internet access, and ticketing, among others. In the case of an existing stadium, what services are currently in use?

- Voice Over Wi-Fi? ☐ ____________________
- Email? ☐ ____________________
- Internet? ☐ ____________________
- Work Orders? ☐ ____________________
- Others? (List beside) ☐ ____________________

2) What types of applications are currently being used for voice, video and data?

- Voice ☐ ____________________
- Video ☐ ____________________
- Data ☐ ____________________

3) What types of equipment already exist in the case of an existing sports venue, and does the client have a preferred vendor?

A Equipment type & model: ____________________
Vendor: ____________________
Specifications: ____________________

B Equipment type & model: ____________________
Vendor: ____________________
Specifications: ____________________

C Equipment type & model: ____________________
Vendor: ____________________
Specifications: ____________________

D Equipment type & model: ____________________
Vendor: ____________________
Specifications: ____________________

E Equipment type & model: ____________________
Vendor: ____________________
Specifications: ____________________

Others ______________________________

4) Other than spectator seating and concession areas, are there high-density areas within the sports venue that need to be considered? (e.g.; admissions & ticket sales, access points from external parking, etc.)

Location & Description of High-Density Areas:

5) Is the stadium located in a high-density urban area adjacent to other buildings which may create Wi-Fi bleed?

Location & Description of Other High-Density Areas:

☐ Current / ☐ Projected ______________________________

☐ Current / ☐ Projected ______________________________

☐ Current / ☐ Projected ______________________________

☐ Current / ☐ Projected ______________________________

☐ Current / ☐ Projected ______________________________

6) In the case of an existing sports venue, how many active Wi-Fi devices currently exist in all zones across the network?

Offices ______________________________

Product Plant/Factory ______________________________

Distribution Center ______________________________

Outside ______________________________

Other ______________________________

7) What are the peak on/off hours in areas other than the spectator seating, do these differ during events.?
(i.e.; are they uniformly staffed and operational 24/24 & 7/7, or does each have a unique peak hour profile?)

Back Offices ____________________

Security & Maintenance ____________________

Retail Locations Open During Non-Event Hours ____________________

8) What is the total number of active devices that you expect the network will need to handle at launch and can expect to handle in the future.

Current Device Capacity ____________________

Projected Device Capacity ____________________

9) Other than the current planned or existing spectator seating levels, are there any current or projected higher-density areas? (e.g.; stadium expansion, addition of new playing fields and seating areas, new concession zones or parking.)

Location & Description of High-Density Areas:

☐ Current / ☐ Projected ____________________

☐ Current / ☐ Projected ____________________

☐ Current / ☐ Projected ____________________

☐ Current / ☐ Projected ____________________

☐ Current / ☐ Projected ____________________

☐ Current / ☐ Projected ____________________

10) What are the current and future performance targets for the network as a whole, and subsequently for each network type?

____

____

____

____

____

11) What is the total surface area to be covered by the network, including interior and exterior, and multi-level structures?

____

Interior surface area coverage requirements: (list sites separately)

______________________________ _________ m2 / _________ ft2

______________________________ _________ m2 / _________ ft2

______________________________ _________ m2 / _________ ft2

______________________________ _________ m2 / _________ ft2

Total: _________ m2 / _________ ft2

Exterior surface area coverage requirements: (list sites separately)

______________________________ _________ m2 / _________ ft2

______________________________ _________ m2 / _________ ft2

______________________________ _________ m2 / _________ ft2

______________________________ _________ m2 / _________ ft2

Total: _________ m2 / _________ ft2

Total surface area coverage requirements (int./ext.) _________ m2 / _________ ft2

12) In the case of an existing sports venue is there an accurate digital or hardcopy floorplan available? Floorplans can be imported into the iBwave Wi-Fi® Design tool to perform crucial predictive RF planning.

☐ Yes ☐ No

Floor plan file types:

____

____

____

____

____

____

13) Can you obtain a list of all incorporated building materials used in the facility? The quantity and location of windows, concrete walls, metal infrastructure, fire-rated doors, and elevators can affect RF signal propagation.

☐ Yes ☐ No

Original contractor and/or architect:

14) Are you subject to local regulations (FCC, CRTC) governing RF propagation, frequency limitations, maximum allowable transmission power and EIRP (Equivalent Isotropically Radiated Power) or other relevant limitations?

Applicable regulations:

15) Will existing backhaul cabling restrict network design including the optimal localization of APs along its backbone?

☐ Yes ☐ No

Description of potential design restrictions:

16) Do you anticipate the need for PoE and PoE+ (Power over Ethernet) capabilities?

☐ Yes ☐ No

17) Is it a requirement that your APs have a look & feel in harmony with the existing architectural design, fit, and finish.

☐ Yes ☐ No

Does the building owner/design approver prefer them to be out of the way and invisible?

☐ Yes ☐ No

Does your installation's propagation profile permit hidden APs?

☐ Yes ☐ No

18) Will exterior APs be required, and if so, will they need to be hardened with protection from the elements?

☐ Yes ☐ No

19) Will you install other security requirements such as captive portals?

☐ Yes ☐ No

Additional security requirement and/or measures:

____

____

____

____

20) Are you hoping to include a wireless intrusion detection and prevention system?

☐ Yes ☐ No

21) Do you intend to include provisions for the prevention of unlawful signal interception?

☐ Yes ☐ No

Unlawful signal deterrence options:

____

____

____

____

22) Are you planning to harden your network equipment and infrastructure against present and future vulnerabilities?

☐ Yes ☐ No

23) Will you recommend to your client the hiring of a Security Manager that understands their current and future security needs, compliance with security regulations and their integration into the network while staying abreast of rapidly changing network security technology?

☐ Yes ☐ No

24) What is the optimal segmentation of data and number of logical networks (SSIDs) your setup may need upon launch, and as the demand on the network grows.

Description of data & logical network segmentation:

Projected data & logical network segmentation:

25) Will your network require seamless roaming capacity? It's hard to envisage a large-capacity sports venue without one as they almost always require hundreds of APs which invariable imply seamless roaming.

☐ Yes ☐ No

26) Will your network require location-based services?

☐ Yes ☐ No

27) Have you determined the network's support requirements, including support for legacy devices? Will 24/7 monitoring be needed from on-site IT professionals, or outsourced to on-call service providers?

Description of network support requirements:

Description of legacy device support requirements:

Will 24-hour monitoring be required? ☐ Yes ☐ No ☐ On-site IT ☐ Outsourced IT

28) Will personnel be available to assist during the planning, design, deployment and validation of the new network?

Planning:	☐ Yes	☐ No
Design:	☐ Yes	☐ No
Deployment:	☐ Yes	☐ No

29) Is the network located in an area where intermittent power outages might require that it be equipped with a UPS backup?

☐ Yes ☐ No

30) Which protocols will your network need to support?

☐ IPv4 ☐ IPv6

31) Have you planned for failover ability and redundancies to ensure seamless operation even at peak sports or music event times where the network is subject to higher stresses?

☐ Yes ☐ No

32) Can you consult with the current network, server, and storage administrators and personnel that have an intimate knowledge of the existing network infrastructure, potential extant issues and its compliance with ISA-95?

☐ Yes ☐ No

33) Do you have access to a site or facility manager who understands the current location's infrastructure and can advise on the placement of APs, power supply, and other equipment that may need to be installed?

☐ Yes ☐ No

34) Has a finance manager or CFO made sufficient allocation of funds available for the design, deployment and continued maintenance of a new Wi-Fi network?

☐ Yes ☐ No

35) Will a project manager be put in place to control & coordinate the successful implementation of the new stadium network?

☐ Yes ☐ No

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