White Paper

Cisco Connected Stadium Wi-Fi for Sports and Entertainment Venues

Introduction

The first Wi-Fi networks installed in sports and entertainment venues were designed to support core back-office services such as ticket scanners and mobile point-of-sale handheld devices. In many cases, separate Wi-Fi networks were deployed to support different applications, each with their own security and connectivity requirements. There was no need for public Wi-Fi access because few, if any, fans carried mobile devices with Wi-Fi capabilities. But the emergence of smartphones with their integrated Wi-Fi radios is rapidly changing how Wi-Fi is used in crowded areas such as sports and entertainment venues.

According to the latest Neilson reports, almost one in three mobile phones in the United States is a smartphone, and the percentage is growing. Smartphone subscribers have come to expect ubiquitous data service coverage in public and private areas, and they now anticipate coverage while at sports and entertainment venues. The vast majority of these smartphones support Wi-Fi, making Wi-Fi the preferred third-generation (3G) and fourth-generation (4G) offload option. Additionally, fans may bring their Wi-Fi-enabled iPods, iPads, or other handheld devices that are not counted in these smartphone penetration numbers (Figure 1).

Figure 1. Stadium Wi-Fi Applications

To meet the growing demands for data service, service providers are increasingly selecting Wi-Fi to provide cost-effective 3G and 4G offload and focusing their cellular resources on voice and text services. Wi-Fi networks have proven to be effective in handling typical Mobile Internet applications such as email, Google, and Facebook, which for sports fans often means uploading pictures of themselves at the game. And because venue patrons are often "sports fanatics," they also want access to sports-related mobile applications that include the latest scores and highlights from other games around the league.

Teams, stadium operators, and stadium vendors also see the availability of public-access Wi-Fi as an opportunity to improve the fan experience, better serve their customers, and pursue revenue growth opportunities with stadium-specific mobile applications that span food ordering to finding the closest bathroom to engaging interactively with fans through trivia contests and voting. These applications can deliver compelling in-venue video content, such as replays of the last big play or live streaming from a variety of unique camera angles that may only be available in the venue.

Although the emergence of smartphones is the catalyst for expanding Wi-Fi access in venues, there are many challenges in supporting critical back-office users and a potentially overwhelming number of fans eager for more and compelling content. For example, operating multiple (competing) Wi-Fi networks in the same area results in higher deployment costs and degraded network performance. Instead, the preferred approach is to provide a unified and converged Wi-Fi network capable of supporting all venue services, each with its own Wi-Fi security and performance requirements. It is equally important to protect critical back-office applications such as ticketing and point-of-sales (POS) applications from fan access. A variety of tools can be used to meet these challenges by separating, protecting, and prioritizing Wi-Fi traffic, including the advertisement [[?]] of different network IDs (SSIDs), the use of different security schemes, and segregating and prioritizing traffic network traffic using VLANs.

In addition there are physical challenges to providing adequate coverage and capacity in the venue "bowl." Standard Wi-Fi deployments cannot address these challenges. Careful placement of the access points, use of specific antennas, and unique radio frequency tuning are required.

Connected Stadium Wi-Fi

To address these challenges, Cisco® has designed the Connected Stadium Wi-Fi solution, which is a unique Wi-Fi network solution. The solution has been deployed in leading venues, including AT&T Park, Cowboys Stadium, and Consol Energy Center. This solution delivers high capacity and complete coverage throughout a stadium, and supports a mix of back-office and fan access applications. Connected Stadium Wi-Fi is built upon Cisco's Connected Stadium solution, a single-connectivity platform that supports innovation and growth in sports and entertainment venues. Cisco continues to introduce solution enhancements and innovative features for high-density environments that will enable new fan experiences and help service providers to satisfy their increasingly data-hungry subscribers, while helping teams and stadium operators to engage with their passionate and content-hungry fans.

The net effect for wireless service providers is twofold:

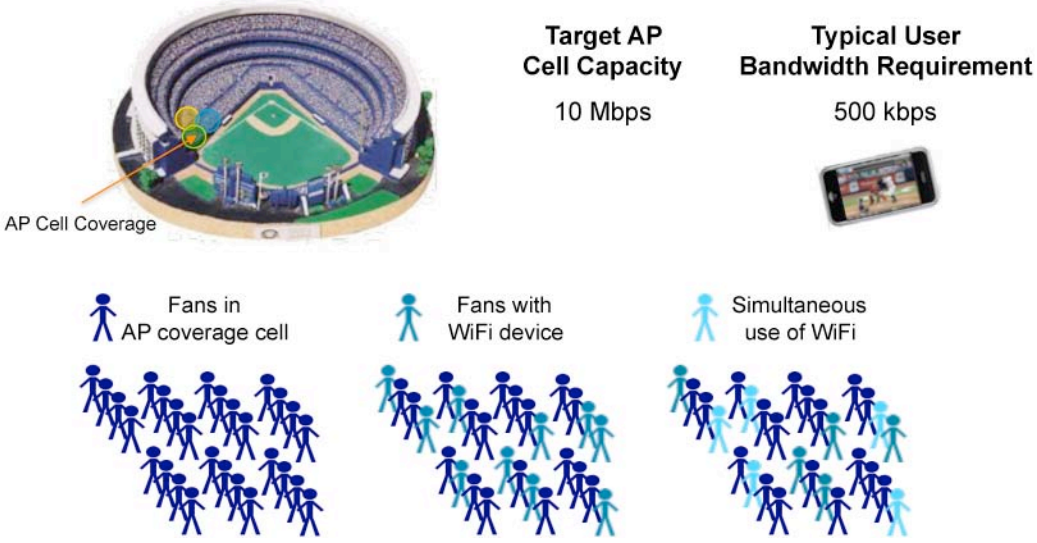
- Cellular customers' data applications work well over a high-capacity Wi-Fi network rather than work poorly over a congested 3G or 4G network in the crowded stadium.
- Because the 3G or 4G network is no longer burdened with bandwidth-intensive data applications, voice calls and texting work again, eliminating the complaints often heard when fans try to use mobile phones in this type of harsh environment.

RF Planning for Capacity

With stadium Wi-Fi designs, it is significantly more challenging to provide ubiquitous coverage and high capacity throughout the venue than with typical enterprise or 3G offload sites (for example, coffee shops and bookstores) because of the total number of Wi-Fi-enabled devices to be supported in stadiums and the high density of these devices in a relatively small area. Large outdoor venues can approach 100,000 fans at capacity, and even indoor venues such as arenas can accommodate 20,000 or more fans. Providing Wi-Fi coverage throughout the venue can be challenging, but the greater challenge is to achieve reliable and high-speed network capacity throughout the venue. Capacity planning starts with accommodating Wi-Fi busy periods (for example, TV timeouts and intermissions) so that fans and other Wi-Fi network users rarely experience poor or unacceptable network access conditions.

The first step in capacity planning is determining the desired coverage per access point (AP). Assume for network planning purposes that the goal is to offer each fan a network throughput of 500 kbps, which is enough for comfortable web surfing or for viewing video formatted for mobile devices. Because many smartphones currently only support the 802.11g standard, the maximum over-the-air data rate is 54 Mbps and the throughput, when supporting only a single device, could exceed 20 Mbps. A stadium design must support many users per access point, multiple networks, devices that must operate at lower data rates, and a mix of upstream and downstream traffic, leading to a less aggressive real-world capacity target per access point on the order of 10 Mbps (Figure 2).

Figure 2. Planning for Stadium Capacity



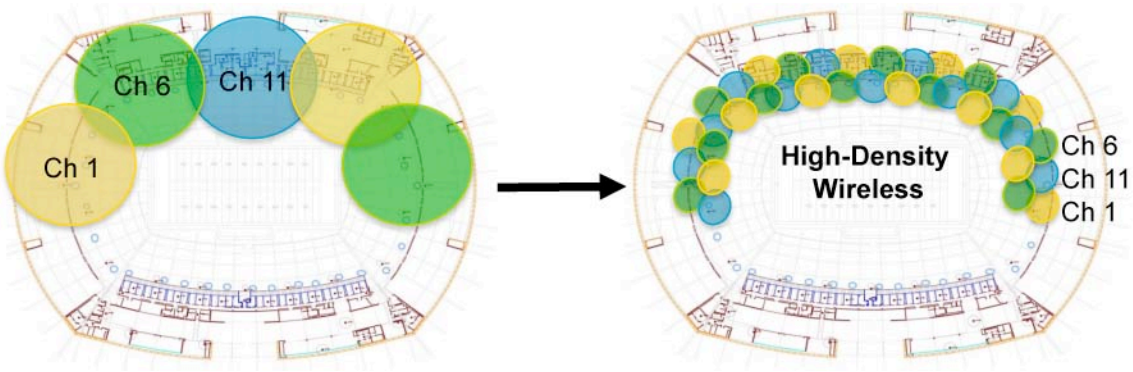
Consider for example, a venue that seats 50,000 fans. Assuming 25 percent of the fans have Wi-Fi-enabled handheld devices, up to 12,500 fans will be able to access the Wi-Fi network. Assuming further that during Wi-Fi busy periods, 25 percent of the fans with Wi-Fi-enabled devices access the network, the access point coverage should be limited to roughly 320 fans: (320 fans) x (25% with Wi-Fi) x (25% active Wi-Fi) x (500 kbps per fan) = 10 Mbps. Limiting an access point's coverage to 320 seats or 320 fans in high-density concourse areas translates to designing coverage cells that are tens of feet in diameter.

Continuing with the 50,000-seat venue example, a minimum of 156 access points would be needed to provide sufficient capacity and coverage throughout the bowl area. More access points would be recommended to accommodate the inevitable growth in the number of Wi-Fi-enabled devices at the venue. Additional access points would of course also be needed for other venue areas (for example, concourse, suites, back office, and parking lots) such that the total number of access points for the 50,000-seat venue would be about 400. By designing for coverage and capacity that meet challenging access requirements throughout the stadium, service providers, teams, and stadium operators can satisfy subscriber needs, complement the fan experience, and enable new revenue opportunities.

Antennas and Managing Co-channel Interference

The Cisco Connected Stadium Wi-Fi solution includes special-purpose antennas that are critical to supporting small-coverage cells and high capacity throughout the venue's crowded areas. Deploying hundreds of access points at a venue with all access point cells designed to simultaneously achieve high capacity can be a daunting task. The limiting factor in a design of this density is typically co-channel interference. With only three non-overlapping Wi-Fi channels at 2.4 GHz, frequency reuse is high and as the example above shows, cells using the same channel can be within 100 feet of each other. Enabling high capacity for all cells requires minimizing the propagation of RFs outside each cell's intended coverage area. The combination of low transmit power and highly directional antennas is effective in containing an access point's transmitted RF energy to the cell it covers, severely limiting the RF energy that the access point receives from devices outside of its cell. This strategy supports a greater number of smaller high-capacity cells than is otherwise possible (Figure 3).

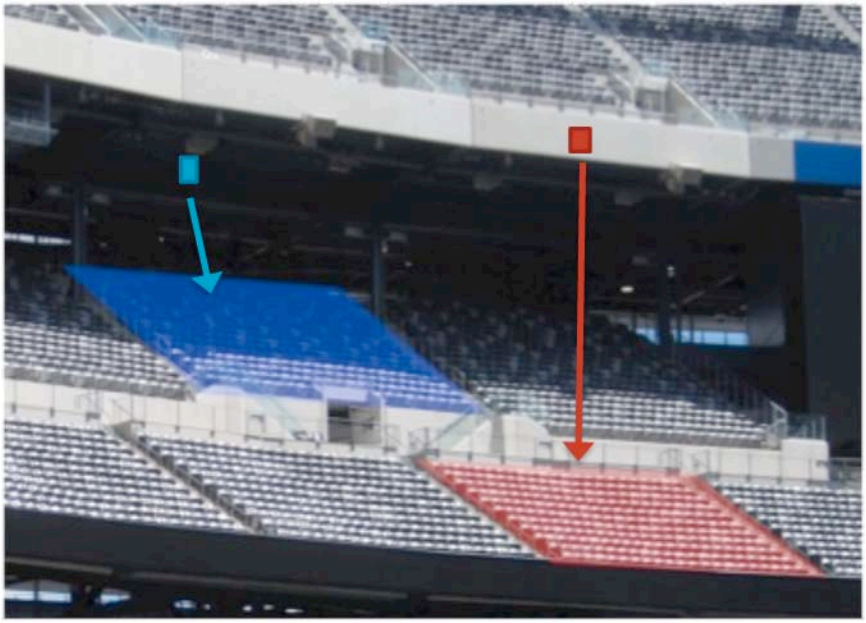
Figure 3. Connected Stadium Wi-Fi Deployment



A critical component in containing RF energy to the access point's intended coverage cell is proper antenna mounting, which is often constrained by limited mounting resources and the absolute requirement that the antennas not obstruct fans' views. Mounts must also be secure enough to handle wind conditions at outdoor venues and other outdoor coverage areas such as parking lots. In addition, venues have aesthetic guidelines that must be maintained – an unsightly antenna that could detract from the appearance of the venue will not be tolerated.

Cisco has designed a new dual-band, high-gain multiple-input multiple-output (MIMO) antenna, the Cisco 25137NP Antenna, specifically to address the tight beamwidth, constrained mounting, and aesthetic requirements needed for high-density venue seating areas (Figure 4).

Figure 4. Cisco 25137NP Antenna Deployment



The Cisco 25137NP Antenna's (Figure 5) beamwidth at 2.4 GHz is an impressive 36 degrees. The beamwidth at 5GHz is larger but more than adequate to support high access point capacity, given the increased number of available channels at 5GHz. (More channels reduce frequency reuse and the resulting co-channel interference.) The 2.4 GHz antenna also includes dual-polarization elements to support handheld devices in different orientations, which is typically required for watching video, as well as for diverse multipath conditions. The mounting system is flexible and weather resistant, and the entire antenna structure can be painted venue colors to match the surrounding area.

Figure 5. Cisco 25137NP Antenna

Radio Resource Management

The Cisco Connected Stadium Wi-Fi solution includes an advanced radio resource management (RRM) system that optimizes overall network performance while simplifying network configuration and manageability. Because it is not practical to individually channelize and tune hundreds of access points at a venue, it is critical that the Wi-Fi system include some form of automated RRM to determine the channel and output power for each access point. RRM can also ensure continuous Wi-Fi coverage throughout the venue by detecting and responding to “coverage holes” to eliminate areas that may not be providing adequate coverage.

The propagation conditions in an empty venue can vary significantly from conditions in a full one. To provide optimal capacity and coverage throughout the venue, the RRM system must be capable of adapting the access point transmit power level and channel selection with the changing RF environment. The RRM system must also accommodate tuning individual access points and their radio resource parameters to optimize overall coverage and capacity. Cisco’s industry-leading RRM system helps to ensure that optimal Wi-Fi network performance is efficiently achieved and maintained as the venue transitions from empty to filled.

Advanced RRM Features

Cisco’s Connected Stadium Wi-Fi solution includes advanced RRM features that support venue-specific deployment challenges such as dissimilar antenna mounting structures throughout the venue. Advanced RRM features allow all access points to share some configuration parameters, while keeping other configuration parameters to within an access point group.

In addition to RRM tuning, higher overall network performance may be achieved by tuning the underlying thresholds of the Wi-Fi Clear Channel Assessment (CCA) mechanism. Wi-Fi is a polite protocol, and is normally tuned to defer transmission when another signal is detected. But higher overall throughput can be achieved by tuning the CCA threshold, the power level at which access points defer transmission, and allowing access points to transmit in the presence of weak transmissions received from another access point that may be several cells away.

Through the use of careful RF design with highly directional antennas, Cisco’s Connected Stadium Wi-Fi solution has demonstrated that very high capacity can be achieved throughout a venue. For example, during a recent sporting event, more than 6,000 devices were able to simultaneously access the Wi-Fi network.

Wi-Fi Network Management and Control

Careful RF design alone may not be sufficient if other devices operating on different Wi-Fi networks compromise capacity. For example, some participants such as vendors, press, and sponsors may attempt to set up their own Wi-Fi networks during the game. Transmissions from these “rogue networks” can reduce the capacity available for the primary, converged Wi-Fi network. It is important, then, that the Wi-Fi infrastructure has the capability to detect rogue access points. Wi-Fi personal area networks (PAN) represent another class of networks and devices that can reduce the primary Wi-Fi network capacity, including the following.

- Temporary networks enable two or more Wi-Fi devices to communicate without requiring an access point.
- Wi-Fi direct allows Wi-Fi-enabled consumer electronics devices such as cameras and phones to transfer files.
- Personal hotspots allow 3G phones to create miniature Wi-Fi hotspots to connect with other nearby devices, such as laptops, tablets, or MP3 players.

The effect of these personal area networks is constrained, largely because the transmit power tends to be lower and there are relatively few applications that motivate their use, but a large number of PANs could have a meaningful impact on the overall Wi-Fi capacity. One positive side effect of having a properly designed Wi-Fi network is that there tends to be fewer PAN networks, because network users will generally join the available public network rather than trying to create their own.

Wi-Fi capacity can also be reduced by other non-Wi-Fi transmissions in the same band, such as those caused by cordless phones, Bluetooth devices, wireless video cameras, and microwave ovens. To help Wi-Fi administrators to manage their Wi-Fi networks, it is important that the Wi-Fi infrastructure be capable of identifying the source of interference and assessing its level of impact on Wi-Fi network performance. The Cisco CleanAir Technology scans, classifies, and locates interfering devices, allowing network administrators to take appropriate action to remove or replace devices that affect Wi-Fi network capacity. In addition, Cisco CleanAir Technology can take action to reduce the impact of interference through automated interference mitigation technologies, including persistent device avoidance and event-driven RRM, which updates an access point's transmit channel and power level.

In addition to monitoring for Wi-Fi and non-Wi-Fi interference, the Connected Stadium Wi-Fi solution provides a comprehensive suite of Wi-Fi performance monitoring tools, including the total number of devices, data rates per device, and cumulative throughput. The available statistics can identify trends and help ensure that the network is operating at levels that meet customer expectations.

The Future: Video Distribution to Mobile Devices

Sports teams and venue operators are aggressively pursuing technologies and solutions that increase the fan experience at venues and induce fans to attend sporting events. For example, Cisco StadiumVision® has been deployed over the past two years at a number of venues to enhance the fan experience. Cisco StadiumVision distributes high-definition video and digital signage to flat-panel TVs mounted throughout the concourse, suite, club, and concession areas. The video streams can include replays and highlights, views from multiple camera angles, and games played elsewhere.

There is a strong and growing demand from venue owners and fans to extend the enhanced video streaming experience to fans' mobile devices, from the parking lot through the concourse to the bowl. But live video streaming in a live sports environment has three fundamental challenges.

- The video quality must be excellent.
- The video displayed on the mobile device must be delayed less than 1 second from the real-time action.
- The video stream must be available to all fans without exhausting the Wi-Fi network capacity.

Conventional video streaming is accomplished using unicast techniques, in which a video stream is sent to each mobile device requesting the stream. The quality can be excellent as long as there is sufficient bandwidth available. But there are two fundamental challenges with unicast streaming. First, video streams are typically delayed by 20 to 30 seconds from real time, which limits their appeal when fans can also see or hear the live event. The second and larger challenge with unicast streaming is scalability. Delivering the same stream to many mobile devices is an efficient use of bandwidth, which is clearly limited by serving only a small fraction of the devices in the access point's coverage cell. The high delay and lack of scalability limit the use of unicast video streaming techniques to applications that are low-demand and do not stream in real time.

Techniques developed for mobile broadcast can be extended to Wi-Fi to support reliable and low-delay video streaming on a truly massive scale. Widely sought video streams can be delivered over the Wi-Fi network using a shared broadcast so that hundreds of devices on the same access point can access the same stream. As with other mobile broadcast techniques, a Wi-Fi-based solution must consider power save mode for extended battery life and provide operators with flexibility in configuring and delivering video streams.

Conclusion

The rapid penetration of smartphones is expanding the role of Wi-Fi in venues, from purely back-office networks to high-capacity, converged networks that can also support fan access. Wi-Fi fan access supports the service providers' goal of increasing 3G offload and supports teams' and venue operators' efforts to engage fans in unique and compelling ways. Cisco's Connected Stadium Wi-Fi solution is designed to provide full coverage and high capacity throughout venues, while simplifying Wi-Fi network manageability. Cisco's Advanced Services have successfully installed the Connected Stadium Wi-Fi solution at multiple venues. Along with Cisco's comprehensive portfolio of new features and products that further expand network capacity, performance, and manageability, the Connected Stadium Wi-Fi solution leads the industry in providing Wi-Fi access at crowded sports and entertainment venues.

For More Information

For more information about the Cisco Connected Stadium Wi-Fi solution and the benefits it provides, please visit http://www.cisco.com/web/strategy/sports/ or contact your local account representative.

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