



## Module 3. Stadium & facilities technology operations



The purpose of this module is to explore the concept of smart stadia and how technology is transforming the sport events and competitions fan experience within the sport stadia and arenas. Modern sports venues have evolved beyond their historical single-purpose existence, now serving as international destinations for rights holders and driving local government policy and social infrastructure development.

New expert institutions and stakeholders are activated. For example, ESSMA, the European Stadium and Safety Management Association, serves as a unifying force in the stadium industry, boasting more than 350 members representing various leagues and federations across Europe. ESSMA facilitates the creation of market-specific research and promotes knowledge sharing through networking events (ESSMA, n. d.). The new stadia incorporate new technologies like mobile and 5G to enhance the fan experience, reducing physical touchpoints by going ticketless and cashless, while also adopting environmentally friendly practices. Despite the preference of younger generations for short-form sports content, live events remain highly valuable in a fragmented rights market.

As stadia digitise infrastructure, they provide valuable data intelligence for rights holders to understand fan preferences and tailor in-game activations and e-commerce campaigns accordingly. Examples include the San Antonio Spurs' cashless ecosystem and Tottenham Hotspur's net-zero carbon matchday initiatives. The

development of stadium infrastructure aligns with sustainability goals, and private investments augment stadium revenues, while also supporting urban modernisation projects. Stadia are no longer just physical assets, but platforms for innovation and digital solutions that benefit communities. The use of virtual reality (VR) and augmented reality (AR) is also emerging in the industry, contributing to the digitalisation of stadium infrastructure and enhancing venue experiences.

 **The three layers of stadium technology**

 **Activities**

 **References**

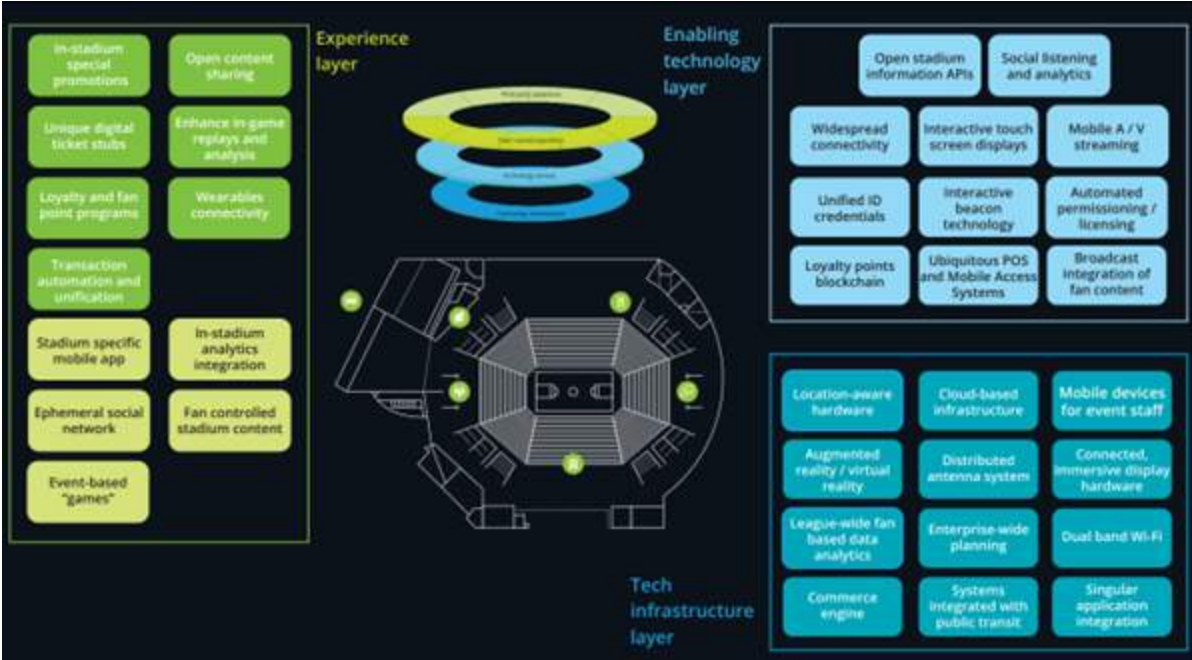
# The three layers of stadium technology

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## The three layers of stadium technology

Stadium technology is a comprehensive framework encompassing infrastructure, resources, and activities that collaborate to empower stadium operators and teams in creating novel experiences for all attendees, regardless of the event type. This multifaceted approach consists of three distinct layers, working in partnership to establish the concept of the stadium as a platform: 1) the technology infrastructure layer, composed of the physical hardware, networking equipment, and software responsible for powering the stadium or arena; 2) the enabling technology layer, which encompasses tools, protocols, and data provided by the team to fans, partners, and sponsors, enabling them to access the core infrastructure, and 3) the experience layer, which harmoniously blends experiences curated by the event organisers and third-party sources, all built upon this dynamic platform (Deloitte, 2016).

**Figure 1. The three layers of stadium technology**



Source: Deloitte, 2016, p. 7.

**The 'smart stadium' concept**

A smart stadium is an advanced sports facility that encompasses state-of-the-art technologies to enhance the fan or/and participants experience and

increase operational efficiency. They are characterised by strong connectivity for social media interaction and content access, data analysis for managing crowds, mobile applications for real-time updates and services, digital displays for information dissemination and interaction, augmented reality and virtual reality for immersive fan experiences, Internet of Things sensors for surveillance, sophisticated security systems, cashless transaction methods, energy-saving solutions, fan involvement via digital platforms, eco-friendly attributes, high-quality audiovisual setups, and intelligent seating (Mahdi et al., 2021).

Smart stadia need a combination of software and hardware components. These encompass sensors, cameras, and digital displays that link up to both wired and wireless networks. These systems are connected to servers that use cloud technology and the Internet of Things (IoT). Upgrading the infrastructure is crucial to establish the appropriate technological groundwork. This involves enhancing power capabilities, implementing high-definition vision boards, adopting LED lighting, establishing high-speed data networks, introducing LED perimeter ribbon boards, and setting up IPTV HD screen networks. The integration of rapid and secure mobile payment methods enables stadium operators to cater to a larger clientele within reduced timeframes.

Nevertheless, the fan experience encompasses interactions within the stadium, as well as the entire journey of attending an event, including preparation, travel, social media engagement, and activities within and around the stadium. Smart stadia have even become experimental hubs for

enhancing citizens' lives, as cities explore Smart City initiatives to improve efficiency and quality of life. This involves leveraging technology, policy changes, and innovative approaches in areas like transportation, safety, and sustainability. The concept of using a smart stadium as a 'living laboratory' is gaining traction, allowing for the testing and evaluation of Internet of Things technologies and Smart City solutions in a practical, yet scalable, environment (Mahdi et al., 2021; Panchanathan et al., 2016).

### **Infrastructure and connectivity**

Designing and maintaining robust Wi-Fi networks and cellular connectivity is a priority to ensure seamless data communication for fans, staff, and athletes. Strong cellular connectivity is essential to accommodate the large number of mobile devices in a stadium. Adequate mobile coverage ensures fans can make calls, send messages, and access data without disruptions, even during peak usage times (Brooksz, n. d.).

5G technology, which stands for fifth generation, is a cellular network technology. It is designed to provide high-speed, low-latency wireless internet access over a wide area, spanning cities and even entire regions. 5G

is meant for broader coverage and supporting a multitude of devices, including smartphones, IoT devices, and more.

Wi-Fi is primarily designed for local area network (LAN) connectivity within a relatively small area, such as homes, offices, cafés, or public spaces. It allows multiple devices like smartphones, laptops, and smart home gadgets to connect to the internet via a local router or access point. Wi-Fi is best suited for local, indoor wireless connectivity, while 5G is a cellular network technology designed for wide-area coverage with faster speeds and lower latency.

### **From 2G to 5G technology**

Over the past few decades, mobile networks have progressed through several generations. Starting with 2G in the early 1990s, which introduced digital radio signals and basic messaging, and evolving to 3G in the early 2000s, that brought web browsing and multimedia streaming capabilities. The introduction of 4G around 2010 marked a significant leap in speed and connectivity, enabling advanced streaming and improved app performance. The latest addition, 5G, emerged in the late 2010s and is still being rolled out globally. Operating on high-frequency radio waves, 5G offers dramatically

increased bandwidth and speed compared to 4G, revolutionising connectivity possibilities (Brooksz, n. d.).

### **Importance of 5G for sport event managers**

Consumers should place their focus on 5G, not solely for its current capabilities, but for the transformative potential it holds for the future. Just over a decade ago, the average mobile user used about 200MB of data monthly, a figure that now approximates daily consumption. As our demand for data continues to surge and novel applications emerge, we must be equipped to address these escalating data requirements. 5G emerges as the optimal mobile technology to support modern needs like live-streaming and online gaming, both of which have gained substantial popularity. Moreover, 5G contributes to the development of more sustainable mobile networks and plays a pivotal role in bridging the digital divide, connecting more individuals, and fostering economic advancement (Newton, 2023).

### **6G technology to come**

The natural progression of telecommunications technology is leading to the forthcoming emergence of 6G. The anticipated commercial deployment of 6G is projected around 2030, with technical specifications expected to conclude by 2028. Like the coexistence of 4G and 5G, these two generations will operate concurrently. While 5G Phase 2 SA introduced a shift toward cloud-native architecture, 6G is focused on enhancing performance, throughput, and convergence. 6G technology stands to revolutionise wireless communication with notable advancements. It promises higher data rates than 5G, enabling data-intensive applications such as ultra-high-definition video streaming and real-time holographic communication. The standout feature is ultra-low latency in microseconds, facilitating real-time applications like remote surgery, autonomous vehicles, and immersive experiences (Wooden, 2023).

## **Wi-Fi technology**

Stadia deploy robust Wi-Fi networks to provide spectators with high-speed internet access. Organisers can leverage Wi-Fi for ticketing, crowd management, and instant communication. Wi-Fi networks are not all the same. In particular, the two most important parameters are speed and coverage. Furthermore, security is another important variant. The kinds of security protocols used by different installations may vary in the degree of protection they offer. One must always balance accessibility vs. security (Cisco, n. d.).

Delivering effective internet access in places like stadia and arenas necessitates Wi-Fi capable of handling multiple users simultaneously. Historically, this has been a challenge for Wi-Fi until Wi-Fi 6 arrived in 2019. Wi-Fi 6 brought significant enhancements in network capacity alongside incremental speed and security improvements. While Wi-Fi 6 is notably faster than its predecessor, boasting a theoretical download speed of 9.6 Gbps (almost three times Wi-Fi 5's speed), its true strength lies in accommodating many users at once, particularly in large venues. Wi-Fi 6 advances data security by introducing the WPA3 certification, incorporating 256-bit AES encryption for user data protection. In contrast, earlier Wi-Fi technologies relied on the WPA2 security, which possesses vulnerabilities due to its long-standing use since 2004. More people are accessing Wi-Fi at sport events, engaging in diverse activities while connected. Expectations for reliable, secure, and fast Wi-Fi access are increasing among sports fans and sport event attendees. Key data uses include social media interaction, messaging, and accessing sports apps for real-time updates and scores (Cisco, n. d.).

## Venue security

### **Crowd management, security, and surveillance technology**

High-quality connectivity supports security measures such as facial recognition, CCTV monitoring, and crowd analytics. This enhances safety by enabling efficient threat detection and emergency response. CCTV images these days can come in many different types, like, for example, full colour (daytime) images, but more recently full colour nighttime images as well. In addition, facilities may use infrared or thermal cameras for additional security. These systems produce vast amounts of data that may need to be transferred to remote sites for processing and storage.

The network traffic (either mobile, landline or internet based) can be significant. Often, such systems will rely on dedicated channels of communication, sometimes directly connected to fibre optic lines installed at the facility itself by the Internet Service Provider (ISP). In addition to the

amount of information being recorded, other contributing factors include the resolution at which images (and audio) are being recorded. The higher the resolution, the higher the load on the network. For these reasons, security camera networks are usually on separate networks to the ones provided for fan use or other operations (Walker-Miller, 2018).

### **Biometric identification and facial recognition**

Although sport events transitioned to digital tickets, the process still presented some inconvenience, as attendees had to retrieve their phones and scan them. Consequently, a shift towards facial recognition emerged, in which the technology captures and identifies your face, facilitating seamless entry into the stadium.

Biometrics is increasingly applied to streamline traditional check-ins, particularly at sports event venues, in which time saving is the main attraction for ticket holders. The core concept involves using facial or fingerprint recognition to facilitate swift access, bypassing lengthy queues. However, there is a notable segment of people who may resist sharing personal biometric data due to privacy concerns and surveillance apprehensions. As a result, venues are likely to integrate biometrics with

conventional check-in methods like physical tickets, stickers, stamps, or wristbands, to account for various scenarios, such as guests leaving and returning or those who prefer not to use biometrics.

The secure management of biometric data is vital to prevent hacking and unauthorised access, necessitating a zero-knowledge security model with full encryption. Moreover, biometrics can enhance security by verifying identities and preventing impersonation. Its expansion is likely, given its ability to simplify crowd management and bolster safety measures in venues.

Many sport stadia and arenas, especially in the US, have begun or are planning to begin using biometrics and facial recognition technology such as Mercedes-Benz Stadium in Atlanta, FirstEnergy Stadium in Cleveland, Citi Field in New York City, Pechanga Arena in San Diego, Save Mart Center at California State University, Caesars Superdome in New Orleans, Toyota Arena in Ontario, California, Sun Devil Stadium at Arizona State University in Tempe, Hard Rock Stadium in Miami Gardens, Florida, BMO Stadium in Los Angeles (Gee, 2023). An interesting video about biometrics facial recognition can be seen here:

Source: **Hard Rock Stadium**. (9 February 2021). *Safer and Smarter* [video file].  
Twitter. <https://twitter.com/hardrockstadium/status/1359208574698860549?lang=en>.

## **AI-powered surveillance**

Security concerns encompass intrusion threats, violence, vandalism, adherence to pandemic guidelines (if any), and parking safety. To address these challenges effectively, sports venue security integrates manned guarding, access control systems, efficient surveillance infrastructure, and AI video analytics tools.

During the Covid-19 pandemic, for example, the rapid, accurate solution needed for crowd entry was facilitated by non-invasive AI-based thermal scanning solutions, detecting elevated skin temperatures and isolating individuals.

The deployment of powerful AI-based video surveillance systems can prevent tensions among supporters and security casualties. Real-time behaviour recognition and anomaly detection solutions analyse existing camera data to identify dangerous behavioural patterns, suspects, and threats, reporting them before escalation.

Smart parking solutions aid in parking area safety management, analysing occupancy and ensuring emergency vehicle access. Perimeter intrusion

detection using AI video analytics provides rapid monitoring and intrusion reporting. AI-powered security solutions can complement access control systems by automatically locking areas upon threat detection. Furthermore, the deployment of gun detection technology and real-time tracking of potential threats is vital to address mass shooting risks.

AI video analytics assists in the search for missing persons, identifying very quickly individuals from extensive camera feeds. Law enforcement protocols, like the 'be on the lookout' (BOLO) alerts, benefit from AI tools that scan video streams and detect persons of interest based on facial biometrics (Scylla AI, n. d.).

## **Cybersecurity at stadia and sport arenas**

Cybersecurity refers to the practice of protecting computer systems, networks, and digital information from unauthorised access, cyberattacks, data breaches, and other forms of malicious activities. It is about safeguarding sensitive data, ensuring the integrity of systems, and preventing disruptions caused by cyber threats. Sports event organisers, clubs, leagues, competition managers, and global sporting associations, hold significant data desirable to cybercriminals, which is vulnerable due to the

multitude of connected devices and networks in such settings. A prime example is the using of the Video Assistant Referee (VAR) system during football matches, aiding referees in decision-making through match review. A potential cyber-attack on this system could manipulate results, negatively impacting on match outcomes. Furthermore, cybersecurity's significance is evident in control of turnstiles, ransomware threats, with high-profile entities being targeted for data theft and extortion, and use the guise of certain organisations to spread messages.

To counter these threats, Microsoft recommends companies to disable unnecessary ports, conduct network scanning for rogue access points, ensure attendees update their apps and devices, avoid sensitive data over public Wi-Fi, and not scan untrusted QR codes. Commerce systems should secure point-of-sale devices, while stadium operations must establish network divisions between IT and OT systems. Microsoft suggests pre-configuring systems before events and conducting testing for rapid redeployment. These measures discourage cyber adversaries from exploiting weak networks during major sporting events (The Hacker News, 2023).

## **Ticketing, access control, and cashless payments**

## **NFC (RFID) technology and beyond**

RFID (Radio-Frequency Identification) and NFC (Near Field Communication) are wireless technologies for short-range data exchange. NFC, a subset of RFID, facilitates close-range communication between devices, useful for contactless payments, mobile transactions, and data sharing. While RFID tracks items, NFC enables secure wireless interactions like payments and data exchange between devices.

With the arrival of NFC (Near Field Communication), fans can now simply add their tickets to their mobile wallets and tap their phones near the reader for instant access. The efficiency and security of NFC transformed ticketing into a seamless process.

## **Mobile and biometric ticketing**

In recent years, mobile tickets started to replace the printed copies. Many sports event facilities already use barcode readers to process paper tickets,

but not only this. Sport event fans who have a WAP-enabled phone can buy the tickets with their phone, store them on the phone and swipe their phone at the event. Mobile tickets offer numerous advantages in sports events, enabling fans to access their tickets via apps or email; they are environmentally friendly, enhance security, mitigating fraud; integrate with event apps for an interactive experience; allow for contactless entry; provide analytics for improved planning and personalisation; enable speedy entry; can be updated in case of changes, save costs and serve as a direct marketing channel. Additionally, mobile tickets facilitate secure resale in secondary markets, ensuring a controlled and authenticated process that benefits both buyers and sellers, enhancing overall ticket accessibility and value (Roos, n. d.).

Biometric entry is rapidly advancing, potentially rendering digital tickets outdated. Citi Field, the home stadium of MLB's New York Mets, has embraced this technology, aiming to provide fans with a swift entry process. Fans no longer want to endure long waits outside stadia. To address this concern, the Mets transitioned from digital tickets, which still required phone scanning, to facial recognition. This innovative technology registers fans' faces, whether they have one or multiple tickets, and grants them entry along with their party, eliminating entry friction and enhancing the fan experience (McCaskill, 2023).

Amazon is exploring revolutionary tech such as 'pay-by-palm', in which fans might simply wave their hands to get into a stadium. Amazon's introduction of 'Amazon One' at their stores showcases the potential of biometric ticketing

for sports events. This was tested already at Denver’s Coors Field, home of Major League Baseball’s Colorado Rockies, which is the first sports venue to offer Amazon One’s age verification capability, Amazon (Olwyn, 2023).

**Figure 2. The Amazon ‘pay-by-palm’ access system**



Source: [untitled image of the Amazon ‘pay-by-palm’ access system], (n. d.), <https://bit.ly/3FYoX9q>.

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## Cashless payments

Many stadia are adopting cashless payment systems that rely on connectivity for quick and secure transactions. This speeds up concession lines and enhances convenience for attendees. They can rely on both the internet (e.g., Wi-Fi or cabled internet connections) or traditional telephone networks (either mobile or landlines). Increasingly, telephony services are provided through the internet, but this may not be available in all countries.

In Tottenham Hotspurs new stadium events, for example, there is a fully cashless policy, as the club aims to provide the best possible fan experience. No cash is accepted for any purchase made within the stadium and its surrounding campus. The result is increased speed of service and shorter queue times, more payment options (bank cards, mobile, gift card) and improved hygiene, as catering staff will not be handling cash. All payments can be made using the following methods:

- all major contactless debit and credit cards, with chip and pin applying for purchases over £30.
- Mobile and wearable payment, including Apple Pay and Google Pay. This method supports high-value contactless payments.

- Gift Card. Traditional Tottenham Hotspur Gift Cards are available in Spurs Shops and can be used as a further payment method (Tottenham Hotspur, 2023).

**Figure 3. The Tottenham Hotspur new stadium hospitality cashless facilities**



Source: [untitled image of the Tottenham Hotspur new stadium hospitality cashless facilities], (n. d.), <https://bit.ly/468eflh>.

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## Audiovisual systems

## **Use of LED technology**

LED stands for Light-Emitting Diode, and it refers to a technology that has gained immense popularity due to its energy efficiency, longevity, and versatility. LED technology finds widespread use in stadia. LEDs illuminate fields with energy-efficient floodlights, meeting high standards for broadcasting and visibility. They power scoreboards and video displays for real-time updates, replays, and ads. Perimeter advertising boards use LEDs for dynamic promotions, while architectural lighting enhances stadium aesthetics. LEDs guide spectators with clear wayfinding signs, and they create customisable atmospheres in VIP areas. They also enhance entertainment through synchronised light shows. LED's efficiency reduces costs and environmental impact, making stadiums more eco-friendly. This technology elevates the fan experience, improves visibility, and promises further innovations in the future. The improved technology has made LED stadium screens more affordable, making them accessible to a wider range of venues. They require minimal maintenance and can be easily replaced or repaired, reducing downtime and cost of ownership.

## Customisation

LED stadium screens can be customised to meet the specific needs of a venue. They can be configured to display different resolutions, sizes, and aspect ratios, allowing venues to create unique and engaging displays. This customisation capability has made LED stadium screens popular among sports and entertainment event organisers (GlobeNewsWire, 2023).

Manchester City installed a large perimeter LED display system at the Etihad Stadium, which is the most lucrative pitchside media space in the Premier League. This two-tier digital display system boasts high-definition screens that enhance picture quality, even for still images and slow-motion footage. These screens can synchronise to create a single, oversized pitchside presence, and content can be mirrored across both tiers, effectively doubling exposure compared to a traditional LED setup. Moreover, the system allows for various aspects of the same campaign to be shown across the two levels, including options for different messages or languages (Carp, 2021).

**Figure 4. Manchester City installed a large perimeter LED display system**



Source: Carp, 2021, <https://bit.ly/46ewBHm>.

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## **The FIBA glass floor**

This state-of-the-art court presents a full video floor that allows for interactive applications. The ASB GlassFloor also boasts the capability to incorporate player tracking onto the video floor, enabling the display of live statistics and athletic achievements on the playing surface. This offers fans an enhanced level of interaction, deeper engagement, and an elevated show staging experience. Moreover, the court provides additional avenues for

sponsorship and marketing opportunities. While NBA teams had already integrated 3D court projections into pregame introductions and celebrations, the introduction of glass courts denotes a substantial advancement beyond that. Alongside heightened stage production, FIBA emphasized that the ASB GlassFloor has the potential to offer real-time stat tracking and in-game graphics synchronised with the on-court action. FIBA revised its regulations, permitting the use of LED glass courts in elite-level tournaments. This change sets the stage for fresh broadcast experiences and activated sponsorships. ASB assures that its flooring boasts the highest levels of shock absorption and elasticity, thus reducing strain on players' joints, and fulfilling the rebound demands of sports like basketball. The GlassFloor features ceramic grip dots, providing consistent control across the surface without causing skin abrasions from falls. Additionally, it offers enhanced elasticity and uniform ball rebound. The ability to display real-time statistics and graphics on the court will substantially bridge the gap between the in-venue and at-home experiences. With instant adjustments to markings for various sports, venues will have the capability to transition seamlessly between basketball, handball, volleyball, and badminton configurations with reduced resource consumption (FIBA, 2023a).

**Figure 5. The FIBA Glassfloor**



Source: FIBA, 2023a, <https://bit.ly/47cOWGj>.

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## Audio systems

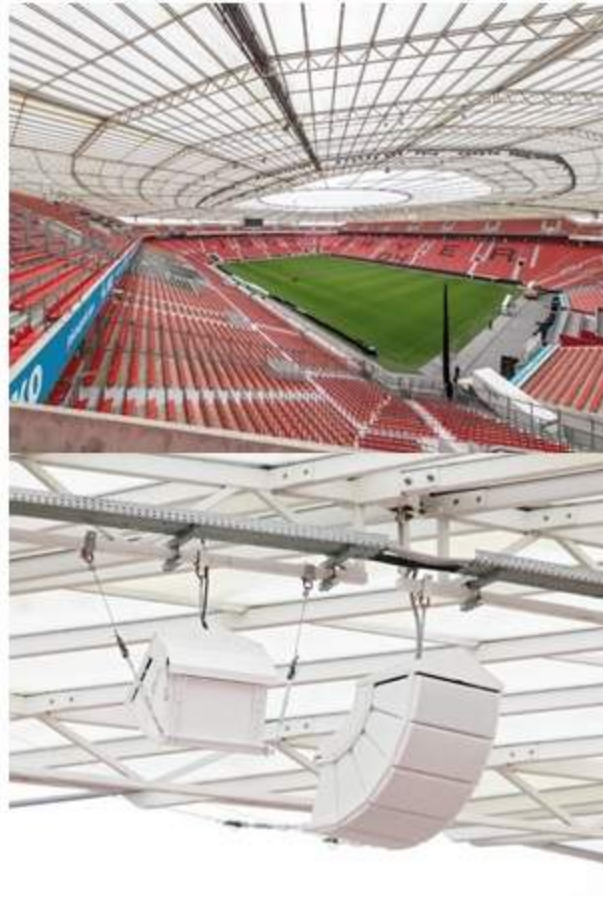
Providing an exceptional guest experience goes beyond video screens and large scoreboards; sound quality is equally vital. Today's stadium audio systems, composed of loudspeakers, amplification, and digital processing, have evolved far beyond basic PA systems. They are now at the core of the

stadium's audio and video setup, serving as both a PA system and a comprehensive fan entertainment system.

The BayArena, for example, a modern sports venue with a capacity of 30,210, and the home of Bayer 04 Leverkusen, recently upgraded its audio system. This project was undertaken by TecArena Plus, a subsidiary of Bayer 04 Leverkusen Fussball GmbH, responsible for facility management and project management. The primary goal of the upgrade was to enhance the stadium's electro-acoustic sound quality while maintaining affordability. TecArena provided existing EASE modeling of the BayArena to ensure that the desired STI (Speech Transmission Index) values were met. The objective was to achieve an STI value of 0.56 in at least 90% of the covered areas with the new audio system.

The BayArena has upgraded its audio system with 82 CODA Audio APS (Arrayable Point Source) loudspeakers. These lightweight and versatile speakers are deployed across sixteen positions inside the stadium, with different dispersion angles to match the tier topology, providing customised sound zones. The system also includes coverage for the pitch itself, with APS units pointing downwards from the roof. Twelve CODA Audio LINUS14D amplifiers power the system, offering flexible audio inputs and efficient energy usage. Large cable cross-sections reduce losses, and the LINUS14's signal routing can be adjusted via remote control software. Additionally, there is an independently operated voice alarm system connected to the pro-audio systems for safety purposes at the BayArena (CODA Audio, 2022).

**Figure 6. The new audio systems in BayArena**



Source: CODA Audio, 2022, <https://bit.ly/46eTOJI>.

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## **The SoFi Stadium**

## **The SoFi Stadium 'Infinity' video screen**

The Infinity screen by Samsung features the most LEDs ever used in a sports or entertainment venue, and also has the first and only 4K, end-to-end, video production in a stadium. The largest videoboard ever created for sports is positioned 122 feet above the playing field, and the 70,000 square-foot oval display features approximately 80 million pixels. With the pixels spaced 8 millimetres from centre to centre, each panel can be congruently programmed with statistics, live and/or animated content. The largest panel is about 40 feet or four stories tall; its smallest panel is nearly 20 feet or two stories tall. Its unique size and shape make it wider than the field of play and offer fans a spectacular view from anywhere in the stadium. The display is also equipped with a state-of-the-art audio system with more than 260 individual JBL by Harman speakers embedded into its frame, equal to 1,500 home theatre systems. Samsung said it had also outfitted the stadium with more than 2,600 large format displays, ribbon boards (long, thin LED screens mounted on the face of balconies) and audio equipment. Every large format display at SoFi Stadium uses HDR10+ tech (Balakumar, 2022).

**Figure 7. The Infinity screen at SoFi Stadium**



Source: [untitled image of the Infinity screen at SoFi Stadium], (n. d.), <https://bit.ly/46iw7QC>.

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## **The SoFi Stadium Wi-Fi**

It is not only about capturing selfies and videos of the Samsung Infinity Screen: there is more at play. SoFi Stadium stands out with high Wi-Fi usage, even measuring in terabytes per hour, and witnessing over 70% of ticketed guests connected simultaneously. This connectivity surpasses data rates seen at previous Super Bowls, attributed, in part, to its digital ticketing and

touchless concessions operations, which reshape the fan experience and drive wireless engagement.

Factors contributing to the surge in data consumption include the auto-connect feature that switches users to Wi-Fi, powerful smartphones, and data-intensive apps. Venues need to reconsider connectivity norms, updating both wired and wireless infrastructure earlier than expected. SoFi Stadium boasts a Wi-Fi 6 network with many access points, using a mix of under-seat and overhead antenna deployment. Initially, the Wi-Fi surge was tied to a cellular distributed antenna system (DAS) lacking full carrier participation, pushing more fans to use Wi-Fi.

A Cellular Distributed Antenna System (DAS) is a network of antennas that are strategically placed throughout an area, such as a stadium, building, or public space, to improve cellular and wireless coverage. The purpose of a DAS is to enhance the wireless signal strength, capacity, and overall performance in areas with high user density or where cellular signals might struggle to penetrate due to obstacles like walls or structures.

Despite carriers coming onboard, Wi-Fi usage remained high due to improvements based on fan and staff feedback. Early 2022 season games at SoFi Stadium attracted high attendance and Wi-Fi demand, with data usage reaching 19 terabytes. One game recorded 24.4 terabytes, indicating robust Wi-Fi consumption.

Compared to other venues, SoFi Stadium's unique combination of digital ticketing, cashless concessions, and full-capacity crowds led to an exceptional 78 percent concurrent take rate and record-breaking throughput. Fans at the stadium use more apps per device and keep apps open longer, highlighting heightened expectations for a connected game-day experience. The growing Wi-Fi consumption during major events suggests a need for ongoing network upgrades, going beyond adding access points and potentially involving substantial enhancements to wired networks and internet connectivity (Kapustka, 2022).

## **VR and AR**

Virtual reality (VR) is technology that immerses users in a simulated environment, often using specialised hardware such as VR headsets. Augmented reality (AR) is a technology that overlays digital information, such as images, videos, text, and 3D models, onto the real world.

Unlike virtual reality (VR), which immerses users in a completely virtual environment, AR enhances the real-world environment by adding virtual elements to it. AR is typically experienced through devices such as smartphones, tablets, smart glasses, and other wearable technology. These

technologies leverage connectivity to provide immersive experiences, but require significant bandwidth and network speeds of to function properly (Medium, 2020).

### **Refereeing assistance**

With the aid of cameras all throughout the court and stadium, technology generates and replays full 3D recreations of game plays in questions during sport events and competitions, giving referees the proper information needed to make the right call. The Hawk-Eye system, for example, currently used in tennis, cricket, badminton, football, and more, can recreate a ball's trajectory with extreme accuracy (no more than a 5 mm margin of error), within less than ten seconds. It has been adopted as the goal-line technology by the Premier League as well as the on-field ruling system for the Wimbledon Championships, the Australian Open, and more.

### **Marketing and advertising**

AR offers a new and interactive way to advertise brands and products during sport events and competitions. For example, digital boards allow companies to target different global audiences with personalised virtual feeds of advertisements. Sports brands are using AR technology to create interactive advertising campaigns, in which fans can point their smartphones at billboards or advertisements to unlock exclusive content. Although the technology does not affect the actual on-field action, the virtual advertising images displayed on pitchside boards are specific to each region. This enables event competition organisers and rightsholders to customise advertisements that are most suitable for the international TV viewers, whether they are tuning in from their homes in Los Angeles, Beijing, Sydney, or any other global market (Kidd, 2018).

**Figure 8. Virtual feed advertising boards technology**



Source: Kidd, 2018, <https://bit.ly/47uqMXj>.

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## Enhancing fan experience

Event organisers are using VR and AR technology to enhance the fan experience by creating virtual replays and real-time overlays of game statistics and player information. This technology allows fans to have a more immersive and interactive experience, giving them a deeper understanding of the game and the players. Especially with younger fans, they are coming from a gaming background where they like to participate. The coupling of the

physical and digital is something which is already happening, and for young kids. More details about VR and AR can be found in the respective course (TheRams.com, 2022; Walker, 2023).

**Figure 9. AR example**



Source: TheRams, 2023, <https://bit.ly/4737V61>.

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**Figure 10. AR example**



Source: TheRams, 2023, <https://bit.ly/4737V61>.

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## **Venue operations software and applications**

Venue management software helps streamline operations and enhance efficiency by automating tasks such as booking, scheduling, event planning, and communication, making it easier for venues to manage events and provide excellent service to their clients. The effectiveness of venue management software focuses on the robustness of software's features

(event scheduling, reservations, CRM, reporting, and staff management) and user-friendliness.

### **Sport events applications example**

A running or other participation event is much more than just a single race; it begins the moment a participant registers. In the market, there exist specialised applications and platforms for sports running events, powered by data-driven technology. These applications, using technology based on both demographics and psychographics, offer a comprehensive solution for participants, encompassing registration, communication, updates, and progress tracking, all in one place. They view each running event as a journey, ensuring that runners have access to all relevant information, so they never miss out on the latest news and updates. These applications are designed to empower organisers and sponsors in creating better and more engaging events. They assist participants in various activities, such as inviting friends to join, setting goals, monitoring others' preparations, and personalising their event preparations. Additionally, they streamline event organisers' tasks, enabling seamless registration, management, and communication with runners, while also helping build relationships with each participant. These platforms provide event organisers with a user-

friendly interface for runner registration, data collection, race field organisation, and participant updates. Furthermore, they equip organisers with digital tools aimed at enhancing runner engagement with races and improving sponsorship program efficiency, ultimately transforming a one-day event into a data-rich 100-day journey. This benefits organisers, runners, and sponsors alike (Athletopia, n. d.).

## **Sustainability and green technology**

Green technology implementation in stadia involves incorporating various technological elements for enhanced sustainability. Key components include LED lighting systems for energy efficiency and smart lighting controls, renewable energy sources like solar panels and wind turbines, energy management systems for real-time insights and optimisation, high-efficiency HVAC and climate control technologies, water-efficient plumbing fixtures and rainwater harvesting systems, waste management solutions with sensor-equipped bins, green roof and landscaping technologies, building automation systems for centralised control, digital displays for promoting green initiatives, remote monitoring and data analytics platforms, electric vehicle charging infrastructure, IoT devices for data collection and automation, and adherence to green certifications and standards.

HVAC stands for heating, ventilation, and air conditioning. It refers to the technology and systems used to control indoor environmental conditions, including temperature, humidity, air quality, and ventilation, in buildings and enclosed spaces.

### **Water and energy efficiency technology**

In terms of water conservation, venues face increasing pressure due to drought conditions, yet must maintain safety and turf quality. Solutions include reclaiming water from various sources, using technologies like connected sensors for sustainable water storage, and ensuring effective low-flow fixtures to prevent water wastage. Timely leak detection is essential.

On the energy front, transitioning to LEDs, adopting solar power solutions, and instilling energy-saving habits among personnel are vital steps. Combining modern technologies with traditional practices can significantly reduce consumption and costs (Grant, 2023).

## **Electric vehicles stadium facilities**

With the rising popularity of electric vehicles (EVs), expected to comprise 40% of all car sales by 2030, providing EV charging stations is a logical step for event facilities and venues. This move aligns with the growing sustainability concerns of venue attendees. For example, 40% of American fans prioritise buying from socially and environmentally responsible companies. Offering EV charging not only underscores a commitment to sustainability, but also attracts attendees who value eco-friendly transportation options. Moreover, local and state authorities are introducing building codes mandating EV charging stations in new constructions, potentially extending these requirements to existing facilities (Gustafson, 2023).

## **Pitch maintenance LED technology**

Allianz Arena has been at the forefront of sustainability in sports, undertaking various environmental initiatives, from converting facade lighting and floodlights to LED technology to introducing a returnable cup

system using recycled plastic for Bayern Munich shirts. Their dedication extends to reducing energy consumption for pitch maintenance, particularly through an innovative growth lighting system. In collaboration with SGL, a leading sports grass technology innovator and their longtime supplier, Allianz Arena has embraced a new smart LED growth lighting system designed for optimal climate control and substantial energy savings of up to 40%. Notably, they were the first stadium globally to adopt this LED growth lighting technology for the entire pitch. What sets this advancement apart is the development of a growth algorithm that intricately calculates the light and heat requirements for every section of the pitch, considering various factors such as climate, weather conditions, playing damage, and shade. This data-driven approach ensures precise and efficient utilisation of the LED lights and heating, guaranteeing pitch quality while significantly reducing energy consumption, as demonstrated by SGL's calculation, making this innovation a game-changer in stadium sustainability (FC Bayern München, 2022).

## **Sustainability technology implementation**

Mercedes-Benz Stadium in Atlanta, Georgia, the home of the Atlanta Falcons NFL team and Atlanta United FC football team, achieved the remarkable

distinction of becoming the first professional sports venue in the USA to earn LEED Platinum Certification. LEED Platinum Certification focuses on renewable energy, energy conservation, water efficiency, and stormwater management. The stadium is outfitted with 4,000 solar PV panels, producing sufficient energy to supply all non-game day operations, totalling approximately 1.6 million kilowatt-hours per year (Thomas, 2023; Evanesce, 2023).

A high-profile environmentally friendly initiative launched for the FIFA Qatar World Cup 2022 has been the introduction of solar-powered fan zones. These zones provided fans with the opportunity to enjoy the matches in a climate-controlled environment, while also helping to reduce carbon emissions (Al-Surf, 2022).

In 2019, Amazon co-founded the Climate Pledge initiative to have companies, organisations, and partners work together to address the climate crisis and solve the challenges around decarbonising. That led to what has become the Climate Pledge Arena. Climate Pledge Arena is the most progressive, responsible, and sustainable arena in the world. Its efforts include being zero-waste by using compostable containers and reducing single-use plastic use, conserving water by retaining rainwater for reuse, and not using fossil fuels in the arena for daily use, including the electric-powered Zambonis, which is the ice hockey resurface equipment (Climate Pledge Arena, n. d.).

## **Accessibility and inclusivity**

Stadiums classified as accessible must adhere to key physical and digital features catering to all types of disabilities. One critical aspect is the provision of wayfinding solutions, especially for individuals with visual disabilities, who may face navigational challenges in unfamiliar environments. Effective wayfinding solutions for people with disabilities entail components such as audio guide assistance, an accessible user interface, and considerations for navigation barriers. Providing accessible information to individuals with visual impairments is integral to facilitating navigation in fan zones and promoting independent living. Fortunately, advancements in wayfinding technologies now enable users with disabilities to navigate indoor and outdoor spaces effortlessly using their smartphones. Free smartphone applications using Bluetooth beacon technology offer an autonomous guide for individuals with visual impairments. These applications offer features such as voiceover recognition of current locations, customised exploration journeys, destination searches, and precise directions, available on both IOS and Android platforms and in multiple languages (Al-Mohannadi, 2022).

In the context of live commentary, providing accessible content for fans with visual impairments is crucial. While most fans rely on multiple senses to

follow the game, individuals with visual disabilities need equal access to real-time updates. Various innovative solutions are available to promote inclusivity. One such technology allows users to track the exact location of the ball through a touch-based table and custom software that syncs with the match, providing a tactile experience of the game. Ensuring the accuracy and precision of information relayed is essential for an inclusive experience. Therefore, live match commentary should include headset assistance and audio-descriptive commentary.

### **Headset assistance**

Noise in fan zones can be distracting for users with visual impairments, which is why providing headsets can enhance inclusivity. Innovative solutions offer features such as a high operating range, individual volume adjustments, co-presenter options, noise reduction, and multilingual support. These headsets allow fans with visual impairments to listen to the match comfortably.

### **Audio-descriptive commentary**

Audio-described commentary is a unique service that provides descriptive details of the match, catering to partially sighted and blind fans who might miss out on important visual elements. Specially trained commentators offer narration that describes significant visual aspects, such as body language, scenery, clothing, and more. This service focuses on conveying the image, venue, match, event, or surrounding ambiance, ensuring that individuals with visual impairments have a comprehensive understanding of the on-pitch action during the match, rather than statistics or tactics (CAFE, 2021).

## **Summary**

In this module, we have covered a range of topics, including the layers of stadium technology, the smart stadium concept, infrastructure, and connectivity in stadiums and sports event facilities. We explored the nature of 5G technology and Wi-Fi technology, extending into topics such as venue security, biometric identification, and AI surveillance. We examined the new trends in digital ticketing and access, as well as cashless payments. Finally,

we evaluated the contribution of new technology in audiovisual systems through LED technology, with the best example cases for these new capabilities. Moreover, we investigated the role of VR and AR in the new realities and presented the latest trends in venue operation software apps, sustainability/green technology, pitch maintenance technology, and the role of technology in accessibility and inclusion.

[CONTINUE](#)

# Activities

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What are the three layers of stadium technology?

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- The technology infrastructure layer.
- The enabling technology layer.
- The technological security layer.
- The experience layer.

SUBMIT

Stadia deploy robust Wi-Fi networks to provide spectators with high-speed internet access. What are the most important parameters of Wi-Fi networks?

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- Speed
- Scope
- Coverage
- Security

SUBMIT

RFID (radio-frequency identification) and NFC (near field communication) are wireless technologies for \_\_\_\_\_.

Type your answer here

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SUBMIT

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