OmniAccess Stellar
High Density Design Guidelines

Best practices for deploying high-density Wi-Fi networks
in dense environments.

Alcatel·Lucent
Enterprise

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1. Introduction

The purpose of this technical note is to outline best practices for deploying a high-density (HD) Wi-Fi network using OmniAccess Stellar access points, especially in dense environments like stadiums or outdoor arenas.

OmniAccess Stellar 802.11ax technology is well-suited for meeting the requirements of such environments, characterized by diverse connectivity needs, high concentrations of users typical for this type of deployment, and complex installations.

The focus of this note is on modern stadiums. The network design, particularly the Wi-Fi aspect, requires project oversight for design and installation, including an analysis of prerequisites, capacity requirements, and access point deployment. It consistently calls for the implementation of a dedicated and autonomous network architecture provided by the ALE network solution managed in Enterprise mode. These various points are detailed in this note.

It's always beneficial to refer to the existing ***OmniAccess Stellar Fine-Tuning Best Practices note*** for indoor Stellar deployments, as it already provides extensive details on key RF parameters, SSIDs, and AP group settings.

This note can also be used with interest for any dense indoor Wi-Fi deployment

2. Requirements

The modern stadium is an extreme case of high-density (HD) wifi in a well-defined space, and a typical example of multiple wireless services with the following main characteristics:

- Several tens of thousands of seats (the example given in this note is for a stadium with up to 50,000 seats)
- +20,000m² surface area for 50,000 seats
- More access points than channels in the 5GHz band
- Different areas and spaces at different tier levels reserved for press, media or VIPs
- Users are mainly guests (up to 2 devices per person)
- Halls and concession areas (stores) around the stands
- Offices, facilities, auditoriums, restaurants or other indoor spaces
- Exceptional concentration of users during events
- High-rise structures, up to 50m high
- Elevated platforms (catwalk-type) to support technical equipment

To setup a high-density WLAN network in a stadium as described above, a WLAN Network design project based on capacity planning is essential. This planning enables us to assess how the network will be used at high density. Based on the '*Capacity planning and deployment*' figure 1 detailed in the ***OmniAccess Stellar Fine-Tuning Best Practices notes*** for capacity, the following points will need to be considered in the case of high-density design in a stadium:

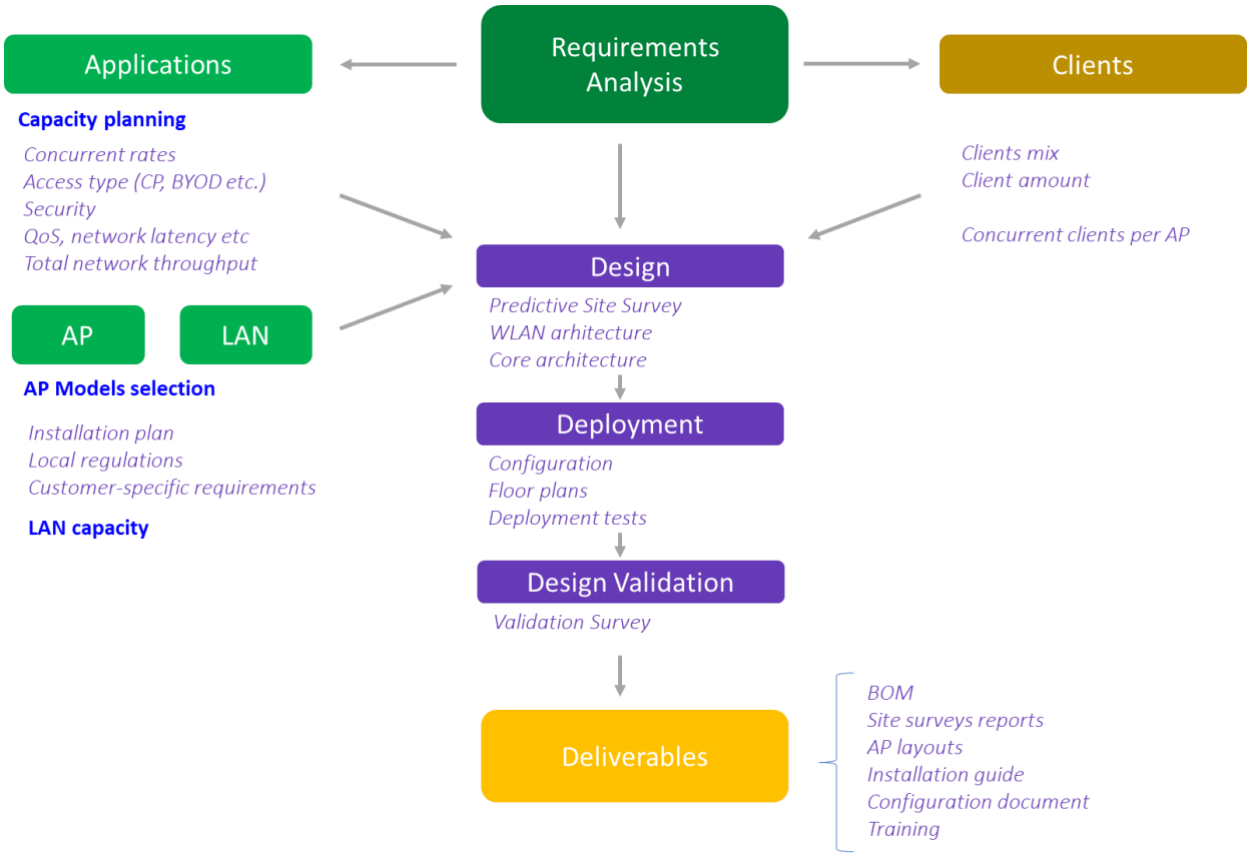

Figure 1: Design for HD in stadium

A requirements analysis is the first and essential step in high-density Wi-Fi design, that is clearly identifying client types and the different applications used: audio/video, data or real-time. This part includes a capacity plan to evaluate the potential network load during events. In particular the number of concurrent clients per access point, and concurrent bandwidth requirements will be determined.

This step takes also into account network access requirements: Captive Portal/ BYOD accesses, Enterprise connections and their associated security, QoS, latency and more.

The selection of AP models is specifically done during the requirements analysis, with a study of APs installation during the deployment phase. The optimal placement of the APs on the different zones and levels of the stadium is an essential factor for an optimal experience. This includes specific coverage areas such as press and VIP areas, as well as halls, high-concentration areas, and stadium facilities.

An estimation of LAN capacity to support HD Wi-Fi is part of the design requirement and is also carried out during this step.

The Design, Deployment and Validation steps depicted in the figure above underline the importance of methodology in the implementation of high-density WLAN. Design includes the creation of a predictive survey site. An implementation project is recommended, including detailed digital maps of the different zones of the stadium to be covered, notably: seating areas, halls, indoor areas and other spaces.

The Design will include the chosen WLAN architecture and its deployment with the configuration of access points as well as the testing phases on various applications used in a stadium.

Finally, the post-installation validation phase in the stadium is carried out by analyzing network performance in real time, and comparing the results obtained with the requirements defined during the planning. Design validation phase can also be carried out by means of real user surveys.

Several deliverables will be provided to site managers at the end of the project, following documents and services are generally required:

- BOM (Bill of Materials), a complete inventory of WLAN/LAN equipment used: access points, switches, servers, accessories, HW/SW support, licenses, end-customer services, etc.
- AP layouts showing the location of each access point in the stadium, with information on their configuration
- Survey site reports detailing on-site results and coverage measurements made
- Installation guide describing the steps involved in installing, configuring and maintaining the wifi network
- Configuration guide detailing network configuration, security parameters, VLANs, QoS and access policies, etc.
- Training of staff responsible for managing and maintaining the WLAN network.

3. Recommendations

3.1 RF for capacity

Success in deployment of a high-density Wi-Fi network in a stadium relies heavily on effective RF management.

- Channel reuse plan: channels available in the 5GHz band in an area are re-used in regular patterns, reducing then CCI and ACI interference in the area.
- Force the 5GHz band and balance the load between APs to avoid overloading certain APs.
- Define appropriate Tx transmission levels: for high-density indoor areas of stadium it's often advisable to set lower Tx transmission levels to reduce interference. For outdoors, this Tx level may vary according to the specific needs of the deployment, for example external Wi-Fi 6 AP1361 installed 30m above the stands could transmit at a power level of around 10 to 15dBm.
- Channel plans: it makes sense to divide a site like a stadium into several channel plans and use DFS channels in stands for better use of 5GHz band, and non-DFS channels for better performance in indoor areas for example.
  Non-DFS channels are more widely available and can be used in indoor areas such as press rooms or catering areas.
  DFS channels are channels that use frequencies shared with other radio services. They can be advantageously used in the stands of a stadium where there is a high concentration of users. It is important to comply with local regulations for their use.
- Use of 20 MHz bandwidth: 20 MHz channel width greatly minimizes interference in outdoor areas, especially CCI (Co-Channel Interference). Use of this base bandwidth is well suited to client mix and coverage of tiered areas.
- Airtime fairness: essential in high-density environments, as it efficiently manages a number of clients with varying throughput requirements at a single access point, guaranteeing fair use of resources for each of them.

RF management on Stellar is therefore essential for high-density deployment, and it is advisable to refer to the ***OmniAccess Stellar Fine-Tuning Best Practices note*** to overview all RF parameters. Defining multiple Stellar RF profiles make it easy to manage all the RF points just seen previously, including a channel plan selection (DFS channels, non DFS channels, channels over DFS etc.) and Auto Channel Selection. OmniAccess Stellar access points automatically adjust the channels of the radios to avoid RF interferences (802.11 and non-802.11) and develop channel plans for the WLAN. Channels can be selectively assigned to be used with each RF profile.

Most Stellar Wi-Fi6 APs have a radio dedicated to the scanning and there's no need to activate a background scanning on the active channels for access points selected for high density, leaving active channels totally free to handle heavy client thoughputs. It is therefore recommended to select APs that support a dedicated full-band scanning radio.

3.2 Clients

There is a high mix of clients and applications in a stadium. Today's stadium visitors generally have the following characteristics:

- Around 90% of equipment/smartphones are dual-band compatible.
- 90% are smartphones, 10% are laptops for visitors in the stands
- The percentage of visitors with Wi-Fi 6 phones is estimated 20%-35%, bringing a high mix of devices into the stadium.
- The majority of Wi-Fi clients today operate in 2x2:2 MIMO mode.
- Most clients support 5GHz DFS channels, then DFS channels can be included in channel plans for visitors.
- Each visitor can have up to two devices.

A stadium requires a variety of Wi-Fi services (up to 7 SSIDs maximum are possible for an average channel utilization in the 5 GHz band of around 12%, refer to *'number of SSIDs versus channel reuse'* table in ***OmniAccess Stellar Fine-Tuning Best Practices note*** for details). These Wi-Fi services need to be specially designed to handle a high density of clients, with an average of 0.5 to 1 m² per seat, and 1 to 2 m² of space in high-concentration areas.

SSID	Usage	Authentication	Access
Visitors	Internet/email/social network/video (roaming optional) Mix of smartphones and tablets	Open SSID with Captive Portal	Captive Portal restrictions
Press, media and VIPs	Internet/files/video Mix of laptops, smartphones and tablets, legacy devices	802.1X WPA2	High QoS No rate limit

Figure 2: Very-high density SSIDs

OmniAccess Stellar SSIDs fine-tuning for very-high density must include:

- Dual-band 2.4 GHz/5 GHz SSIDs with band forcing to 5 GHz at RF level.
- Minimum data rates of 12 Mbps to take account of different client types.
- Some devices, notably Apple and Chromebook, may have particular behavior with regard to Address Resolution Protocol (ARP) when roaming or associating. The application of the ARP broadcast filter is recommended to avoid these problems during their roaming/association.
- QoS implementation and application prioritization, particularly for audio/video applications.

The “Sticky avoidance" must be managed at RF level for these high-density SSIDs. It enables better signal quality for clients and better load balancing between APs.

SSID	Usage	Authentication	Access
Ticketing/points of sales	Real-time (Ticketing system) Tablets, smartphones or Scanners	802.1X WPA2	QoS Back office application
Equipment/video surveillance	Multicast/data/video, IoT	802.1X WPA2	Streaming rate
Employees	Office/data/collaborative Laptops, smartphones, tablets	802.1X WPA2 and more	Site policies BYOD
IT	Office/data/collaborative Laptops, smartphones, tablets	802.1X WPA2 and more	Site policies

Figure 3: SSIDs specific to the site

SSIDs for equipment and employees deployed for site operation generally follow the same design rules, with a management similar to that found in offices. However, care must be taken to optimize broadcast/multicast for wireless video equipment.

3.2.1 Maximum client throughput in very high-density

The following table gives an indication of the maximum throughput that can be expected for clients connected in a tier/seat VHD area. The client mode in the table is 2x2:2SS with use of MCS8 modulation* (256QAM 3/4). From information available for WLAN use cases in stadiums and for users connected to visitors SSIDs we have:

- A measured throughput of 80Mbps (MCS8 modulation*) for a single Wi-Fi 6 user on a 5GHz channel using TCP protocol (http protocol to the Internet), dropping to 40Mbps when there's a high concentration of clients connected on the same channel (average of 60 clients connected simultaneously is depicted in example here).
- A 25% ratio, specific to VHD in stadium, is introduced to account CCI/ACI effects (interferences from other APs on the same channel), Wi-Fi interference, non-Wi-Fi interference and considering a moderate duty cycle for stadium context (time when the channel is effectively used).

Mode	Datarate	Datarate/HT for TCP (http)	Client concentration (60)	VHD in stadium
802.11ax HE20	206Mbps	165/80Mbps	50Mbps	37Mbps
802.11ax VHT20	173Mbps	140/70Mbps	40Mbps	30Mbps

Figure 4: Maximum client HT for VHD in stadium

3.3 AP counting

3.3.1 Metrics in high-density

The table below lists the following recommended AP count values to be included in the capacity plan for high-density stadiums.

Area type	AP counting	Notes
Tiered/seats	Up to 120 devices per AP/radio (up to 150 seats/AP)	AP count method is devices due to client density
Press/media/VIP	1 AP/100m²	Very-high density use with a minimum of 2 APs for a correct load balancing. Specific AP counting per seat can be applied for the press in the case of very heavy use, counting 1 AP/25 seats in this case
Halls/concessions	1 AP/100m²	High-traffic areas with high client density
Surrounding area	1 AP/100m²	Especially with high density at stadium entrances
Service	1 AP/100m²	Density for IT/employees areas is similar to that of other zones due to intensive use of thick walls in the stadium

Figure 5: AP counting per areas type

For tiered/seats areas, a ratio of 30% of connected people to the total number of visitors is generally applied, which is value considered in first calculation for a high WLAN usage by visiting users in the case of stadiums. For example, in a stadium with a capacity of 52,000 seats, this equates to a load of 21,000 concurrent devices, or 60 devices per AP and more.

3.3.2 Benefits of using Wi-Fi 6 access points

As already mentioned in the ***OmniAccess Stellar Fine-Tuning Best Practices note***, the technologies integrated by 802.11ax (Wi-Fi 6), such as OFDMA and BSS coloring, as well as the evolution of beamforming, evolution of MU-MIMO and the contribution of fast modulation for nearby clients, offer numerous advantages in high-density applications. Full use of 802.11ax in high-density installations means:

- The support for large numbers of clients
- More efficient use of airtime in high-density applications
- A better channel reuse in the 5GHz band
- A better control of CCI

The recommended Stellar Wi-Fi 6 access points in high-density are:

Model	Recommended use	LAN capacity
AP1360 serie	Outdoor wings, surroundings, entrances, video surveillance (poles and walls mounting)	2.5Gbps
AP1322	Stand/seats with 30x30° antennas or 60x60° antennas (height less than 15m/structure) (catwalk and high structure, walls mounting)	2.5Gbps
AP1361D/AP1361	Stand/seats with catwalk-type structure for installation (catwalk and high structure, walls mounting)	2.5Gbps
AP1331/AP1351	Press areas, halls, gates, auditorium (ceiling, walls mounting)	10Gbps
AP1311/AP1331	Offices, locations (ceiling mounting)	5Gbps

Figure 6: AP models for high-density

For stands/seats areas, other installation strategies are possible upon use cases:

- Seat and handrail installations: some APs can be installed directly under seats, which can be useful for providing connectivity to nearby spectators. Handrails also enable APs to be positioned at the right height to provide effective coverage for visitors seated in the stands.
- Wall and structure installations: stadium walls and other structures can also be used to support APs and provide Wi-Fi coverage in areas where stands are not present.

For example, the use of AP1321 model with integrated antennas can be envisaged for this type of installation, particularly for seats with the use of suitable protective boxes (NEMA enclosure protection rating IP3 or IP4). These installations are generally designed to meet specific needs, and their implementation must be carefully planned to ensure optimum coverage in these areas.

The use of low-performance Wi-Fi 6 APs is not recommended for stadiums with more than 5,000 seats.

3.3.3 Examples of AP installations

Various installation options are possible for access points in a stadium. Here are the most commonly used methods for: conventional outdoor installations with mounting on poles and infrastructure walls, rooftop installations for overall coverage and targeted configurations for specific areas and sections requiring high throughput.

Figure 7: AP1361/directional AP1361D outdoor mounting option

For surrounding areas, parking lots, and exposed locations to environmental elements, industrial hardened Stellar AP1361/AP1361D, or higher, will be deployed. Installation involves mounting on back walls and/or vertical structure pillars.

Figure 8: Directional AP1322 with NEMA enclosure on catwalk-type support

AP1322s can be mounted on back walls and/or vertical pillars configured with external directional antennas.

Figure 9: AP1321 with NEMA enclosure mounted on catwalk-type support

Figure 10: AP1321 under seat or on handrail with NEMA enclosure

Note: This deployment type can be used in front of or in the middle of each spectator section on each floor. APs must be protected from intentional destruction when installed in this manner.

Figure 11: AP1331 high-density indoor

Because of the large number of APs to be installed in large spaces or high-density interior rooms, it makes sense to carry out AP placement study in false ceilings for a clean visual appearance.

The physical placement of each AP depends on the physical site survey, which guarantees the strongest signal coverage while minimizing channel interference. An installation guide is provided for each type of placement and installation guide document is one of the important deliverables to be provided at the end of the project.

3.3.4 Example of installation for 50,000 seats

The following map illustrates a stadium with a capacity of 52,000 seats and shows a study for the location of 260 AP1322s equipped with ANT-S-M4-60 and ANT-S-M4-30 external antennas. The installation strategy is to place these directional access points on the roof

structure, to ensure complete, high-density coverage of the visitor area on both levels of the stadium's stands.

With this approach, each AP1322 covers an average of up to 180 seats. One telecom satellite cabinet is required approximately every 3,200 seats, with each cabinet equipped with a 24-port switch in this example. To further improve connectivity in the stands, auxiliary installations such as additional access points and reinforcement antennas can be considered in high-traffic areas, such as access gates, for example.

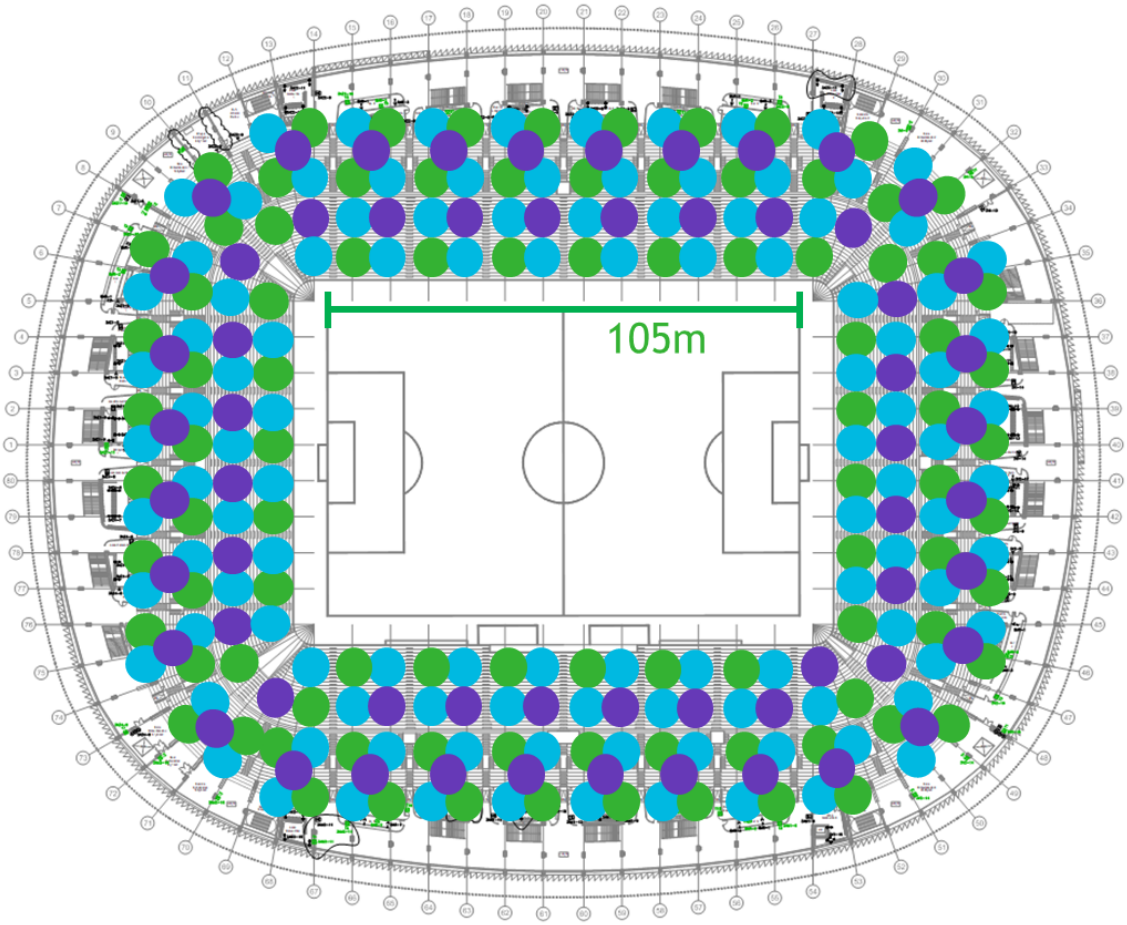

Figure 12: AP layout for 50,000 seats

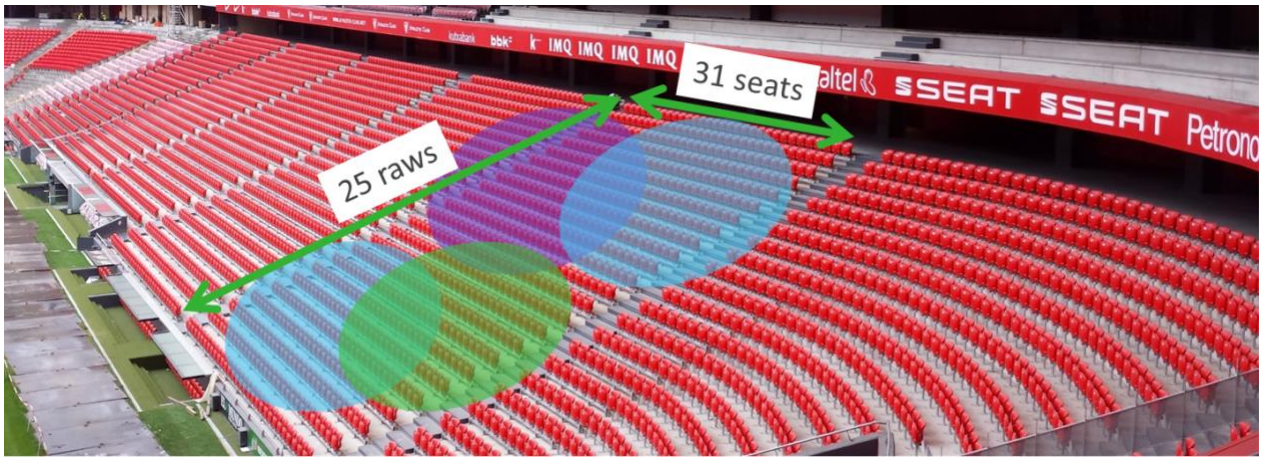

Figure 13: Example of AP coverage on tier 1

The image above illustrates the coverage of AP1322s access points for an area of 775 seats on level 1 of the stadium's stands. You can see, the signals from the access points are carefully aligned to provide uniform coverage across level 1, ensuring stable and consistent connectivity in this area.

4. End-to-end architecture for high-density

Implementing a high-density Stellar WLAN network in a large-capacity stadium, as described above, is a complex project requiring a carefully planned network architecture. The WLAN and core LAN network is typically an autonomous, mission-critical network managed by the Omnivista 2500 management system (NMS).

The architecture illustrated below showcases a multi-service network that has already proven its effectiveness in various ‘always-on’, strategic networks scenarios including: high-speed rail signalling, CCTV-IP networks for airports, data centers for police, governments and so on. This network is designed to support array of services such as video-surveillance, diverse network entities, security, access control and notably high-density WLAN in the case of stadium/large arena.

OmniAccess Stellar high-density WLAN is based here on a network core consisting of two redundant Omniswitch 6900s and features the following:

- Virtual chassis
- Autofabric

- VLAN scalability
- Device scalability (288K MACs)
- Low latency
- Application visibility & analytics (real-time Layer 7 application processing)
- Service isolation
- Guaranteed 40Gbps traffic, with the ability to peak at 100Gbps

The network core provides full redundancy for all appliances in the data center, with a physical location across two separate sites.

- Omnivista 2500 NMS operates in high availability (HA) mode with a duplicated database.
- DHCP/DNS servers need to be high-performance and accomodate multiple IP scopes and a large database for support of WLAN for visitors.
- The Captive Portal (CP) service can be entirely managed by Omnivista 2500. Omnivista 2500 offers a significant advantage due to its ability to handle a large number of users while consolidating CP functions and access policies on a same server. Omnivista 2500 greatly simplifies the management of visitor access in a high-density user environment, such as a stadium.

  It is also possible to manage the CP function with a third-party CP solution, and the solution must be able to support at least 15,000 users immediately (for example, the UCOPIA Edge solution with on-site controllers and Advanced licenses for a high number of users using CP services).

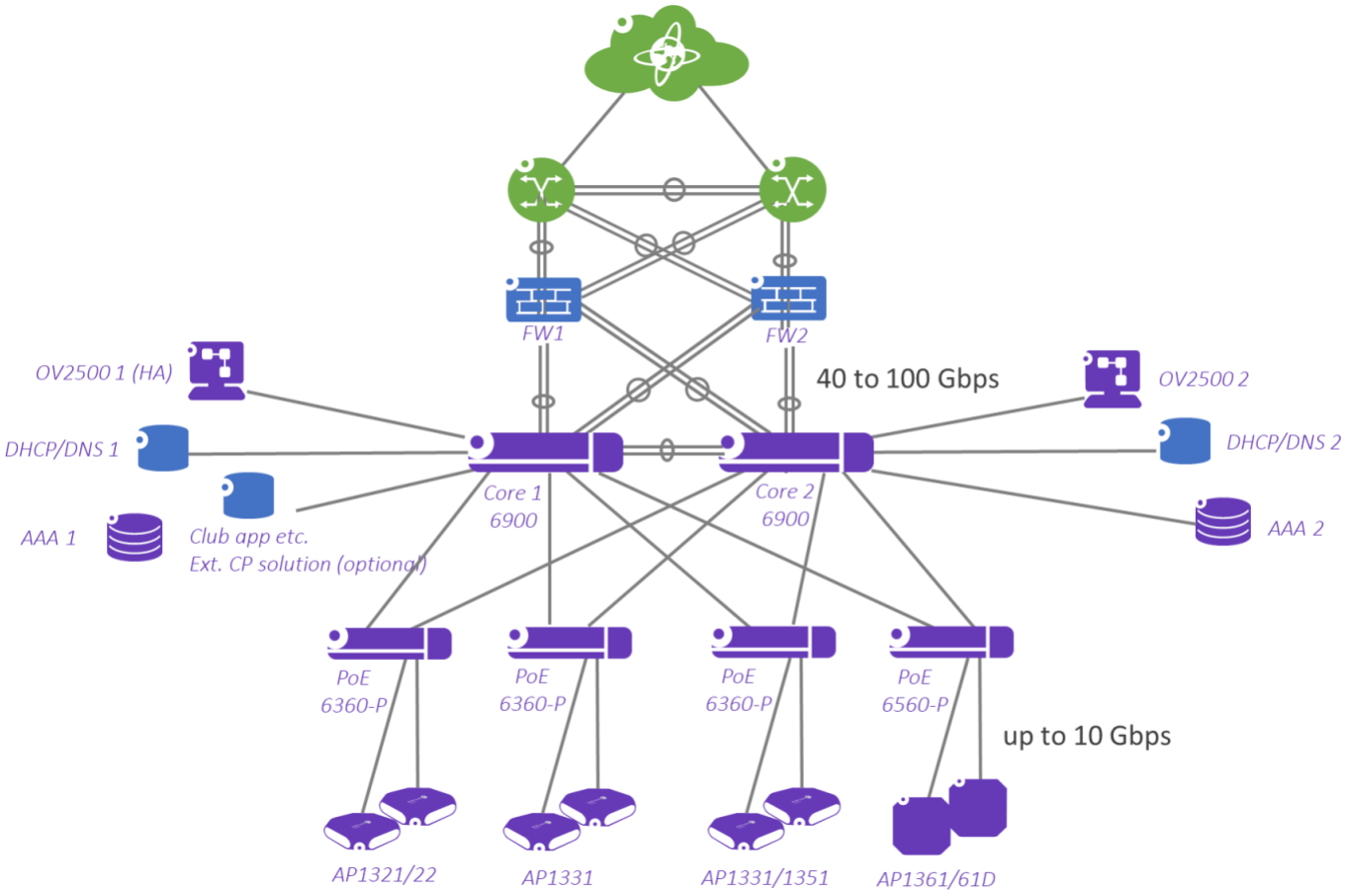

Figure 14: HD network design for stadium/large arena

4.1 LAN capacity for HD

To perform a proper evaluation of the sizing for 6900 core network, several key parameters need to be considered and integrated into the capacity plan.

Let's delve into the core network sizing for WLAN visitor traffic, which represents the most significant load in the stadium example. The following aspects should be taken into account:

- The number of visitors for the guest VLAN.
- The required bandwidth in LAN for the visitor area.

- A proper sizing of visitor DHCP scopes.
- The size of the Omnivista 2500 license for guest users.
- Necessary firewall resources.

To estimate the required LAN bandwidth within the seating area, it's important to consider the channel reuse factor. This factor represents the ratio of available channels to the channels used in a given Very High Density (VHD) area. It depends on the specific channel plan defined for the seating areas to be covered and the deployment strategy employed, whether it involves rooftop installations or extreme VHD deployments under the seats. For instance, selecting a DFS channel plan with a minimum of 8-10 channels specified for a particular stadium zone would result in a channel reuse ratio close to 1 (8 divided by 8). With OmniAccess Stellar DRM in operation, all channels defined in each channel plan are available and utilized, and then distributed in an optimized pattern of reuse.

In the context of stadium scenarios, it's essential to aim for a channel reuse factor as close to 1 as possible, especially within VHD areas. For seating-based installations, the channel reuse factor can extend up to a maximum of 3.

The estimation of LAN bandwidth to be provided for a WLAN VHD area follows this formula:

LAN BW = channel reuse factor * number of APs * number of clients per AP * VHD bandwidth per client

As an example, for a stadium featuring 50,000 seats with the following conditions:

- 15,000 users connected simultaneously in the seating areas.
- An average of 1 device per person.
- An average required bandwidth of 2 Mbps per client.
- An average of 60 clients per AP.
- 90% of users utilizing the 5GHz band.

In this scenario, the estimated LAN bandwidth for visitors amounts to 1 * 260 * 60 * 2 = 31,200 Mbps. To account for wired bandwidth, a precautionary additional 50% is included in the initial assessment, resulting in a total of 47 Gbps for the core LAN.
For comprehensive coverage encompassing all areas of the stadium, including halls, rooms, outdoors, etc. and for deployments involving seat-based strategies, it is advisable to consider an architecture with a 100 Gbps 6900 core.

4.2 Advanced analytics in high-density

Omnivista 2500 in High Availability (HA) mode for a stadium ensures that no access points are lost in a high-density WLAN network. Omnivista 2500 handles a variety of AP groups, supporting up to 4000 APs per appliance, along with compatibility for all AP models suitable for their deployment within a stadium.

The combination with an Omnivista Cirrus 10 Cloud instance for statistical and analytical tasks, specifically tailored for high-density environments, complements with interest Omnivista 2500 NMS management of the site. All Stellar Wi-Fi 6 series AP13XX support advanced analytics, reporting and logging, and can send their data to a Cloud instance of Omnivista 10 for advanced analytical services on-site, particularly when the WLAN network is managed by Omnivista 2500, such as in a stadium. The only prerequisite is to authorize access to the Omnivista Cirrus 10 instance in the firewall of stadium for all APs and stadium areas to be monitored.

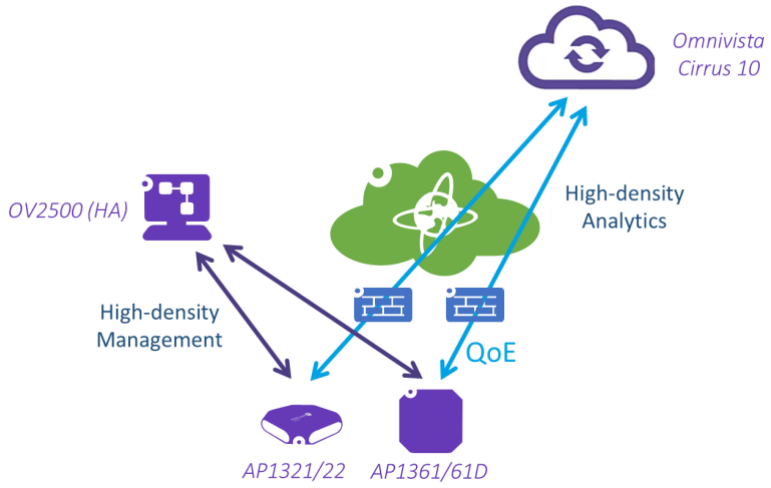

Figure 15: HD analytics with Omnivista Cirrus 10

Omnivista Cirrus 10 cloud instance provides the ability to manage and deliver various dashboards for advanced analysis tasks in high density, covering the entire WLAN of a stadium through a single platform and in a variety of table and graph formats.

In the example of a high-density area such as the press box, Omnivista Cirrus 10 already generates a number of interesting statistics on the APs and RF ("Network Analytics" menus), including:

- AP uptime
- CPU usage
- Memory and flash usage
- Client distribution accross used channels
- Channel usage

Statistics on connection mode of Omnivista Cirrus 10 ("Client Analytics" and "QoE" menus) provide information on:

- Time on connections (with failure reasons)
- Roaming behavior of clients
- Coverage quality
- Successful connections

These statistics can be complemented by statistics on applications: users access to domains/URLs, users connections across high-density SSIDs, user access through captive portal, connections times for visitors or the number of devices per user.

In the case of a VHD area in a very confined space such as the press box, all these statistics can be grouped into a single dashboard ("Custom Dashboard" menu), entirely customized for the use of this area. In the example the tools grouped for the area include:

- Top N clients for the press box
- Categorization of clients for the box
- Bandwidth consumption
- Number of successful connections
- Usage of channels
- List of channels and APs in the box
- CPU and memory usage for box APs

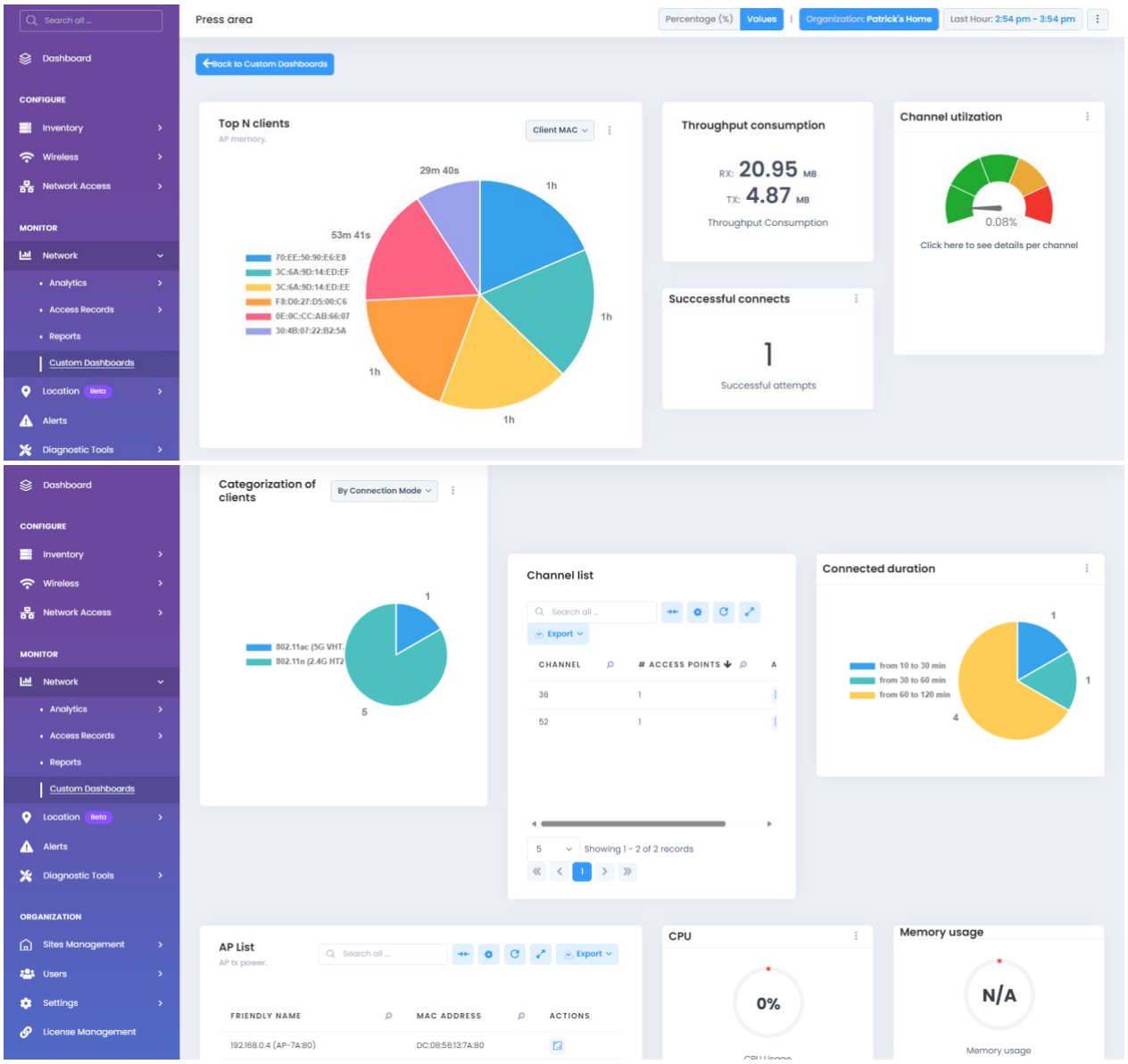

Figure 16: Press box dashboard with Omnivista Cirrus 10

Omnivista Cirrus 10 is enhanced (version 10.4.1+) with WLAN heatmap tool and specifically with a client density map tool (“location” menus) allowing for a quick overview of the complete WLAN coverage of the site and the current WLAN usage for a particular area.

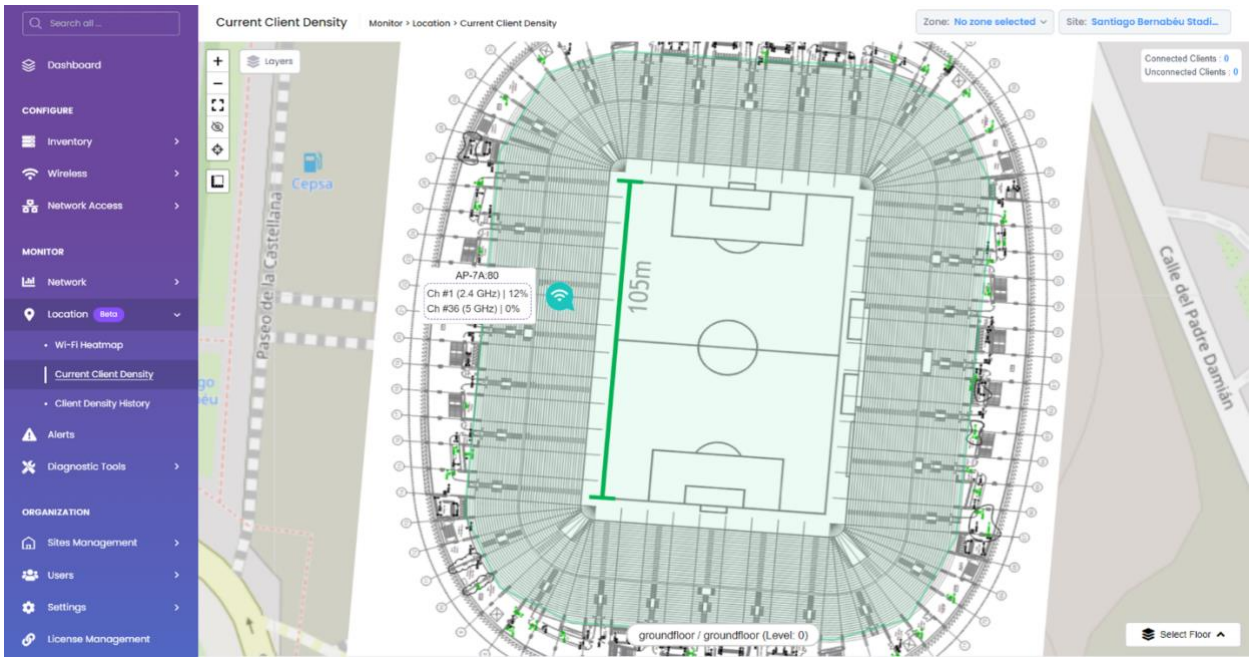

Figure 17: Client density analytics (beta) with Omnivista Cirrus 10

Achieving a QoE score and maintaining control over the density of certain Wi-Fi coverage areas is essential for the maintenance of a high-density WLAN with a large user base, and Omnivista Cirrus 10 fully meets these requirements.

5. Conclusion

In conclusion we have emphasized the importance of a well-planned WLAN network design project that encompasses capacity planning, access point selection, and optimal placement for deploying a high-density Wi-Fi network using OmniAccess Stellar access points, with a specific focus on the challenging environment of modern stadiums. We have outlined the best practices for such deployments, recognizing the unique requirements of these spaces, including extensive seating, a significant number of access points, and the need for various wireless services.

To ensure reliable and robust connectivity in high-density scenarios, it is crucial to implement a dedicated network architecture managed by the ALE network solution in Enterprise mode. This approach is recommended to address the specific demands of stadium environments.

We have recommended a thorough consideration of RF management, the types of clients and applications, and the benefits of using Wi-Fi 6 access points to meet the connectivity needs of stadiums. This combination of factors is essential for success in deploying a high-density Wi-Fi network in challenging conditions.

Furthermore, the use of advanced analytics provided by Omnivista Cirrus 10 offers valuable insights into quality of experience and application analytics. These insights are indispensable for maintaining a high-quality, high-density network, ensuring seamless connectivity for thousands of users in stadium environments.

A careful planning, network architecture, RF management, and advanced analytics are keys to successfully implement and manage high-density Wi-Fi networks in stadiums. These practices are vital to guaranteeing a seamless and reliable experience for users in such demanding conditions.

6. Annexes

The following templates are provided here as recommendations and are subject to adaptation based on the project's requirements. Here our example applies to the channels used in France in the 5GHz band for enterprise Wi-Fi and is transposable worldwide according to the channels defined for the country.

We will delve into fine-tuning Stellar for two SSIDs examples:

- One for stadium visitors (HD), including halls and press rooms (VHD) and using DFS channels (UNII-2 extended – channels 100 to 140)
- One for equipment and video surveillance using non-DFS channels (UNII-1 and UNII-2 – channels 36 to 64)

6.1 Appendix A – Fine tuning for guests

RF profile

Setting	Default	Guidelines
Band Steering	Disabled “OFF”	For very high-density deployment, this attribute is recommended to be ***enabled***.
Force 5GHz	Disabled	This functionality is recommended to be ***enabled*** for environments where the client population is dense. When enabled it will reject all association requests on the 2.4Ghz band.
Association RSSI Threshold	Disabled “0”	Recommended to be ***enabled*** for both 2.4Ghz and 5Ghz bands and set a minimum RSSI threshold of **22** which translates to **-74 dBm** (using -96 dBm as base noise floor).
Dynamic Load Balance	Disabled “OFF”	Recommended to be ***enabled*** to enable load balancing between neighboring APs
Airtime Fairness	Disabled “Both Bands”	Recommended to be ***enabled***, the newer devices will take advantage of these advanced features through the support of the new standards in a fair manner since they will have equal airtime as older devices while using faster processors, new wi-fi standards, etc.
Background Scanning	Enabled “ON”	Recommended to stay **enabled**: Background scanning is used to examine the radio frequency environment in which the wireless network is operating, discover neighbor APs, and identify interference and attacks. Background scanning is the basis of some advanced features such as: WIPS, Radio Dynamic Adjustment (ACS/APC) etc.
Scanning Channel	“Working Channel”	Wi-Fi 6 APs perform their scan on a dedicated radio chipset, and "***Working channel and Non-working Channel***" operating mode must be selected to make this radio operational.

DRM Time Control	Disabled “OFF”	Recommended to be ***enabled*** in a high-density environment. As the DRM feature makes dynamic changes and channel and power adjustments that could impact the channel plans, it is preferable that these are made outside of heavy load periods during events.
DRM Start Time	Disabled “00:00”	**02:00** setting will start the DRM feature at 2am, it will stop it 6h later by default
Band	“2.4G, 5G all, 5G low, 5G high, 6G” All selected	All bands are selected by default for their management, each AP model applies the adaptations made for each: Dual-band models: 2.4G, 5G all Tri-radio models: 2.4G, 5G low, 5G high
Channel DRM	5G All “OFF” 5G Low “OFF” 5G High “OFF”	Recommended to be ***enabled*** for 5GHz all (or 5GHz low and 5GHz high for the tri-radio model) to manage properly these bands in high density.

CSA	Enabled “ON”	The CSA (Channel Switch Announcement) in high-density WLAN must stay ***enabled*** when using DFS channels to allow Wi-Fi devices to detect the presence of radars and switch channels to avoid interference and comply with regulations.
Channel List	0 selected	Only supported when “Channel DRM” for 5G bands is enabled. A ***channel plan for France with DFS*** can include for example all DFS UNII-2 channels and UNII-3 channels (i.e. channels 100 to 165)
Channel Width	Enabled “Auto”	Recommended to select the ***20MHz*** band width for WLAN in very high-density for both 2.4G and 5G bands
Minimum TX Power(dBm)	Disabled “configurable range from 3-40 dBm”	For very high-density RF, this parameter is recommended to be set at minimum Tx at ***6 dBm*** for 2.4GHz and ***12 dBm*** for 5GHz bands.
Maximum TX Power(dBm)	Disabled “configurable range from 3-40 dBm”	For very high-density RF, this parameter is recommended to be set at maximum Tx power at ***12 dBm*** for 2.4GHz and ***18 dBm*** for 5GHz bands.
External Antennas Gain(dBi)	Enabled “configurable range from 1-16 dBm”	Only applicable to APs supporting external directional antennas ie. AP1322 (AP1362 also but does not apply for visitors areas in general).
Beacon Interval(ms)	Enabled “100” ms	This indicates how often the 802.11 beacon management frames are transmitted by the AP, the configurable range is from 60-500ms. Default value of ***100 ms*** is sufficient in most cases and can be increased to 150ms if network load is considered really high.

SSID

Setting	Default	Guidelines
SSID Setting		
Usage	Guest Network (open or CP)	Users to go through a Captive Portal to be ***enabled***
Allowed Band	2.4GHz and 5GHz selected	Keep the default selection due the mix of clients visiting in very high-density
Roaming Controls		
FDB Update on Association	Disabled	Overall, 802.11k and 802.11v roaming options aren't necessary, given the mix of devices and the ability of each to handle this type of protocol, it's preferable for devices to stick to a better AP in the worst-case scenario. However, FDB update can be ***enabled*** to allows the switches' forwarding table be updated when devices are moving across APs.
Client Controls		
Max Number of Clients Per Band	"64"	The number of clients that can be associated with a radio in the case of very high density and high client concentration can be very high in the case of guests; the recommended value is ***128 client max*** for this type of SSID.
802.11b Support	Enabled	Can only stay enabled when the 802.11a/g setting is enabled. Recommended to be ***disabled*** by default.
Minimum Client Data Rate Controls		
2.4GHz Minimum Client Data Rate Controller	Disabled	Recommended to be ***enabled.***
2.4GHz Minimum Client Data Rate	Disabled	Recommended to be ***enabled,*** setting the value at **6 Mbps**.
5GHz Minimum Client Data Rate Controller	Disabled	Recommended to be ***enabled.***

5GHz Minimum Client Data Rate	Disabled	Recommended to be ***enabled,*** setting the value at **12 Mbps**.
Minimum MGMT Rate Controls		
2.4GHz Minimum MGMT Rate Controller	Disabled	Recommended to be ***enabled.***
2.4GHz Minimum MGMT Rate	Disabled	Recommended to be ***enabled,*** setting the value at **6 Mbps**
5GHz Minimum MGMT Rate Controller	Disabled	Recommended to be ***enabled.***
5GHz Minimum MGMT Rate	Disabled	Recommended to be ***enabled,*** setting the value at **12 Mbps**

Settings	Default	Guidelines
Bandwidth Contract		
Upstream Bandwidth	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Downstream Bandwidth	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Upstream Burst	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Downstream Burst	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Broadcast/Multicast Optimization		
Broadcast Key Rotation	Disabled	For security purposes and for broadcast handling optimization, this attribute recommended to be ***enabled***.
Broadcast Filter All	Disabled	Recommended to be ***enabled*** to help alleviate issues with certain devices that have issues with dynamic frequency selected channels. Apple and Google design documents recommend 5GHz only SSIDS to support these devices.
Broadcast Filter ARP	Disabled	Recommended to be ***enabled***. for the same reasons explained above.
802.1p Mapping		
Uplink/Downlink 802.1p markings for AC_BK, AC_BE, AC_VI, AC_VO categories	802.1p default values	In general 802.1p marker values are those usually used by default for such use case. But can be always adapted especially for AC video category, if required for guest applications with video.
DSCP Mapping		
Trust Original DSCP	Disabled	The original DSCP can be trusted for all uplink traffic returning to the network. Recommended to be ***enabled***
Uplink/Downlink DSCP markings for AC_BK,	DSCP default values	In general DSCP marker values are those usually used by default for such use case. They can be always adapted or some values added if required.

AC_BE, AC_VI, AC_VO categories		

AP Group

Setting	Default	Guidelines
SSH		
SSH Login	Disabled “OFF”	Recommended to be ***enabled*** SSH console is used for rooftop stadium APs which could not be routinely dismounted during maintenance, ensuring their efficient access and management.
Client Behavior Tracking		
Upload To SFTP/TFTP Server	Disabled “OFF”	Recommended to be ***enabled*** for configuring Wi-Fi log collection to record user behavior for compliance with local regulations. Logs are securely transferred via SFTP located in the stadium's Data Center at a defined frequency.
SNMP Setting		
SNMP Agent	SNMP and Trap Service “OFF”	Recommended to be ***enabled*** SNMP is employed to gather and organize access point information, as well as monitor the activity of access points registered within the Omnivista 2500.

6.2 Appendix B – Fine tuning for equipment/video surveillance

RF profile

Setting	Default	Guidelines
Band Steering	Disabled “OFF”	For very high-density deployment, this attribute is recommended to be ***enabled***.

Force 5GHz	Disabled	This functionality is recommended to be ***enabled*** for environments where the client population is dense. When enabled it will reject all association requests on the 2.4Ghz band.
Association RSSI Threshold	Disabled “0”	Recommended to be ***enabled*** for both 2.4Ghz and 5Ghz bands and set a minimum RSSI threshold of **22** which translates to **-74 dBm** (using -96 dBm as base noise floor).
Dynamic Load Balance	Disabled “OFF”	Recommended to be ***enabled*** to enable load balancing between neighboring APs
Airtime Fairness	Disabled “Both Bands”	Recommended to be ***enabled***, the newer devices will take advantage of these advanced features through the support of the new standards in a fair manner since they will have equal airtime as older devices while using faster processors, new wi-fi standards, etc.
Background Scanning	Enabled “ON”	Recommended to stay **enabled**: Background scanning is used to examine the radio frequency environment in which the wireless network is operating, discover neighbor APs, and identify interference and attacks. Background scanning is the basis of some advanced features such as: WIPS, Radio Dynamic Adjustment (ACS/APC) etc.
Scanning Channel	“Working Channel”	Wi-Fi 6 APs perform their scan on a dedicated radio chipset, and "***Working channel and Non-working Channel***" operating mode must be selected to make this radio operational.
DRM Time Control	Disabled “OFF”	Recommended to be ***enabled*** in a high-density environment. As the DRM feature makes dynamic changes and channel and power adjustments that could impact the channel plans, it is preferable that these are made outside of heavy load periods during events.
DRM Start Time	Disabled “00:00”	**02:00** setting will start the DRM feature at 2am, it will stop DRM 6h later by default

Band	“2.4G, 5G all, 5G low, 5G high, 6G” All selected	All bands are selected by default for their management, each AP model applies the adaptations made for each: Dual-band models: 2.4G, 5G all Tri-radio models: 2.4G, 5G low, 5G high
Channel DRM	5G All “OFF” 5G Low “OFF” 5G High “OFF”	Recommended to be ***enabled*** for 5GHz all (or 5GHz low and 5GHz high for the tri-radio model) to manage properly these bands in high density.

Channel List	0 selected	Only supported when “Channel DRM” for 5G bands is enabled. A ***channel plan for France with non DFS*** can include for example all non DFS UNII-1 channels and DFS UNII-2 first channels (i.e. channels 36 to 64)
Channel Width	Enabled “Auto”	Recommended to select the ***20MHz*** band width for WLAN in very high-density for both 2.4G and 5G bands
Minimum TX Power(dBm)	Disabled “configurable range from 3-40 dBm”	For very high-density RF, this parameter is recommended to be set at minimum Tx at ***6 dBm*** for 2.4GHz and ***12 dBm*** for 5GHz bands.
Maximum TX Power(dBm)	Disabled “configurable range from 3-40 dBm”	For very high-density RF, this parameter is recommended to be set at maximum Tx power at ***12 dBm*** for 2.4GHz and ***18 dBm*** for 5GHz bands.
External Antennas Gain(dBi)	Enabled “configurable range from 1-16 dBm”	Only applicable to APs supporting external directional antennas ie. AP1322 or AP1362.
Beacon Interval(ms)	Enabled “100” ms	This indicates how often the 802.11 beacon management frames are transmitted by the AP, the configurable range is from 60-500ms. Default value of ***100 ms*** is sufficient in most cases for RF designed for equipment/video.

SSID

Setting	Default	Guidelines
SSID Setting		
Usage	Guest Network (open or CP)	Protected Network (Pre-Shared Key & optional Captive Portal) to be ***selected***
Allowed Band	2.4GHz and 5GHz selected	Keep the default selection
Encryption Type	WPA2_PSK_AES	Keep the default selection
PSK/Passphrase	Passphrase to confirm	Enter up to 63 characters passphrase
Client Controls		
802.11b Support	Enabled	Can only stay enabled when the 802.11a/g setting is enabled. Recommended to be ***disabled*** by default.
Minimum Client Data Rate Controls		
2.4GHz Minimum Client Data Rate Controller	Disabled	Recommended to be ***enabled.***
2.4GHz Minimum Client Data Rate	Disabled	Recommended to be ***enabled,*** setting the value at **6 Mbps**.
5GHz Minimum Client Data Rate Controller	Disabled	Recommended to be ***enabled.***
5GHz Minimum Client Data Rate	Disabled	Recommended to be ***enabled,*** setting the value at **12 Mbps**.
Minimum MGMT Rate Controls		
2.4GHz Minimum MGMT Rate Controller	Disabled	Recommended to be ***enabled.***

2.4GHz Minimum MGMT Rate	Disabled	Recommended to be ***enabled,*** setting the value at **6 Mbps**
5GHz Minimum MGMT Rate Controller	Disabled	Recommended to be ***enabled.***
5GHz Minimum MGMT Rate	Disabled	Recommended to be ***enabled,*** setting the value at **12 Mbps**

Settings	Default	Guidelines
Bandwidth Contract		
Upstream Bandwidth	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Downstream Bandwidth	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Upstream Burst	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Downstream Burst	Disabled	Configurable in 'Kbits/s' from 0-2621440 (Based on application parameters)
Broadcast/Multicast Optimization		
Broadcast Key Rotation	Disabled	For security purposes and for broadcast handling optimization, this attribute recommended to be ***enabled***.
Broadcast Filter All	Disabled	Recommended to be ***enabled***
Broadcast Filter ARP	Disabled	Recommended to be ***enabled***. for the same reasons explained above.
Multicast Optimization	Disabled	Recommended to be ***enabled*** to allow efficient management of video streaming for a group of wireless cameras for example. It offers the possibility of converting multicast data packets into unicast data packets for wireless video transmissions.
802.1p Mapping		

Uplink/Downlink 802.1p markings for AC_BK, AC_BE, AC_VI, AC_VO categories	802.1p default values	802.1p marker values are those usually used by default for such use case. But can be always adapted especially for AC video category defined for the stadium
DSCP Mapping		
Trust Original DSCP	Disabled	The original DSCP can be trusted for all uplink traffic returning to the network. Recommended to be ***enabled***
Uplink/Downlink DSCP markings for AC_BK, AC_BE, AC_VI, AC_VO categories	DSCP default values	DSCP marker values are those usually used by default for such use case. They can be always managed or some values added if required for the stadium

AP Group

Setting	Default	Guidelines
SSH		
SSH Login	Disabled "OFF"	Recommended to be ***enabled*** SSH console is used for rooftop stadium APs which could not be routinely dismounted during maintenance, ensuring their efficient access and management.
SNMP Setting		
SNMP Agent	SNMP and Trap Services "OFF"	Recommended to be ***enabled*** SNMP is employed to gather and organize access point information, as well as monitor the activity of access points registered within the Omnivista 2500.
Miscellaneous		
IGMP Snooping	Disabled "OFF"	Recommended to be ***enabled*** IGMP Snooping enables the switches to direct multicast traffic only to the ports where wireless cameras of the group are located, thus reducing the load on the WLAN network.

6.3 Appendix C – Bill Of Material

We give here an example of list of material that could be provided for the wireless LAN of a stadium with over 40,000 seats. The stadium has over 40,000 seats for visitors on a 20,000 m² surface spread over two levels, 16,000 m² of facilities, halls and concession indoors and 50 seats for a press box. A full 5-years support is provided for the WLAN solution for this stadium and HW/SW support is included in the list.

For the wireless LAN of this stadium, we have provided a total of 454 access points, distributed as follows:

- 262 access points for seating areas.
- 192 access points for indoor and outdoor areas, including:
    - 160 access points for facilities and halls
    - 2 access points for the press box
    - 30 outdoor APs for equipment and video.

Note that this BOM does not include: NEMA enclosures, servers appliances, DHCP/DNS servers appliances, LAN hardware, LAN core and satellites.

Model	Description	Quantity
Outdoors, equipment		
OAW-AP1361-RW	OmniAccess Stellar Outdoor AP1361. Dual radio 5GHz 4x4:4 / 2.4GHz 2x2:2 802.11ax, integrated omni. 1x1 scanning radio and BLE radio. 2.5GbE, 1GbE, 1GbE SFP, USB, 48V DC. AP mount order seperately. Not for use in US, Egypt, Israel, Japan	30
SW5N-OAWAP1360	5 Yr End Customer Support Software for OAW-AP1360 series. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	30
AP-MNT-OUT	Outdoor mount kit (Pole/Wall). Standard configuration in the AP1251 product packaging. Applicable for OmniAccess Stellar AP1251, AP136x Outdoor series.	30
SW5R-OAWAP1360	5 Yr Renew End Customer Support Software for OAW-AP1360 series	30
Seats tier 1		
OAW-AP1322-RW	OmniAccess Stellar Indoor AP1322. Dual radio 5GHz 4x4:4 / 2.4GHz 2x2:2 802.11ax, external antenna connectors. 1x1 scanning radio and BLE radio. 1x 2.5GbE, 1x 1GbE, USB, 48V DC. AP mount order seperately. Not for use in US, Egypt, Israel, Japan	104
ANT-S-M4-30	Single band 5GHz, 4-element, Wall-mount, sector antenna , 13dBi, H-Plane 37°, E-Plane 37°, includes 4* 30-35in RF cable (SMA-J/RPSMA-J), includes mount	104
OAW-AP-MNT-W	Mounting kit, Type A wall mount and ceiling mount with screws. Applicable for OmniAccess Stellar AP1101, AP12xx and AP13xx Indoor series.	104
SW5N-OAWAP1320	5 Yr End Customer Support Software for OAWAP 1320 Series. Includes 24x7 phone support, problem	104

	diagnosis, access to support portal, software updates and upgrades.	
SW5R-OAWAP1320	5 Yr Renew End Customer Support Software for OAW-AP1320 Series. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	104
Seats tier 2		
OAW-AP1322-RW	OmniAccess Stellar Indoor AP1322. Dual radio 5GHz 4x4:4 / 2.4GHz 2x2:2 802.11ax, external antenna connectors. 1x1 scanning radio and BLE radio. 1x 2.5GbE, 1x 1GbE, USB, 48V DC. AP mount order seperately. Not for use in US, Egypt, Israel, Japan	160
ANT-S-M4-60	Dual band 2.4/5GHz, 4-element, Wall-mount, sector antenna , >5dBi, 60Hx60V 1x) includes 4* 30-35in RF cable	160
OAW-AP-MNT-W	Mounting kit, Type A wall mount and ceiling mount with screws. Applicable for OmniAccess Stellar AP1101, AP12xx and AP13xx Indoor series.	160
SW5N-OAWAP1320	5 Yr End Customer Support Software for OAWAP 1320 Series. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	160
SW5R-OAWAP1320	5 Yr Renew End Customer Support Software for OAW-AP1320 Series. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	160
HD indoors		
OAW-AP1331-RW	OmniAccess Stellar Indoor AP1331. Dual radio 2.4/5Ghz 4x4+4x4 802.11ax, with integrated omni antenna. 1x1 scanning and BLE radio. 2x 5GE up, 1x RS-232 Console, USB, 48V DC. AP mount to be ordered separately. Not for use in US, Egypt, Israel, Japan.	160
SW5N-OAWAP1331	5 Yr End Customer Support Software for OAWAP1331.	160

	Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	
SW5R-OAWAP1331	5 Yr Renew End Customer Support Software for OAWAP1331. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	160
Press box		
OAW-AP1351-RW	OmniAccess Stellar Indoor AP1351. Tri radio 2.4 + Dual 5Ghz 4x4+8x8+4x4 802.11ax, omni antenna. 1x1 scanning and BLE radio. 2x 10GE up, 1x RS-232 Console, USB, 48V DC. AP mount to be ordered separately. Not for use in US, Egypt, Israel, Japan.	2
SW5N-OAWAP1351	5 Yr End Customer Support Software for OAWAP1351. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	2
SW5R-OAWAP1351	5 Yr Renew End Customer Support Software for OAWAP1351. Includes 24x7 phone support, problem diagnosis, access to support portal, software updates and upgrades.	2
Omnivista 2500		
OV4-START-NEW	OV4-START-NEW -OV2500 NMS-Starter Pack-NEW R4. Incl 10 ALU-E device lic. 1xlic. /switch in stack/VC config) 10 3rd Party Lic. 1x lic. / mgmt IP) VMM lic. for 10vm, 10 AP, 10GA, 10 BYOD licenses. Use add EX parts for add. config. Req. online activ.	1
OV-AP-NM-100-N	OV-AP-NM-100-N OV2500 NM R4 Lic - Lic. 100 AP-NEW for 100 ALU-E Stellar AP lic. (1lic. /Stellar AP)-Covers all Stellar AP models (11, 12xx & 13 series). Apply to OV2500 Serv. Pack NEW. Used w/other NM ext. NEW for adequate config. Act. Online	5
OV-GA-5K-N	OV-GA-5k-N - OV2500 GA R4 Lic. - Lic. 5000 GA NEW for Guest Access Policy Manager enable 5000	3

	Guest Access concurrent active devices on ALU-E Network. Used w/other GA ext. NEW for adequate config. Act. Onlin	
OV4-NMS-HA	OV4-NMS-HA - OmniVista 2500 HA (High Avaibility) Software license . Apply to OV2500 Serv. Pack NEW. Provide HA services for Single Instance OV2500 NMS platform including UPAM Service. Required Min OV4.3r1 to operate. Act. Online	1
SW5N-OV4START	5YR 24x7 SUPPORT SOFTWARE for OV4-START-NEW / OV4-START-UPG. Incl. 24x7 Remote TEL. Supt., 24x7 Remote Problem Diagnosis, SW. Update, / access to supt. portal. If MAINT. is ordered on one OV R4 Model No needed on all OV Model No for each OV server.	1
SW5N-OVAPNM100N	5YR 24X7 SUPPORT Software for OV2500 NMS - RELEASE 4 OV-AP-NM-100-N. Includes 24x7 Remote Tel Support, Problem Diagnosis, SW Updates, Support portal access Maintenance to be ordered on all OV Model No for each OV server.	5
SW5R-OV4START	5YR Renewal SUPPORT Software OV4-START-NEW and OV4-START-UPG.One must submit $0 PO. If MAINT. is ordered on one OV Release 4 Model No it is needed on all OV Model No for each OV server.	1
SW5R-OVAPNM100N	5YR Renewal SUPPORT Software for OV2500 NMS - RELEASE 4 OV-AP-NM-100-N. Includes 24x7 Remote Phone Support, Problem Diagnosis, SW Updates, Support portal access Maintenance to be ordered on all OV Model No for each OV server.	5
SW5R-OVGA5KN	5YR Renewal SUPPORT Software for OV2500 NMS - RELEASE 4 OV-GA-5K-N. Includes 24x7 Remote Phone Support, Problem Diagnosis, SW Updates, Support portal access Maintenance to be ordered on all OV Model No for each OV server.	3
SW5R-OV4NMS-HA	5YR Renewal SUPPORT Software for OV2500 NMS - RELEASE 4 OV4-NMS-HA. Includes 24x7 Remote	1

	Phone Support, Problem Diagnosis, SW Updates, Support portal access Maintenance to be ordered on all OV Model No for each OV server.	

6.4 Appendix D – Related documents

https://www.al-enterprise.com/-/media/assets/internet/documents/omniaccess-stellar-wireless-fine-tuning-best-practices-techbrief-en.pdf
or search '*best practices fine-tuning stellar*' on https://www.spacewalkers.com