Sectored Wi-Fi™ Architecture

BENEFITS

November, 2005

XIRRUS

Executive Summary

There are many problems that legacy Omni-directional access points have in creating high performance Wi-Fi™ networks. Xirrus has delivered a sectorized approach to Wi-Fi networking through the Wireless LAN Array. The Xirrus Wireless LAN Array provides the bandwidth and capacity benefits of channel re-use, elimination of hidden nodes, reduced multi-path, and enhanced RF performance inherent to a sectored architecture.

Introduction

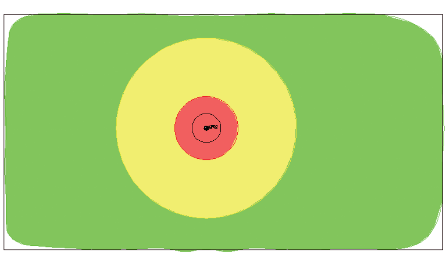
IT Administrators are facing an ever-increasing demand for wireless capacity (bandwidth). With the increased number and types of devices and new applications such as voice, current enterprise Wi-Fi networks will not scale to meet these demands.

This White Paper details the issues surrounding the use of legacy Omni-directional access points that populate today's Wi-Fi networks and presents how Xirrus' sectorized Wireless LAN (WLAN) architecture addresses these issues; creating a high-performance, scalable Wi-Fi network.

Omni-Directional and Sectored Antennas

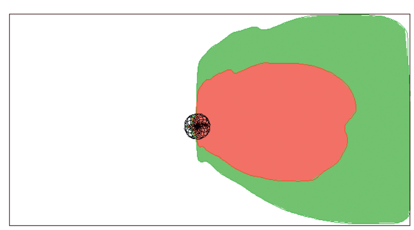
Most legacy access points today make use of Omni-directional antennas. Omni-directional antennas transmit and receive RF energy in all directions much like a light bulb. Sectorized antennas (also known as "high-gain" antennas) focus RF energy into a single direction, thereby intensifying the strength of the signal that is transmitted much like a flashlight directing a strong beam of light in the direction that it is pointed. Another physical property of high-gain sectored antennas is the ability to transmit further and "listen better" to the signals of wireless stations (clients). Some sectored antenna systems have multiple radios and multi-sectored or sectorized antennas that allow for 360 degrees of coverage.

Omni-directional Antenna Pattern



Shown from the top down

Sectored Antenna Pattern



Shown from the top down

Omni-directional Access Point Problems

The vast majority of access point deployments today consist of products that use omni-directional antennas. For the most part, this type of deployment has served the market well for home use and light use in the enterprise. But as the number of wireless users has dramatically increased and the number of access points deployed to meet the needs of users increases, the omni-directional antenna becomes its own worst enemy in the battle to address improved performance.

No matter what type of access point is used ("fat" or "thin") blasting RF energy in all directions becomes a barrier to the performance needed for today's wireless networks. This problem consists of a number of issues that all limit high-performance deployments: cell size, channel reuse, hidden nodes and multi-path. These problems become even more acute with Omni-directional access points, and are described in the following sections.

Cell Size and Co-channel Interference

In early wireless LAN deployments, coverage was king and little attention was paid to capacity. What was soon realized is that the larger the "cell", the more users you had connected to the same access point. Acceptable performance became quickly problematic. Providing acceptable levels of performance (capacity) is important and with data rates of 54Mbps per access point (and real-world throughputs of about 22Mbps), only 10-12 active users can be handled per access point.

One common approach to increasing capacity is to simply add more access points on different channels and to make sure that any two access points that are on the same channel cannot hear each other. Adjacent cells must be on different channels (or clients from one cell will wait for clients on another cell before transmitting), therefore careful channel planning needs to be done with the limited number of non-overlapping channels available (3 802.11b/g channels, and 12 802.11a channels).

The next most widely used approach to increase capacity is to try to use smaller and smaller cell sizes to increase the number of cells (access points) where one re-uses the limited set of non-overlapping channels more often. Smaller cells also allow higher sustained data rates to be used. While these approaches are commonly used, they create a number of major issues.

First, shrinking the cell size of an access point by lowering the transmit power **does not lower the transmit power of the wireless station (client).** Second, the client's transmit power and receiver settings are not under the control of the access point and do not change. By decreasing the transmit power of the access point, the overall cell size shrinks only slightly and anyone deploying a wireless network must realize that the real size of a wireless cell is not just the transmission range of the access point. In fact, **the real size of a wireless cell is the transmission range of the access point and the transmission range of all the wireless clients in that cell.**

Extended Cell Size

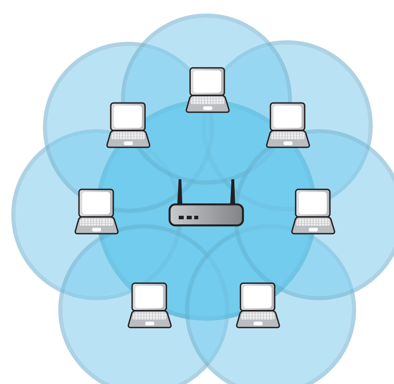


Figure 1: The true size of a Wi-Fi cell is determined by the access point and the wireless clients in the cell

This concept of the "extended cell" is very important because it sets a limit on how small cells can really be. This is why some recent solutions prescribe the placement of an access point in every cubicle and turning its transmit power down. However, this solution won't work as the wireless stations (clients) will transmit right over the top of any adjacent access points. In fact, cell sizes should only (at most) be half as small as the transmission range of the wireless clients; any smaller and the wireless stations will bleed over to at least two cells over.

Shrinking a Cell

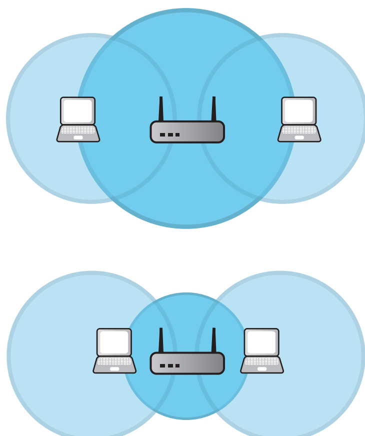


Figure 2: Decreasing the access point's cell size only slightly decreases the transmit range of the "extended" cell

Because of the collision avoidance scheme that governs data transmissions in an 802.11 network, clients and access points will wait until the medium is free before attempting to transmit their own packets. Additional access points that are deployed within range of other access points on the same channel will not add any additional capacity. Access points or clients that can "hear" each other will result in them waiting for the other transmitter to cease before attempting to transmit their own packets. In effect, adding more access points on the same channel simply causes the cells to "merge" into a larger cell which actually degrades performance.

Interfering Stations

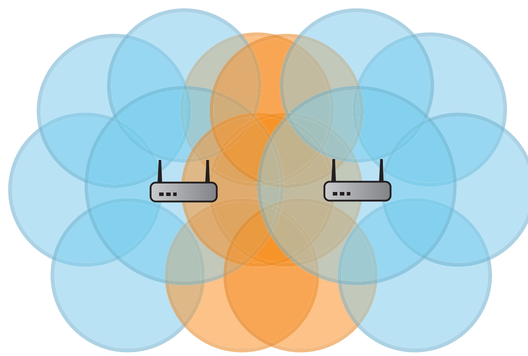


Figure 3: When two access points are placed near each other on the same channel, they may not hear each other but the stations (clients) that associate to those access points will interfere with stations on the adjacent cell and vice versa. Interfering stations are shown in orange [top]

IT administrators need to have at least one cell on another channel between cells on the same channel (in all directions) and make the cells large enough so that wireless stations within those cells do not hear each other. This required distance between cells sets a hard limit to the amount of capacity that can be provided.

Minimum Cell Spacing

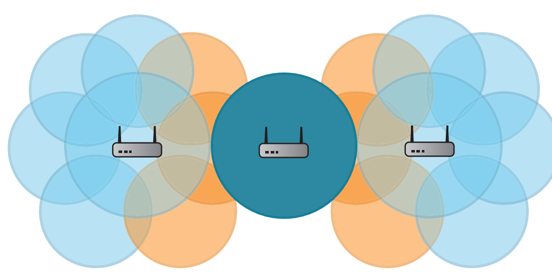


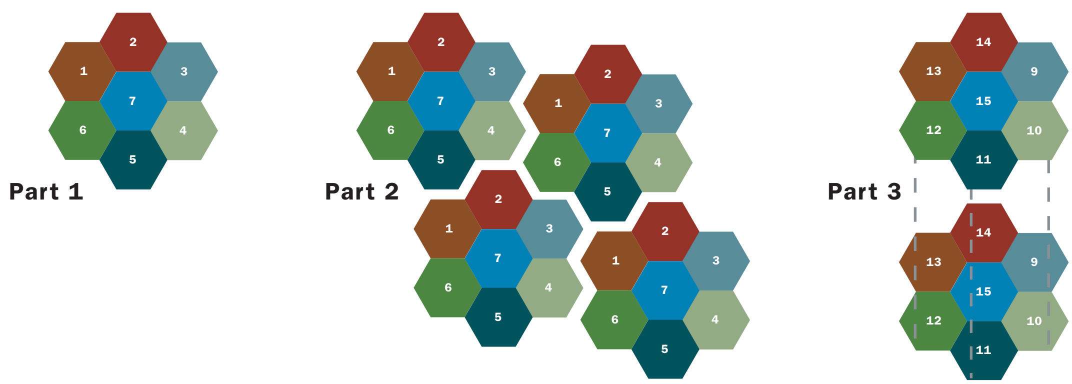
Figure 4: Access points on the same channel must have at least one cell between them so wireless stations cannot hear each other

Adding Capacity and Bandwidth

As the previous section pointed out, using omni-directional access points requires careful planning to have at least one cell between other cells on the same channel. This gets tricky with the limited number of non-overlapping channels available.

Having cells laid out on separate channels like those in Part 1 below, allows for seven cells to be on a unique channel (this is referred to a re-use pattern of 7). This pattern can be repeated over and over without interference between client stations or access points (Part 2 below). If needed, the number of access points in each cell can be doubled by assigning them a completely different set of channels. This requires fourteen unique channels (Part 3 below).

Channel Assignment and Re-use



The issue of adding more bandwidth (capacity) becomes clear because there are only 12 802.11a and 3 802.11b/g non-overlapping channels that can be used to create cells. Given this, in terms of adding capacity, one can only double the number of channels in each cell to add capacity (12 + 3 = 15 channels; 15 channels/ 7 channels per reuse = 2 access points per cell). This also assumes that all the client adapters are 802.11a/b/g capable (as is the current trend).

At best, deployments using Omni-directional access points can at most, **in a repeatable pattern,** provide about 108Mbps per cell of wireless capacity (54Mbps of real throughput). In a typical cell that could handle 70 or more users; only 500Kbps of bandwidth is provided to each user. Far less capacity is available if 802.111b/g-only clients are used.

Hidden Node Problems

Omni-directional access points have another inherent problem. A wireless station on one edge of a cell may not hear a station on the other side of the cell. Because of this, wireless stations will not be able to hear when the other is transmitting, incorrectly assuming the air is idle and begin to transmit its own packets. This will cause the two transmissions to collide requiring both stations to re-transmit greatly reducing the effective bandwidth within the cell. A protection mechanism exists called CTS-RTS that can help address this issue requiring each client to ask for permission from the access point before transmitting. But the use of this protocol will reduce overall performance by 30%.

Hidden Node Problem

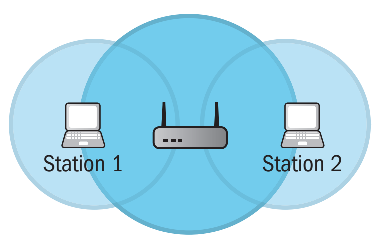
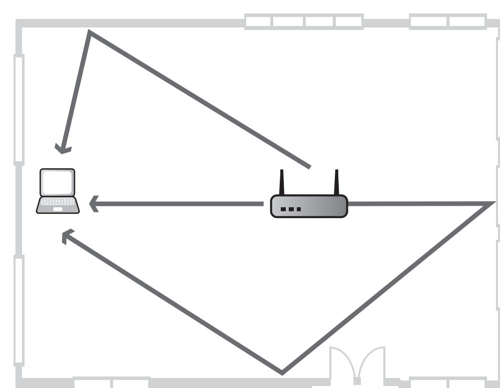


Figure 5: Station 1 and Station 2 cannot hear each other's transmissions

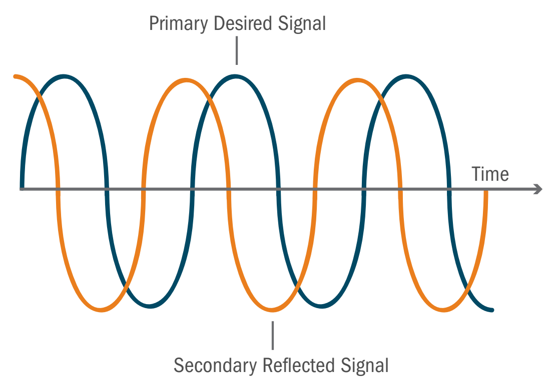
Omni-directional Access Points and Multi-path

Omni-directional access points are not only bad neighbors for adjacent cells but also generate a vast amount of performance-reducing multi-path. Multi-path occurs when signals bounce off multiple objects in the environment and are reflected back to the receiver. The effect is that weaker "copies" of the original signal arrive slightly later than the primary signal. This causes inter-symbol interference and gets worse as the "delay spread", or time between the reception of the primary signal and secondary signal increases. The end result is corrupt packets that must be re-transmitted, lowering network performance.

Multi-path Interference



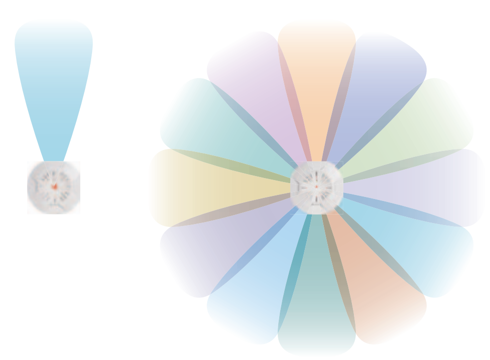
Multi-path Time Delay



The Benefits of a Sectorized Architecture

Xirrus developed the Wireless LAN Array for enterprise Wi-Fi networks using a sectored antenna system to focus RF energy into a single direction. This next generation architecture provides multiple sectors and multiple radios together in a single platform providing a 360 degree coverage pattern with extremely high capacity. Xirrus' architecture delivers a number of important advantages over legacy Omni-directional access points including high capacity channel re-use, elimination of hidden nodes and enhanced wireless performance.

Single and Multiple Sectors Covering 360°



Sectored Antenna System and Channel Re-use

A sectored approach is vastly superior to that of omni-directional access point. As the following diagrams indicate, a sectored approach creates sectors or "slices" of cell coverage. Each sector uses a unique channel and by its very design, clusters clients together on the same channel under the area of the sectorized antenna pattern. If a wireless station moves too far to the left or right of any one sector, it will automatically re-associate to the next sector.

By grouping or clustering wireless stations together, the sectored architecture creates enough separation between sectors and stations on the same channel that the entire pattern of sectors can be repeated by an adjacent Xirrus Wireless LAN Array in such a way that wireless stations do not interfere with each other.

Two Sectored Systems Side-by-Side

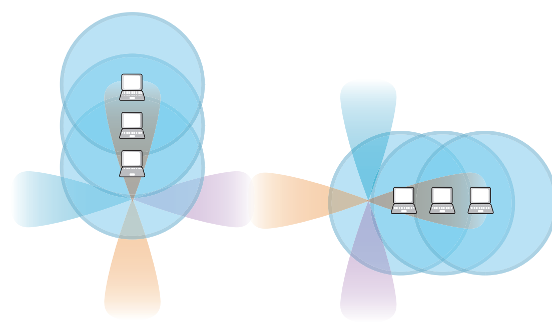


Figure 6: Stations on the same channel are isolated so that they do not interfere

Cellular network operators have long understood this benefit and make use of sectored base stations. The result of a sectorized approach is that the indoor wireless network can operate at full wireless capacity and allows an adjacent Wireless LAN Array to use the same set of channels. In fact, each Wireless LAN Array can provide up **to 810Mbps per cell** if all twelve 802.11a channels and three 802.11bg channels are used. This pattern can be used over and over. Contrast this with 108Mbps in an Omni-directional deployment, the Wireless LAN Array provides **eight times the capacity.**

Multiple Sectored Cells

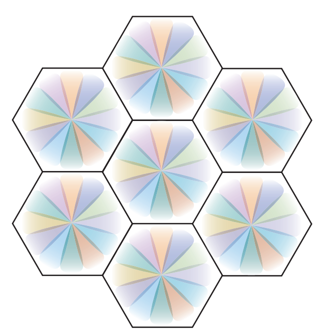
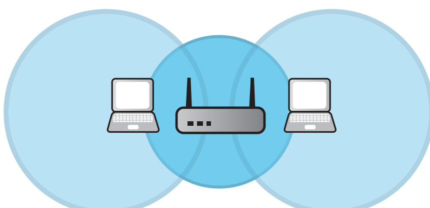


Figure 7: Multiple Sectored Cells can be deployed where each Wireless LAN Array re-uses all channels

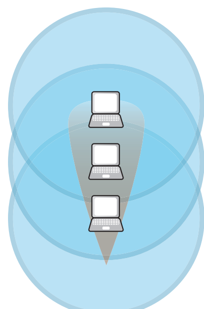
Sectored Antenna Systems and Hidden Nodes

A sectorized approach is vastly superior to that of an Omni-directional access point in eliminating Hidden Node issues because all wireless stations (clients) in a given RF sector are associated to the same radio; so they are geometrically on the same side of the Wireless LAN Array. Since the clients exist in the same sector, the hidden node problem is eliminated as all stations are able to hear each other and correctly determine when the air is busy or idle. This eliminates the performance-robbing issues found with legacy Omni-directional access points and the need to use the CTS-RTS protocol.

Omni-directional Hidden Nodes



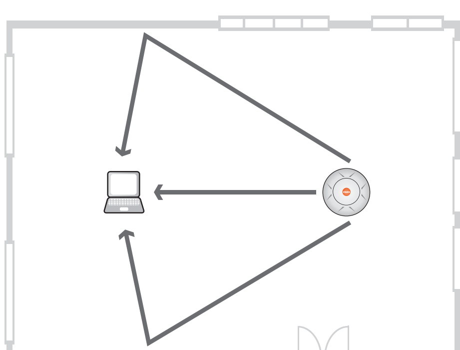
Sectored Approach Eliminates Hidden Nodes



Sectored Systems; Multi-path and Performance

As previously discussed, Omni-directional access points inherently create large amounts of performance-robbing multi-path. With a sectorized approach, this problem is greatly reduced because RF energy is not blindly transmitted in all directions. RF signals are transmitted in the direction of the wireless client within a given sector and not in the direction opposite the wireless client that would otherwise come back as distorting multi-path.

Reduced Sectored Multi-path

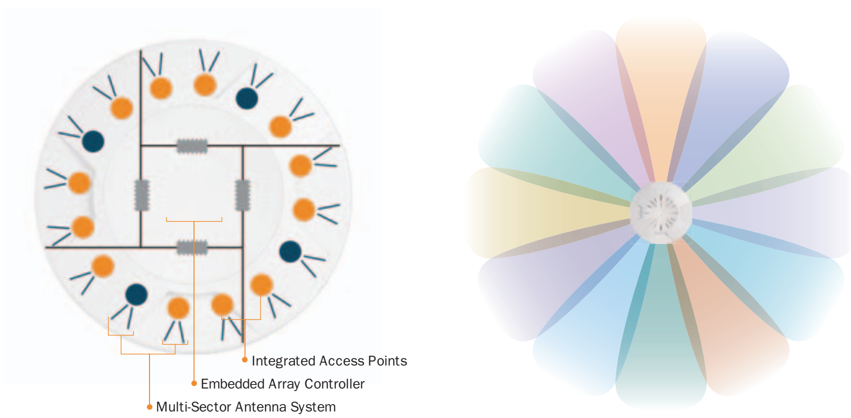


Lastly, because a sectorized antenna system typically has higher gain antennas than an Omni-directional system, it can transmit stronger signals to wireless clients and receive weaker signals from others. These increased rate and range performance metrics throughout the sectorized wireless cell results in the ability to use and sustain higher data rates at all distances within the cell improving overall wireless bandwidth.

Wireless LAN Array: A Sectorized Approach

Xirrus has delivered the most efficient use of Wi-Fi spectrum with its family of Wireless LAN Arrays. By using a sectored antenna system and solving the fundamental problem of allowing multiple Integrated Access Points to function in a single platform, Xirrus has created a new paradigm for enterprise Wi-Fi deployments. No longer do Wi-Fi networks require a sea of "inconsiderate" Omni-directional access points that limit channel reuse, create hidden node and multi-path issues that yield a poor performing network.

Wireless LAN Array: Sectorized Antenna System



Xirrus: Powerful Wi-Fi Deployments

The Xirrus approach of using a Multi-sector Antenna System has important benefits for high performance Wi-Fi deployments.

The Wireless LAN Array can create a sectorized wireless cell of up to 864Mbps (16 x 54Mbps). By integrating up to 16 separate Integrated Access Points in a single platform, Xirrus has created a solution for today and tomorrow's bandwidth intensive applications. Each Xirrus Wireless LAN Array can take the place of up to 16 separately installed legacy access points and handle hundreds of simultaneous users. Additionally, one integrated access point can be used as a dedicated full-time RF sensor for the detection of rogue access points and other security threats.

The sectorized approach of the Wireless LAN Array provides a superior level of automatic channel planning, load balancing, and station roaming. Because the Wireless LAN Array makes use of every available non-overlapping Wi-Fi channel, the best possible channel plan can automatically be used and changed as conditions change in the environment.

Xirrus eliminates re-architecting and re-deployment of the wireless network. Legacy architectures force the need to continuously re-architect, re-wire and re-deploy the wireless network and manage even more devices when additional capacity is needed. With the Wireless LAN Array, the maximum possible bandwidth is instantly provided such that you can "deploy it once and forget it".

The Wireless LAN Array allows for high density radio service at a fraction of the cost of deployment, and a fraction of the management pains of legacy products. Instead of installing large numbers of access points that each requires a power and Ethernet connection, a single Xirrus WLAN Array can be installed.

The Wireless LAN Array architecture is completely Wi-Fi interoperable. No special client devices are needed and the products support all three Wi-Fi modes: 802.11a, 802.11b, and 802.11g.

Lastly, the Xirrus approach frees IT administrators from the hassles of managing a sea of legacy omni-directional access points. The Xirrus architecture allows for a greatly reduced number of devices to manage by a factor of sixteen. The ongoing expenses of management and maintenance are costly in a Wi-Fi network, and the fewer devices to manage, maintain, troubleshoot and upgrade the better. Xirrus leads the way with extreme capacity and simplicity of deployment.

Summary

This White Paper has shown the problems with legacy Omni-directional access points and how a sectored approach solves the channel re-use, hidden node, and multi-path problems of the past. Today's legacy equipment cannot keep pace with the trajectory of needed wireless capacity. Xirrus has developed the Wireless LAN Array that utilizes a sectorized approach that puts IT administrators ahead of capacity demands, makes deployments a snap, and creates a high-performance Wi-Fi network that is simple to deploy, easy to manage and flexible enough to handle anything that gets thrown at it. ●

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