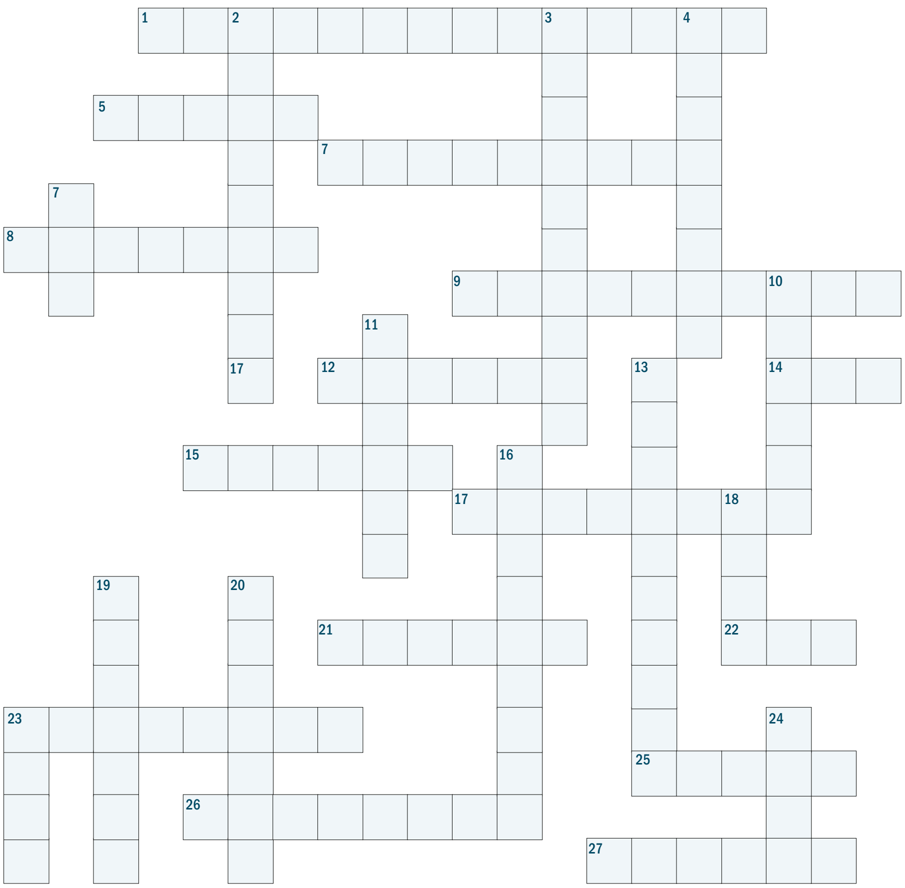
XIRRUS®

802.11a/b/g Demystified

Tutorial



Across

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Down

2. Files divided and scattered
3. Circuitry to interpret and execute
4. Opposite of transmitter
7. One-million cycles per second
10. Conveys data between points
11. 802.11 High Rate
13. Amount of data sent in a given time
16. Rate at which a repeating event occurs
18. Splits one band into many
19. Receive/send radio signal
20. Xirrus language
23. Service identifier
24. Institute of engineers

Contents

Introduction 3

Standards Overview 3

802.11 Data Rates 4

RF Interference Issues 4

Spreading Techniques 5

802.11 Channels, Capacity, and Allocation 5

802.11 b/g Channel Reuse and Cell Planning 6

802.11a Channel Reuse and Cell Planning 6

Client and Access Point Interaction 7

Frame Format 8

Summary 8

Leading Architecture 9

About Xirrus 9

Introduction

This guide will provide an overview of the 802.11a/b/g standard, including a discussion on how these standards compare in regards to bandwidth, available channels, and the impact of interference on each. Armed with this information, you will be able to more effectively plan your wireless network for today and the future, ensuring that the decisions you make today will ultimately benefit your organization over the long-term.

Standards Overview

Many people think wireless LAN, or Wi-Fi networking, is a recent technology development. Actually, the first Wi-Fi standard, 802.11, was ratified almost 10 years ago by the IEEE committee, and was designed to operate in the 2.4GHz unlicensed band known as ISM, or Industrial, Science and Medical.

A lot of effort went into the development of the MAC protocols and modulation techniques. These early standards used frequency-hopping and direct sequence methods, which was a great start, however, at that time the most that could be achieved was about 2Mbps. These speeds allowed Wi-Fi to get started, but it was soon realized that higher speed technologies would be required if Wi-Fi was to become more than just a niche technology.

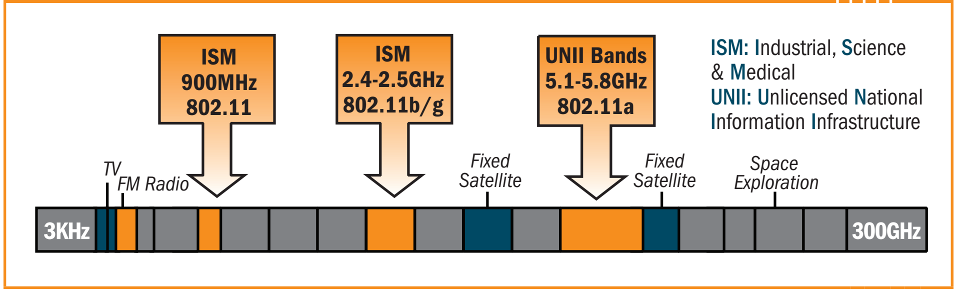
Changes weren't too long in coming, with the first amendment, known as 802.11a, being ratified in 1999. The 802.11a standard raised the basic data rate to 54Mbps and operated in the 5GHz band. The additional bandwidth was a dramatic improvement in throughput, and moving to the 5GHz band eliminated most of the interference issues found in the existing 2.4 space.

Although this was a vast improvement over the existing technology, 802.11a was slow in acceptance. Due to technical hurdles, it took another year and a half for products to roll out. Additionally, the newer technology required chipsets that made the products cost prohibitive to many. The IEEE was aware of this issue and another amendment, 802.11b, was in parallel development, and was also ratified in 1999.

802.11b saw immediate acceptance as it raised the bandwidth to 11Mbps while remaining in the 2.4GHz band. The latter was most important, as chipsets in this band were much less costly to produce. This addendum to the 802.11 standard quickly became the adopted standard and overshadowed 802.11a for many years to come.

As Wi-Fi was jumping from 2 to 11Mbps, wired Ethernet clients were going from 10 to 100 and even higher bandwidth rates. Wi-Fi needed to raise the bar once again — This led to the 802.11g addendum, which the IEEE committee ratified in 2001.

802.11 Frequency Bands



802.11b/g operate in the 2.4GHz band, while 802.11a operates in the 5GHz band.

This new addendum could be loosely described as a faster version of 802.11b. A major primary benefit of 802.11g was that it offered data rates up to 54Mbps, the same as 802.11a; however it was also backward compatible to 802.11b. This meant that not only would 802.11g devices offer higher speeds with other 802.11g clients, it would also support lower speed communications with existing 802.11b clients and access points.

To support this backward compatibility, 802.11g devices were required to communicate in a way and at a rate that stations in the basic service set would be able to understand. In other words, if an access point was to serve both 802.11b and 802.11g clients, then it would need to send Beacon frames at a frame data rate of no higher than 11Mbps. If an 802.11b client associated to an 802.11g network, then all 802.11g clients would be required to understand communication at the lower rates of speed.

802.11 Data Rates

802.11b was able to increase the raw data rate from 2Mbps to 11Mbps by improving the modulation method. 802.11b added CCK, or Complementary Code Keying, a more efficient form of modulation. It was quickly determined that trying to get higher data rates using CCK was impractical, so a technique called OFDM (Orthogonal Frequency Division Multiplexing) was developed, thereby increasing rates to 54Mbps. This method is used for both 802.11a and 802.11g.

OFDM made it possible to transmit large amounts of digital data over radio waves by splitting the radio signal into multiple, smaller sub-signals which are then transmitted simultaneously at different frequencies to the receiver. For this reason, the more non-overlapping channels available, the better the performance will be for the clients.

RF Interference Issues

In addition to signal strength, one of the key issues in wireless networking is mitigating interference. As discussed previously, both 802.11b and 802.11g devices operate in the 2.4GHz band. Because 2.4 is an unlicensed band that is also available to other technologies, a host of other devices operate here, including cordless phones, microwaves, Bluetooth devices, etc. In the presence of these other technologies, Wi-Fi networks can have their communication throughput severely restricted.

Interference in the air can cause transmissions to be garbled, which reduces end user throughput and causes increased latency of data traversing the RF network – greatly compromising voice and video applications. One key advantage to 802.11a is that it operates in the 5GHz band, which currently is a less cluttered spectrum. In addition, it offers up to 23 non-overlapping channels, therefore even if interference is present it has additional channels it can move to try to avoid the interference. The advantage of 5GHz is clear when you compare this to the 2.4GHz band, which is already cluttered and offers only three non-overlapping channels.

Now that dual-band clients and access points are commonplace, deployments should use the 5GHz range as much as possible to get the cleaner and greater spectrum for high-bandwidth applications. Deploying an 802.11a/b/g infrastructure allows you to get the best of both worlds by supporting older clients in the 2.4GHz band while taking advantage of the cleaner spectrum and more non-overlapping channels of 802.11a.

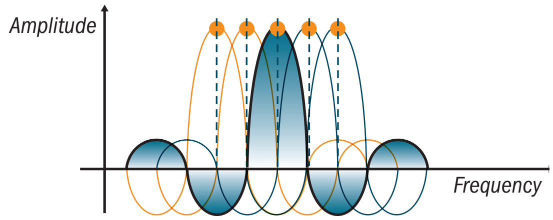
Spreading Techniques

The 802.11 standards spread data transmissions across the full channel bandwidth in two different ways — Direct Sequence spreading and OFDM. The 802.11 channel bandwidths, or the difference between their highest and lowest occupied frequencies, are all defined to be about 25MHz wide. It is desirable to utilize the full width of the channel because it maximizes the amount of data that can be transmitted, or, it allows less data to be transmitted, but in a more robust manner.

Direct Sequence spreading, like that used in 802.11b, takes a data signal and spreads it across a wider band than it might normally require for transmission, resulting in higher signal-to-noise immunity. Alternately, OFDM, used in 802.11a and 802.11g, divides the channel into multiple, concurrently transmitted sub-carriers to provide the highest data throughput possible.

Channel Bonding

OFDM
Conceptual



OFDM spreads the transmission data across 52 concurrent subcarriers within the channel. Subcarrier signal peaks occur at neighboring subcarrier nulls, providing orthoganality.

802.11 Channels, Capacity, and Allocation

As discussed earlier, both 802.11b and 802.11g operate in the 2.4GHz band, and while there are 11 channels to choose from, most of them overlap with each other, leaving only three non-overlapping channels [typically channels 1, 6 and 11]. Alternately, 802.11a offers up to 23 non-overlapping channels.

The total capacity available is significantly different between the three standards, ranging from 33Mbps in 802.11b, to 162Mbps in 802.11g to more than 1.2 Gigabits in 802.11a. Keep in mind that in a mixed environment of 802.11b and 802.11g clients, the average throughput will vary greatly depending upon the number of clients that are using each protocol. It is also helpful to note that channel availability differs greatly by country, especially between Japan and the rest of the world.

Channel Allocation

2.4GHz Channel Allocation

Channel	Frequency f_c (MHz)	U.S.	EU	Japan
1	2412	X	X	X
2	2417	X	X	X
3	2422	X	X	X
4	2427	X	X	X
5	2432	X	X	X
6	2437	X	X	X
7	2442	X	X	X
8	2447	X	X	X
9	2452	X	X	X
10	2457	X	X	X
11	2462	X	X	X
12	2467		X	X
13	2472		X	X
14	2484			X

5GHz Channel Allocation

Channel	Frequency f_c (MHz)	U.S.	EU	Japan
184	4920			X
188	4940			X
192	4960			X
196	4980			X
208	5040			X
212	5060			X
216	5080			X
36	5180	X	X	X
40	5200	X	X	X
44	5220	X	X	X

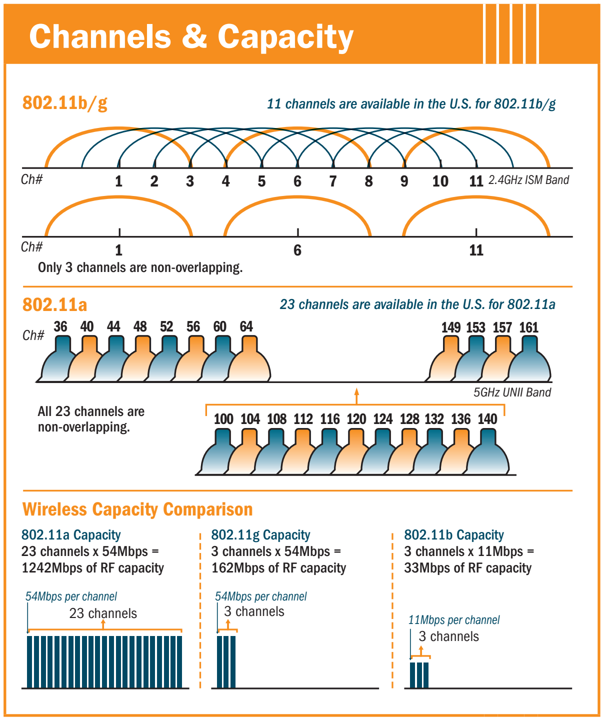
Channel	Frequency f_c (MHz)	U.S.	EU	Japan
48	5240	X	X	X
52	5260	X	X	X
56	5280	X	X	X
60	5300	X	X	X
64	5320	X	X	X
100	5500	X	X	
104	5520	X	X	
108	5540	X	X	
112	5560	X	X	
116	5580	X	X	

Channel	Frequency f_c (MHz)	U.S.	EU	Japan
120	5600	X	X	
124	5620	X	X	
128	5640	X	X	
132	5660	X	X	
136	5680	X	X	
140	5700	X	X	
149	5745	X		
153	5765	X		
157	5785	X		
161	5805	X		

802.11 b/g Channel Reuse and Cell Planning

Since there are only three non-overlapping channels available in 802.11b and 802.11g, it gets very difficult to deploy a series of access points while keeping them separated enough so that they do not interfere with each other. If they are close enough to detect or see other devices operating on the same channel, serious degradation of the overall performance to all Wi-Fi clients will result. In an 802.11b/g network, access points need to be deployed in a repeating pattern of three because the bleed-over for the other access points ultimately degrades performance and reduces overall network capacity.

What is worth noting here is that because of the limited number of non-overlapping channels, the shortest distance between cells on the same channel is typically less than a single cell. What this means is that even though on paper it may look like you have created cleanly defined cells, the clients attaching to these cells might actually be within range of two or more access points on the same frequency.



Even though there are 11 channels for 802.11b/g, only three are non-overlapping, while 802.11a offers 23 non-overlapping channels.

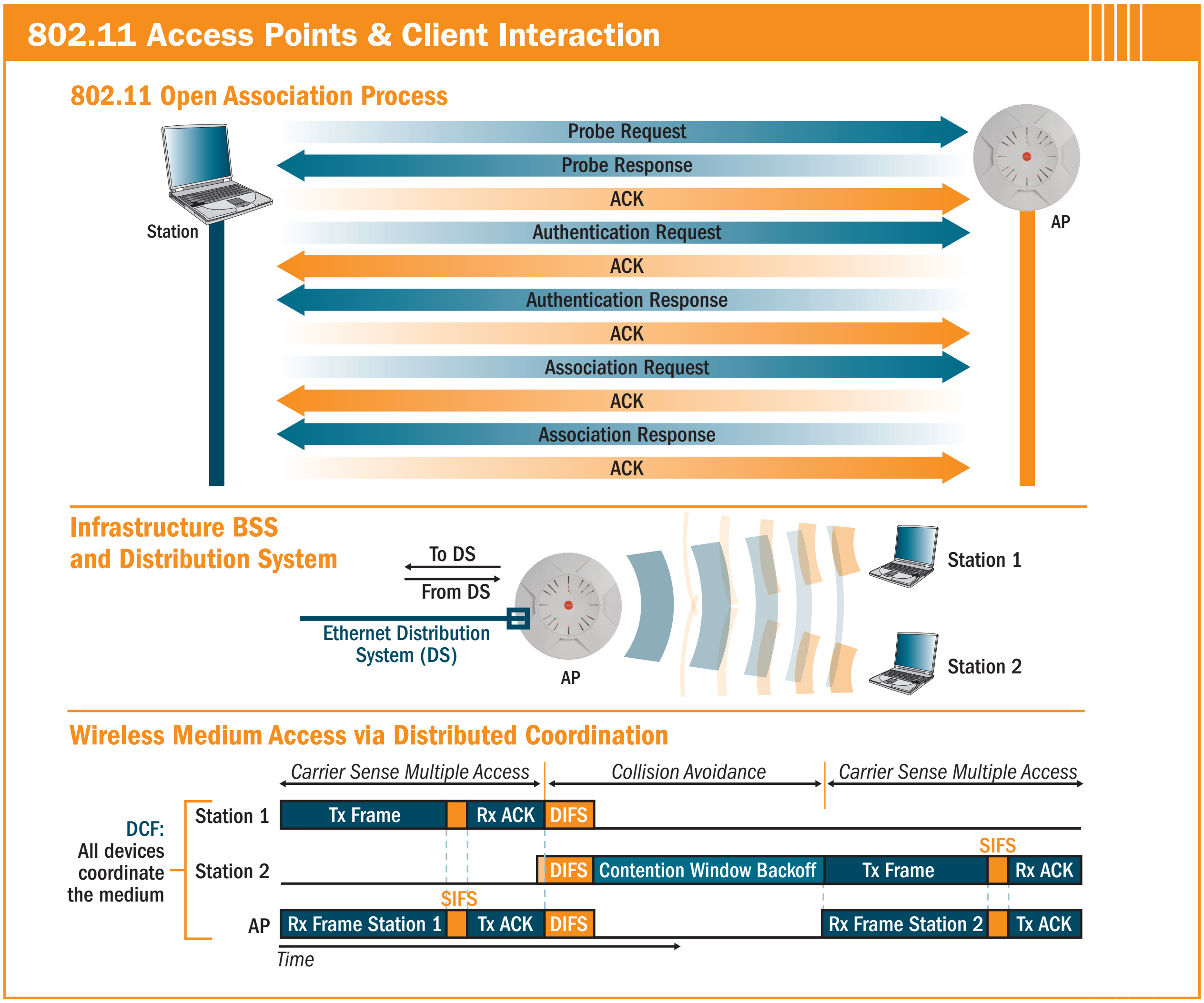
802.11a Channel Reuse and Cell Planning

The issue of channel reuse and cell planning is greatly reduced in 802.11a because the 5GHz range offers an additional 20 non-overlapping channels. Further, because of the increase in the number of non-overlapping channels, the distance between cells on the same channels is at least two cells.

Client and Access Point Interaction

The 802.11 standard defines very specific rules for both clients and access points operating in a wireless network. As an example, the open association process governs the way clients are allowed to join the network. Critical information such as supported data rates, client identification, and access privileges are sent between the access points and the clients. Once joined, additional rules exist to ensure that all devices share the medium in a courteous manner. This is accomplished using 802.11's collision avoidance scheme.

802.11's DCF, or Distributed Coordination Function, is the common method for defining how all devices access the network. Fundamentally, all devices will sense, or monitor, the air to see whether it's busy before beginning a transmission — much like people do when carrying on a conversation. This is the heart of 802.11 — everyone needs to listen first to make sure the air is clear before making a transmission. Once the air is determined to be available, a device will transmit. The receiving device will reply with an acknowledgement, which confirms to the sending station that the message was cleanly received. If no acknowledgement is received, the sending station will assume the message was lost and retry the transmission.



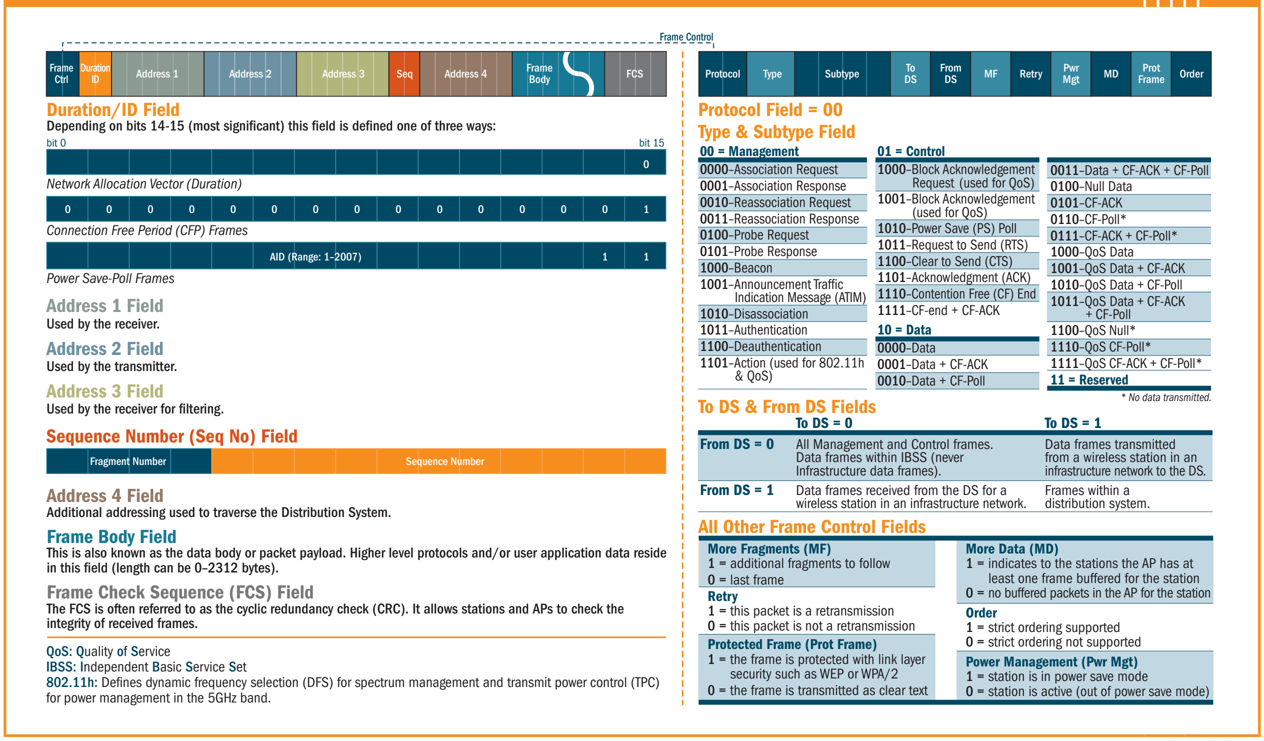
802.11 is a shared medium where all clients must listen to make sure the air is clear before making a transmission.

Frame Format

An 802.11 frame looks a lot like all networking standards — it has detailed definitions on frame formats for the wireless medium. A frame control field at the start of each frame identifies it as either a management, control or data frame, as well as critical information such as retry state and power management status. It also indicates whether the frame transfer is within the wireless network or for a wider distribution system.

Following the frame control field is the duration field, which is mainly used to indicate how long the frame will be occupying the air. This helps other stations within the network to coordinate their transmissions with the least amount of collisions. Other fields in the frame identify the source and destination addresses of the sending and receiving stations to allow proper routing of the frame.

802.11 Frame Format



An 802.11 frame looks much like other networking standards – it has detailed definitions on frame formats for the wireless medium.

Summary

To summarize, 802.11 is a mature standard that has been adopted and is beginning to replace wired networks as the edge of the network. Wi-Fi will continue to be the industry standard for local area wireless technology for the foreseeable future and will continue to evolve into future standards, such as 802.11n, which will offer an order of magnitude in higher throughput.

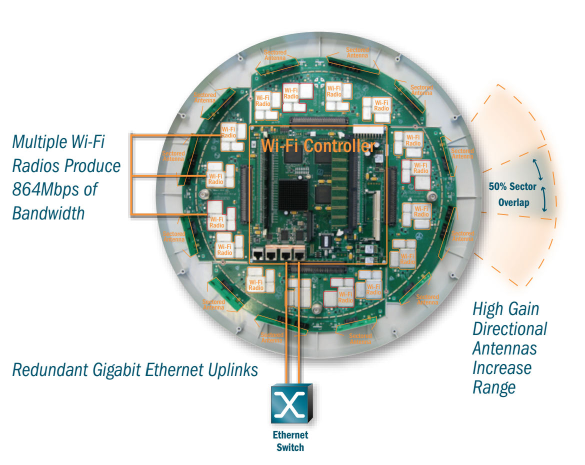
When looking at a new deployment, or an extension of a current one, make sure you deploy only 802.11a/b/g compatible devices. This gives you the backward compatibility you need to support legacy devices and allows you to take advantage of 802.11a's cleaner spectrum, more non-overlapping channels and higher overall throughput.

Leading Architecture

Xirrus planned for the success of Wi-Fi by developing an award-winning Wi-Fi architecture powerful enough to handle high-bandwidth applications today and modular enough to be upgraded for future enhancements.

With the Wi-Fi Array, Xirrus delivers the only 'Power Play' architecture in Wi-Fi networking with the most bandwidth and coverage per cable drop in the industry. Xirrus Wi-Fi Arrays deliver up to 8x the bandwidth of a single access point and are compact, easy-to-install, ceiling-mounted devices. No other current-generation Wi-Fi technology can deliver the bandwidth or throughput of Xirrus Arrays because they are limited to 2 radios producing only 108Mbps of shared bandwidth.

Xirrus Wi-Fi Array



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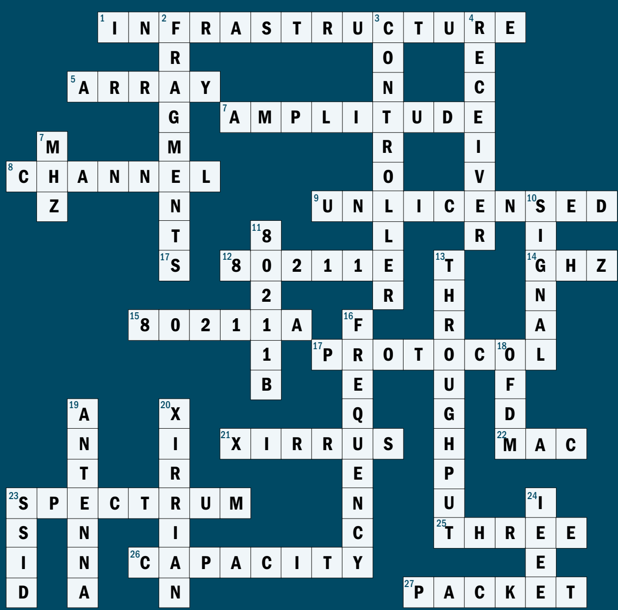
By integrating these key components: the Wi-Fi controller, Gigabit Ethernet Switch, Gigabit uplinks, multiple access points, sectored antenna system, Wi-Fi stateful firewall and Wi-Fi threat sensor into a single device, Xirrus Arrays are able to provide a centrally-managed platform that delivers unparalleled range, client capacity and performance, along with better RF management and roaming for voice, video and data applications — all in a single device that is fully upgradeable to 802.11n.

About Xirrus

Xirrus, Inc. is a privately held firm headquartered in Westlake Village, California. Founded by the same team that created Xircom (acquired by Intel in 2001), Xirrus has developed the next generation in enterprise wireless LAN architectures centered around the award-winning Array.

Backed by leading venture capital firms U.S. Venture Partners and August Capital, Xirrus brings a proven management team and patented approach to delivering the performance, scalability and security needed to deploy a true wireless extension of the wired Ethernet network capable of delivering Triple Play (voice, video, data) enablement.

802.11a/b/g Demystified
Crossword Puzzle—Answer Key



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