High Performance Wi-Fi™ Networks

MULTI-MODE DEPLOYMENTS

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XIRRUS

Introduction

The Wi-Fi™ market of today offers IT administrators a variety of IEEE standards for deploying high-performance, scalable wireless networks. These standards include IEEE 802.11b, 802.11g and 802.11a. This White Paper contrasts the major differences between these standards as they apply to enterprise-class deployments and offers recommendations in the deployment of a Wi-Fi network.

IEEE 80211 Background

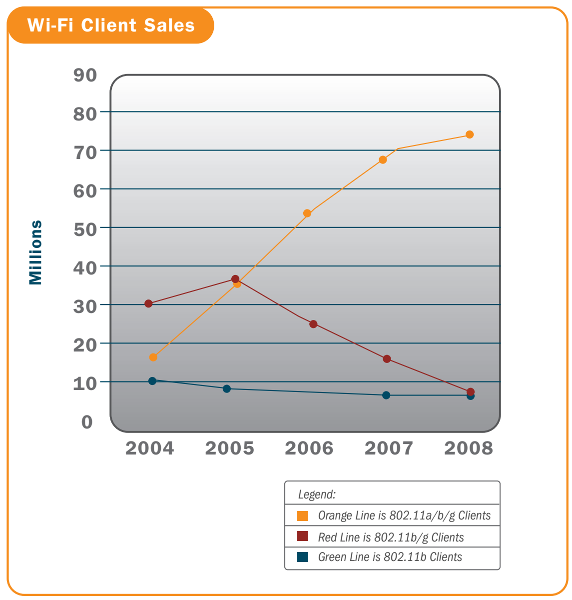
The first wireless LAN (WLAN) standard (designated 802.11 by the IEEE) was ratified in 1997 for data rates up to 2Mbps in the 2.4Ghz unlicensed band. As usage of the technology grew, the IEEE ratified two additional amendments to the 802.11 physical layer standard in 1999 to address the speed and capacity limitations inherent in the first standard.

The first amendment to the IEEE standard was 802.11b which added support for 5.5 and 11Mbps data rates utilizing a Direct Sequence Spread Spectrum (DSSS) modulation technique within the same 2.4GHz band. Concurrently, 802.11a, added support for data rates up to 54Mbps within the 5GHz band using a radio transmission technique called Orthogonal Frequency Division Multiplexing (OFDM).

At the time, 802.11a-based products were more expensive than their 802.11b counterparts and were not interoperable with the 802.11b standard so the IEEE ratified the 802.11g amendment in 2001 adding the same OFDM data rates of 802.11a to the 802.11b standard. 802.11g now had the higher data rates of 802.11a (54Mbps) and was backwards compatible to 802.11b.

Migration to Multi-mode Clients

The cost of Wi-Fi chipsets has been significantly reduced over the past 2 years leaving little difference between the cost of products operating in the 2.4GHz and 5GHz bands. The result of this cost erosion is that most new 802.11 client adapters and access point products now offer all three modes of operation in a single device allowing a user to connect to any available 802.11a, 802.11b, or 802.11g network.



Migration to Multi-mode Clients
- 802.11a/b/g client shipments surpass other client types
- 802.11a/b/g solutions in development for cellular phones
- 2.4GHz does not support future WLAN needs

Executive Summary

IT administrators upgrading existing Wi-Fi networks or deploying green field sites should deploy 802.11a/b/g infrastructure. Deploying 802.11a/b/g infrastructure provides:
- Increased bandwidth and more non-overlapping channels in 802.11a
- Backwards compatibility for older clients devices that need to use 802.11b/g
- Allows IT administrators the flexibility and bandwidth needed to deploy Wi-Fi networks that can be used as the primary means of connectivity

Future-proof Wi-Fi networks utilizing the Xirrus Wireless LAN Array simultaneously use all the non-overlapping channels within the 802.11b/g and 802.11a specifications providing the maximum amount of bandwidth (capacity) for end users.

In addition to the influx of "traditional" Wi-Fi computing clients, the number of application-specific devices such as Wi-Fi enabled cellular phones will dramatically increase over the next year ending up on the IT administrator's doorstep. These hybrid cellular phones will be able to carry voice traffic over the Wi-Fi network. This explosion in client connectivity, along with the time-sensitive nature of voice traffic will force capacity, the need for more channels and cleaner spectrum to the forefront of deployment issues to resolve within the enterprise.

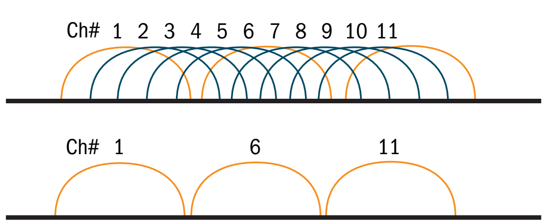
Recommendation: Wi-Fi Client Purchases

- Take advantage of the cleaner spectrum and the increased number of non-overlapping channels offered under the IEEE 802.11a specification
- Purchase Multi-mode clients and infrastructure that support 802.11a/b/g

Operating Channels and Capacity

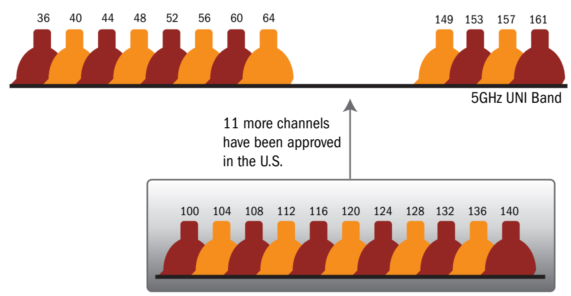
The IEEE 802.11b and 802.11g standards both operate in the 2.4GHz ISM band. In North America, there are 11 channels to choose from and operate on within this band. Unfortunately, most of these channels overlap with each other such that there are only three non-overlapping channels for use (Channels 1, 6, 11 in the diagram below). On the other hand, the IEEE 802.11a standard currently has twelve non-overlapping channels defined and has been allocated an additional set of channels for use in the U.S. by the FCC which will take the number to 23.

802.11b/g Operating Channels



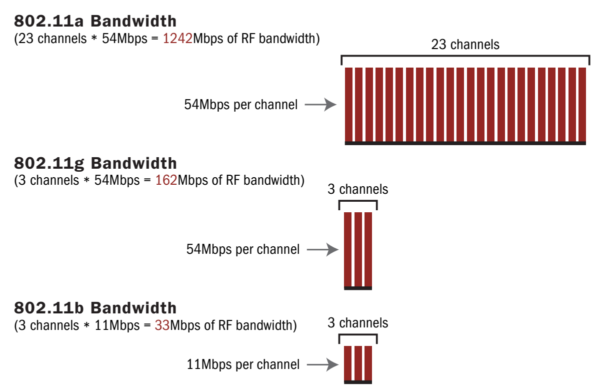
- 11 channels are available in the U.S. for 802.11b/g
- Only 3 channels are non-overlapping

12 Non-Overlapping Channels For 802.11a



- 23 non-overlapping channels will now be available for 802.11a
- Only 3 non-overlapping channels are available for 802.11b/g

Given the channel availability between the two standards, it becomes apparent that there is a large difference in the amount of aggregate bandwidth (capacity) each standard can provide. 802.11b provides a maximum of 33Mbps of wireless capacity (3 channels x 11Mbps = max data rate), 802.11g provides 162Mbps of wireless bandwidth, and 802.11a provides a whopping 1242Mbps of wireless bandwidth as shown in the diagram below. 802.11a provides over seven times the aggregate wireless capacity of 802.11g and over thirty-seven times that of 802.11b.



Interference

802.11b/g uses the 2.4 GHz ISM band. Many other devices operate in the 2.4GHz ISM band that is shared with 802.11b/g clients. Interference causes data to be garbled forcing packets to be re-transmitted. This causes reduced end-user throughput and increased latency of data traversing the Wi-Fi network.

Other Devices in the 2.4GHz ISM Band:

- Bluetooth Devices
- HomeRF
- Cordless Phones
- Microwave Ovens
- X10 wireless video cameras
- HAM radio operators

Conversely, the 5GHz band for 802.11a is relatively clean from interfering devices. 802.11a is also deemed as the primary user of the spectrum. This disallows other types of wireless data devices in this band.

80211g Degradation In The Presence of 80211b

Additional capacity issues exist for 802.11g in the presence of 802.11b devices. In order for 802.11g to be backwards compatible with 802.11b, it must make some compromises. 802.11g must use low data rates to share communication with 802.11b clients because 802.11b devices cannot understand the faster data rates of 802.11g. When 802.11b devices are present, 802.11g devices use a mechanism called CTS-To-Self that prevents 11b and 11g clients from stepping on each other's transmissions. There are also differences required in other parts of the protocol that must be used to support 802.11b clients such as long packet preambles and differences in slot times. Given these factors, 802.11g networks can quickly be reduced to near 802.11b rates as the number of 802.11b client devices increase. Overall throughput of a mixed 802.11b/g network is typically limited to 18Mbps.

Deployments and Channel Interference

Over the past three years, most enterprise WLAN deployments were based on the 802.11b standard and those deployments were architected to provide the maximum amount of coverage with the fewest number of access points. Maximizing coverage was the key driving factor in these deployments because only a small number of users were active and there was a desire to deploy a limited number of access points due to cost and management considerations.

As more and more Wi-Fi clients started accessing the network, IT administrators would add additional access points to handle the needed increase in bandwidth (capacity). However, additional access points create an issue of channel interference given the limited number of non-overlapping channels that exist within the 802.11b/g standard.

802.11b/g Non-Overlapping Channels

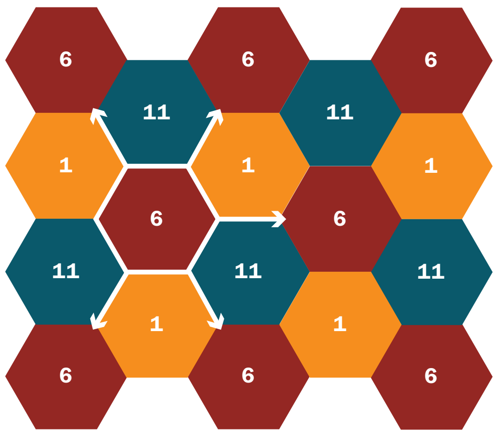
• Number of 802.11b/g non-overlapping channels available = 3

The limited number of non-overlapping channels imposes a significant restriction on 802.11b/g networks as only three access points can be installed within a coverage area without experiencing co-channel interference. This forces access points to be placed in such a way that the same channels are "re-used" frequently throughout the coverage area, increasing co-channel interference between cells.

Co-channel interference significantly impacts the overall performance of the WLAN. Access points operating in the same area using overlapping channels will cause interference with each other and force stations to re-transmit data. This ultimately degrades the overall performance of the network.

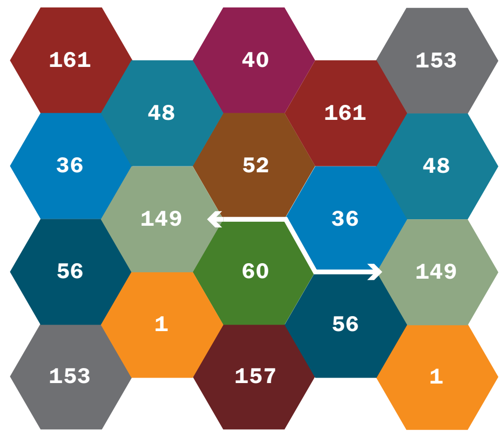
Deploying 802.11a provides far less channel reuse as the below diagram depicts. This avoids inter-cell interference and allows high data rate transmissions within each cell providing maximum capacity.

802.11b/g Cell Planing



- Number of 802.11b/g non-overlapping channels available = 3
- Distance to cell with same channel is less than a single cell
- Inter-cell interference from other cells on the same channel causes:
  - Bleed-over that retards higher data rates
  - Greatly reduces overall network capacity

802.11a Cell Planning



- Number of 802.11a non-overlapping channels available = 12
- Distance to cell with same channel is at least two cells
- Inter-cell interference from other cells on the same channel will be low
- Allows for full wireless capacity for every cell

Even when the access points are placed at some greater distances from each other, they can still create transmission deferrals and increased back off times (the time between client transmissions) because stations can still "hear" the traffic from the other cell at a fairly large distance and will wait until the channel is quiet before transmitting. Additionally, the overall "noise floor" of that cell will be increased. An elevated noise floor lowers the data rates that stations use to transmit (in an attempt to reduce the error rate). This further impacts the overall performance of the network.

Simply put –once a network has maximized its use of non-overlapping channels within the coverage area, adding more access points will only degrade the networks throughput and lower its overall capacity.

Range

Early 802.11b deployments were focused on range in order to cover as much floor space with the fewest access points possible. As soon as additional access points were added to the network to increase capacity, it quickly became obvious that in order to re-use channels the transmit power for each access point had to be turned down to limit interference with other cells on the same channel. 802.11a does not suffer from this problem as the distance between cells using the same channel can be much greater. This allows 802.11a devices to use higher transmit power which increases range and achieves higher data rates for all devices. Range becomes less of an issue as more clients connect to the network given the inherit limitations of today's access points. This is even more apparent within 802.11b/g networks because of the channel reuse issues inherit within those specifications.

The optimal WLAN deployment makes the maximum number of non-overlapping channels available while deploying the fewest number of access points in a given coverage area. This provides for the greatest amount of aggregate network capacity for Wi-Fi clients. This is especially critical for applications such as voice over Wi-Fi (VoWLAN) that drive a substantial number of clients in a given area.

Wi-Fi Deployment Summary

The below chart summarizes the major differences between each of the 802.11 standards as previously discussed.

	802.11a	802.11b	802.11g
Wireless Data Rate	54Mbps	11Mbps	54Mbps (De-Rated to 18Mbps by 11b)
Available Non-overlapping Channels	23	3	3
Maximum Wireless Capacity (Mbps) = Rate x # of Non-overlapping Channels	1242Mbps	33Mbps	162Mbps
Interference From Other Cells	Low	High	High
Interference From Other Devices	Low	High	High
Approximate Users Per Cell	10-20	3-5	6-9
Total User Capacity (TUC) = Users Per Cell x # of Non-overlapping Channels	480 (20 x 23)	15 (5 x 3)	27 (9 x 3)

The 802.11a standard is optimal for Enterprise deployments. 802.11a offers the advantage of far more non-overlapping channels, less interference, higher achievable data rates and a seven-fold increase in terms of capacity. Given the large number of existing 802.11b/g clients, Wi-Fi networks need to be rolled out and/or upgraded to support all three standards (802.11a/b/g).

The issue of capacity is critical for IT administrators as they deal with an increasing number of client devices and the need to support new applications such as voice and video over WLAN. This need will ultimately drive the migration from 802.11b/g to 802.11a within the Enterprise market and the need for infrastructure products that take advantage of all available channels.

Supporting this migration is the availability of tri-mode, dual band clients that automatically connect to whatever standard is being used (802.11a , b, or g). Tri-mode client devices allow IT administrators to easily migrate from their legacy 802.11b/g networks over time and add 802.11a capacity as they refresh their installed base.

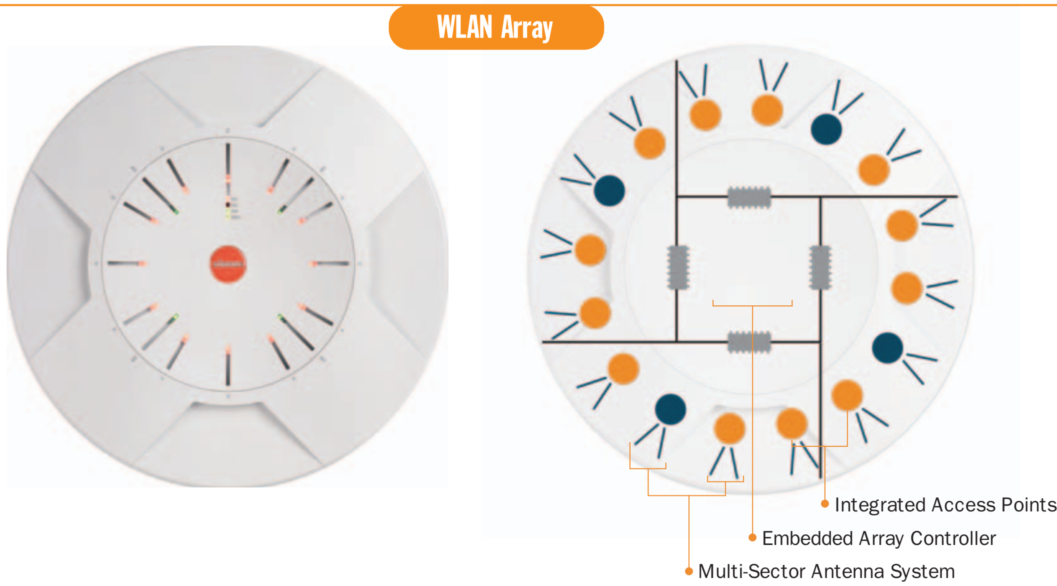
Recommendation: Wi-Fi Infrastructure

- Deploy Wi-Fi networks that support 802.11a/b/g
- Allows older clients running 802.11b/g to still access the Wi-Fi network while opening up the increased bandwidth under 802.11a for newer clients and bandwidth-hungry applications

The Future of Wi-Fi: Wireless LAN Array

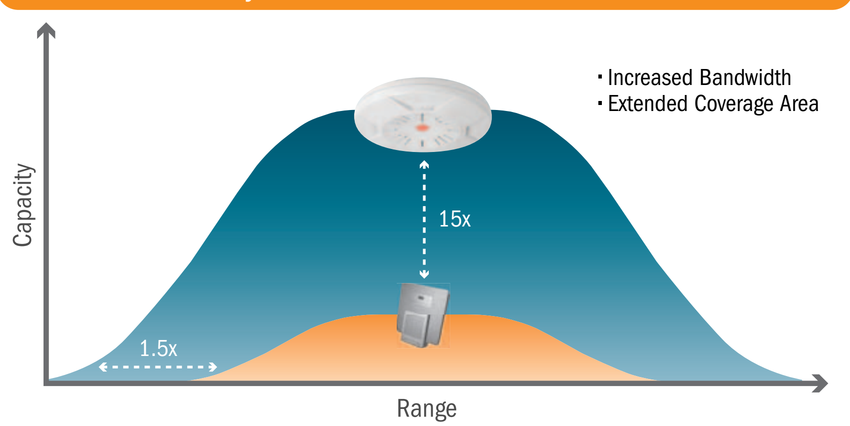
Xirrus has created the next generation in enterprise Wi-Fi infrastructure that takes advantage of 802.11a technology and is capable of handling the clients of today and providing a platform for IT administrators to deploy the applications of tomorrow. The Xirrus Wireless LAN Array integrates a WLAN switch, up to sixteen Integrated Access Points and a high gain, Multi-sector Antenna System to provide 864Mbps of Wi-Fi bandwidth over an extended coverage area.

WLAN Array



This unique architecture simultaneously uses up to 15 non-overlapping channels (twelve 802.11a and all three 802.11b/g) where each RF sector of the Wireless LAN Array is assigned one of the 15 non-overlapping channels limiting interference, and maximizes the RF bandwidth available within a given coverage area. Each Wireless LAN Array also provides a dedicated listen-only Integrated Access Point for continuous monitoring and reporting of the RF environment for the detection of rogue access points and other security threats. The WLAN Array can deliver up to 864Mbps of RF bandwidth within an area measuring approximately 300 feet in diameter. Simply put— maximize RF bandwidth using a fraction of the devices that would otherwise need to be installed and managed.

Wireless LAN Array Benefits



- Simplify: Deploy Fewer Wi-Fi Devices
- Maximize: Bandwidth and Coverage
- Save: Lower Total Cost of Deployment

Xirrus allows IT administrators to cover both types of deployments (802.11a and 802.11b/g) while maximizing capacity and coverage avoiding constant upgrading, re-architecting and re-deploying the WLAN.

5GHz: The Path to the Promise of 80211n

While many in the industry are touting 802.11n as a path to higher performing (bandwidth) Wi-Fi networks, there are a number of important items to consider when making your deployment decisions today! In reviewing the technical underpinnings of 802.11n, fully half of the improvement that 802.11n provides comes from the ability to combine two adjacent RF channels to double the throughput of a link. Unfortunately, only 3 non-overlapping channels exist in the 2.4GHz band meaning at most; only two channels can be “bonded” together to increase throughput. The remaining non-overlapping channel can be used at half the throughput of the bonded pair. Contrast this with the available non-overlapping channels in the 5GHz band of 802.11a which has up to 22 non-overlapping channels. This provides up to 11 pairs of bonded channels that will be available for 802.11n devices in the 5GHz band.

Another important consideration is legacy devices that are already occupying a channel in the 2.4GHz band will prevent bonding altogether, or greatly reduce its performance. This can already be seen today where 802.11b devices are prevalent. In the 2.4GHz band, 802.11g clients are drastically slowed down by 802.11b clients– the same will be true for 802.11n as 802.11b clients will drastically reduce the throughput of 802.11n devices in the 2.4GHz band. In contrast, 802.11a clients will be much better partners for 802.11n devices, as they will interoperate at five times greater data rates, which will increase the overall performance of the network. Because only a single channel can be bonded for 802.11n in the 2.4GHz band, existing 802.11b devices will drastically reduce overall throughput.

To obtain the benefit promised by 802.11n, the best action to be taken by IT administrators NOW is to ensure the purchase of Multi-mode 802.11a/b/g client adapters and infrastructure equipment to allow the best compatibility with legacy devices, and will allow the best performance with future 802.11n networks in the 5GHz band.

Conclusion

The increased penetration of Wi-Fi into portable computing devices and new applications such as VoWLAN are driving the need for increased capacity in Wi-Fi networks. 802.11a provides the needed channel capacity. Future-proof Wi-Fi networks utilizing the Xirrus Wireless LAN Array make use of the all non-overlapping channels available while using the fewest number of devices in a given coverage area to provide the greatest amount of aggregate network capacity. Xirrus has created the next generation of Wi-Fi infrastructure equipment maximizing the use of non-overlapping channels across an IEEE 802.11a/b/g network allowing IT Administrators to deploy the maximum amount of bandwidth (capacity) while simplifying the overall deployment. ●

Recommendation: Deploy Xirrus

- Wireless LAN Array uses all non-overlapping channels simultaneously for both 802.11a and 802.11b/g— all in a single device
- Wireless LAN Array provides extended coverage reducing the number of devices needed in the Wi-Fi network— simplifying the network and reducing the total cost of deployment

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