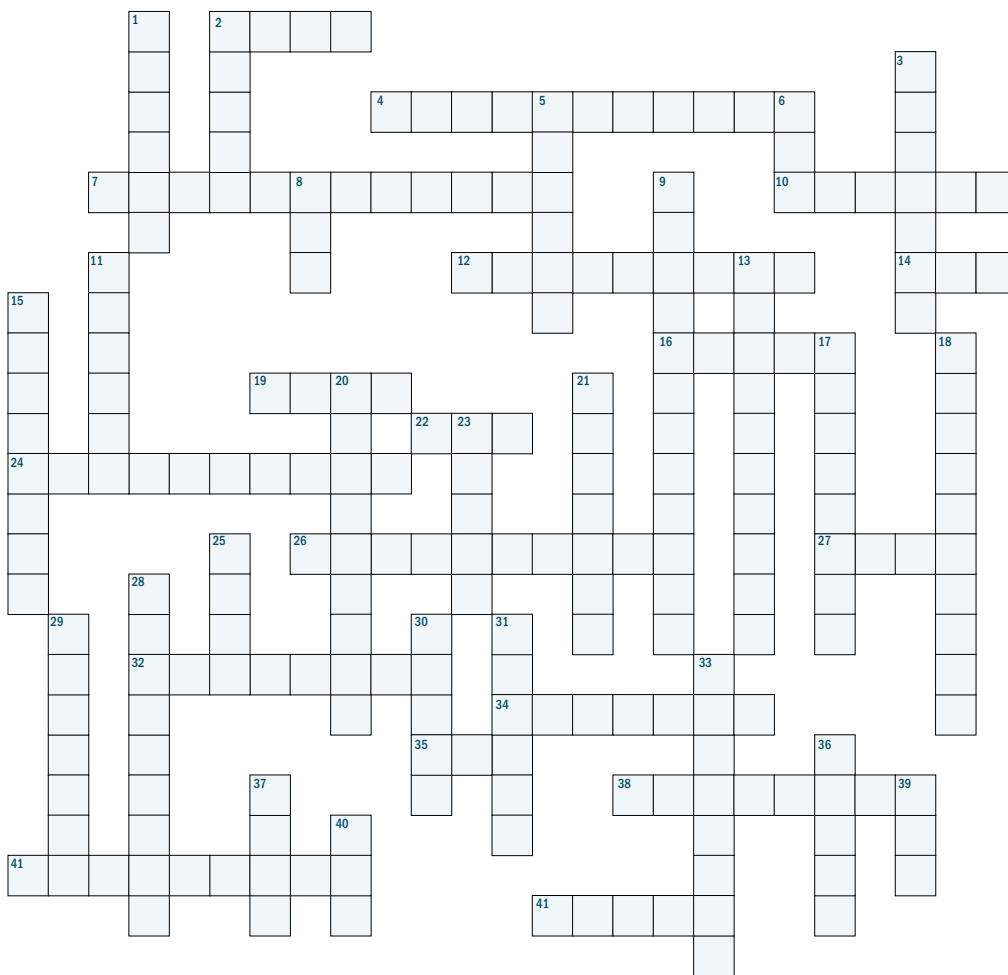


# 802.11n Demystified

## Tutorial



### Across

- 2. Service identifier
- 4. Receiver antonym
- 7. Combine multiple streams into one
- 10. 802.11 medium
- 12. Files divided and scattered
- 14. Acknowledgement
- 16. Number of 802.11b/g non-overlapping channels
- 19. Improvement to SIFS
- 22. Improved in 802.11n
- 24. Circuitry to interpret and execute
- 26. Carried on top of carrier
- 27. Institute of engineers
- 32. Format for transmitting data
- 34. Path for signals
- 35. Complementary Code Keying
- 38. Contiguous frequencies
- 41. Pipe diameter
- 42. Requesting information

### Down

- 1. Only Wi-Fi Power Play
- 2. 802.11n guard interval
- 3. Xirrus language
- 5. Conveys data between points
- 6. Request to Send
- 8. Lowest level of OSI network model
- 9. Number of 802.11a non-overlapping channels
- 11. Targets at least 100Mbps of throughput
- 13. Amount of data sent in a given time
- 15. Maximum amount of users
- 17. Converting code
- 18. Public use
- 20. Rate at which a repeating event occurs
- 21. Combining two adjacent channels
- 23. Highest performing access device
- 25. Multiple antennas to improve rate and range
- 28. Height of a crest
- 29. Receive/send radio signal
- 30. Group of bits or bytes
- 31. Fragment of data
- 33. Transmitter antonym
- 36. Manages addressing and protocol information
- 37. Splits one band into many
- 39. One-million cycles per second
- 40. 109 Hz

# 802.11n Demystified

## Contents

Introduction .....	3
Applications and Devices Driving Wi-Fi .....	3
History of 802.11n .....	4
What is 802.11n? .....	4
What is MIMO? .....	5
MAC Improvements .....	6
Interoperability .....	6
Channel Bonding .....	7
Obtaining Higher Data Rates.....	7
Throughput Comparison.....	8
Rate and Range Comparison .....	8
Status of 802.11n.....	8
Network Readiness.....	9
Recommendations.....	9
Leading Architecture .....	10
About Xirrus.....	10

## Introduction

802.11n is one of the most significant wireless technology developments to come along in recent years. And, it's a major area of interest to everyone managing or planning a Wi-Fi network, or any type of wireless application.

While a ratified IEEE 802.11n standard isn't expected until 2009, some vendors have already begun shipping "Pre-N" or "Draft 2.0" products, leading more organizations to question how the upcoming standard will play into their Wi-Fi plans.

The promise of increased coverage and performance of 802.11n has created a firestorm of questions and uncertainty throughout the IT community, such as:

- Should I deploy pre-standard products?
- What should I do until 802.11n is ready?
- What will happen to my existing Wi-Fi infrastructure?
- And, is my wired network ready?

Given the influx of the pre-standard products and the associated hype within the networking industry, it is imperative that IT administrators understand the technology behind 802.11n and how this next Wi-Fi standard will affect both their wireless and wired network infrastructures.

This guide will provide an overview of 802.11n — including how this new standard will deliver higher performance than existing 802.11a/b/g networks, and what network managers should do to prepare their networks to achieve the highest performance possible both today and tomorrow.

---

## Applications and Devices Driving Wi-Fi

The need for increased range and capacity is being driven by users demanding wired-like performance from their wireless networks. Many companies today are eyeing wireless technology as becoming their primary method of connecting end-users to their networks, shifting the need for high-capacity, high-performance wireless networks from what was a "nice-to-have" to now what is rapidly becoming a "must-have" solution.

Wireless technology is becoming more and more prevalent wherever we go. Wireless networks are now commonplace in almost every type of LAN setting: in the home, in small businesses, in the enterprise, in education, healthcare, manufacturing and hospitality, just to name a few.

High-capacity wireless networking is available today in some products, such as the Xirrus Wi-Fi Array, but technology like 802.11n will help address the myriad of

high-bandwidth applications that are emerging in the marketplace, such as: mobile-to-mobile convergence, video conferencing, and high-end graphics applications.

In addition to the enterprise, the new 802.11n technology will also help boost performance in home-based applications, such as whole-house coverage of HDTV broadcasting. These high-end applications, along with the proliferation of Wi-Fi in general, are driving the need for higher-performance Wi-Fi networks across the board.

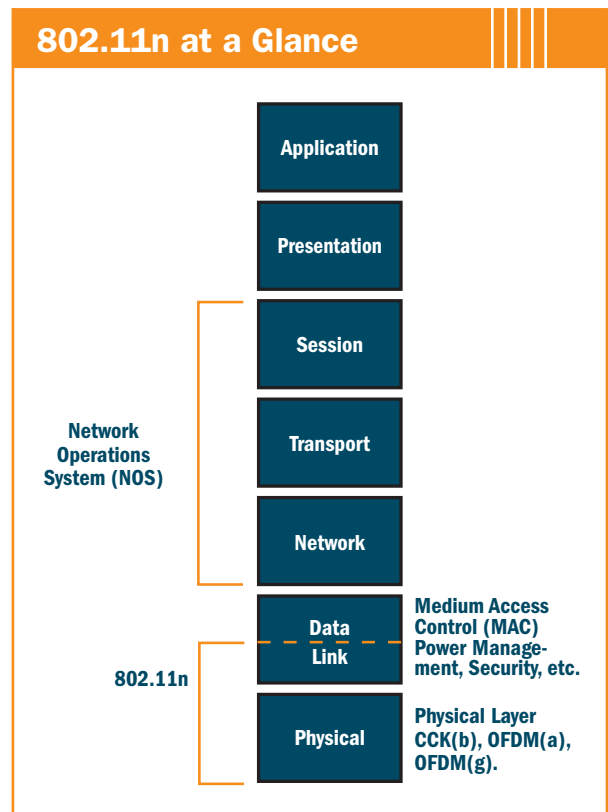
But, Wi-Fi is a shared medium, which means that as more clients and higher-bandwidth applications become available, less and less bandwidth is available per user, thereby decreasing overall throughput and performance across the network. The new 802.11n standard will help to alleviate this problem by significantly boosting both the coverage and performance of Wi-Fi networks.

## What is 802.11n?

There is still quite a bit of confusion as to precisely what 802.11n is. In a nutshell, 802.11n is an amendment to the existing 802.11 standard, which today incorporates 802.11a/b and g. This new 11n standard requires a new physical layer, along with changes to the bottom half of the data link layer, particularly the MAC, which handles power management and security. In its current state, 11n adds over 500 pages of additions and changes to the current 802.11 standard.

With 802.11n, the other aspects of the Wi-Fi network, from the upper-half of the data link layer through the application layer, are untouched. In other words, the switches, protocols, etc. all remain the same.

The primary benefit of the upcoming 802.11n standard is higher throughput for clients. Utilizing MIMO technology (refer to page 3), clients can reach well over 100 Mbps of TCP throughput. Additionally, 802.11n will be backward compatible, so that 802.11a/b/g clients will still function as usual on an 802.11n network. However, in order to take advantage of these faster speeds, legacy 802.11 devices will need to be upgraded to 11n.



*802.11n requires a new physical layer, along with changes to the bottom half of the data link layer — the other aspects of the Wi-Fi network are untouched.*

## History of 802.11n

Taskgroup “n” was formed in the beginning of 2003. It took a couple of years to go through all of the proposals and the down-selection process that eventually provided a joint proposal in 2006, and the first-draft letter ballot in Q2 of 2006, which later became Draft 2.0. Today, the IEEE is going through comment resolution on the second-draft letter ballot – down from over 12,000 to currently about 300 comments. Final working approval is expected to occur sometime in 2008, followed by final ratification and publication in early 2009.

The Wi-Fi Alliance is also working alongside Taskgroup “n” to ensure compatibility testing. They have finished testing and certifying the Draft 2.0 products, and expect to have final profiles and final certification programs in place around the same time as the final published standard, again targeted for sometime in early 2009.

## What is MIMO?

To better understand 11n, it is important to understand MIMO. MIMO stands for Multiple-In Multiple-Out, and is one of the core technologies of 802.11n. MIMO Signal Processing uses multiple antennas that send and receive data at the same time to improve signal coherence. The receiver listens to multiple signals on multiple antennas at the same time. There is a separate radio for each antenna in the receiver. With MIMO, the multiple antennas only need to be slightly separated to see substantially different signal characteristics from the same source transmitter, enabling 802.11n to process and produce a much greater signal than is possible today.

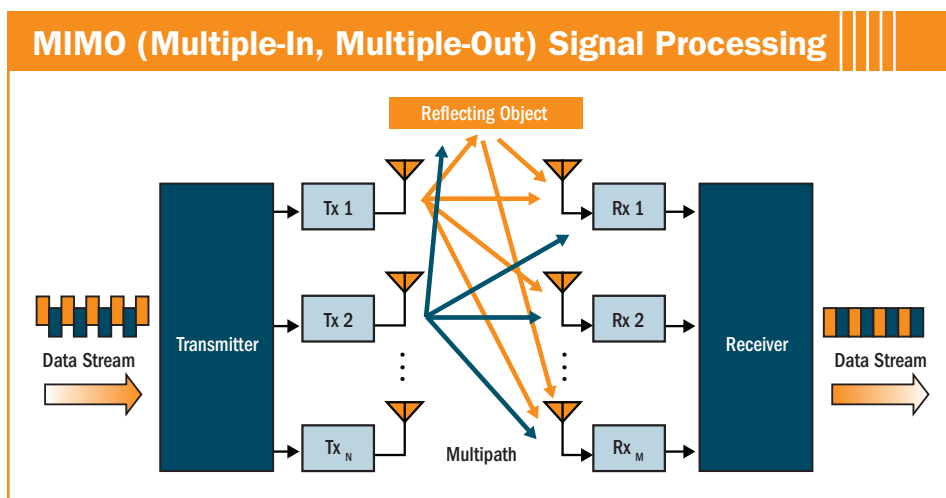
Referred to as Spatial Multiplexing, this technology can best be described as a 3-dimensional radio. Spatial Multiplexing makes it possible to double or triple existing data rates. With Spatial Multiplexing, a source data stream is sent out over different transmit antennas. The transmitter divides and sends the data stream, preferably through two or more antennas. This data is reflected and echoed across the environment over the same channel. It is then recombined at the receiver, also with multiple antennas, thereby doubling the data rates that can be achieved today. To make sense of all the streams

being transmitted over the air, it is recommended that at least one more receive antenna than transmit antenna is used.

With Spatial Multiplexing, 802.11n can greatly increase existing data rates, depending upon the number of antennas being used. The more antennas that are used, the better the reception will be, and the better the receiver will be able to reconstruct the original intended signal.

But, one thing to keep in mind, is that along with these additional antennas comes a higher cost as well. Though it is possible to have as few as 1x1 or as many as 4x4 antennas, expected implementations of MIMO will be 2x3 – in other words, two transmitting antennas and three receiving antennas.

As would be expected, MIMO requires a significant amount of signal processing. This new signal is much more sophisticated in terms of its ability to remove nulls, fades and incoherence in the channel, such that we end up with almost 10dB more of signal processing advantages, with a 10dB increase in signal-to-noise ratio (SNR) available. This SNR works with any standard mode 11a/b or g radio today to improve existing data rates.



*Utilizing MIMO, 802.11n can more than double existing data rates, depending upon the number of antennas being used.*

## MAC Improvements

Another important aspect of the 802.11n standard is MAC improvements. A lot of work has been done to increase the efficiency of the 802.11 MAC. The first improvement is Frame Aggregation, which combines multiple packets and transmits them together as one packet over the network. This greatly cuts down on the overhead that is associated with sending each individual packet out one at a time.

Typically, in a standards mode network, the transmitter sends a packet, then waits for an acknowledgment, sends another packet, waits for another acknowledgment, and so on. In 802.11n, there is something called a Block ACK Frame. Instead of sending and receiving one ACK (acknowledgement code) after each packet, 802.11 devices will be able to send a whole stream of packets and at the end request a single ACK Frame that indicates only those packets that need to be retransmitted. This increases efficiency by approximately 40% and reduces the overhead of the 802.11 MAC.

The second improvement to the 802.11n MAC is Reduced Interframe Spacing (RIFS). This is a change from the current standard, where Short Interframe Spacing (SIFS) is used. RIFS greatly minimizes the space between packets that are being sent out over the air, thereby decreasing unusable dead time.



## Interoperability

The question of interoperability is paramount in the minds of many network managers. The first thing most network managers want to know is, “How do existing 802.11a/b/g networks work with 11n devices?” There are two elements in 802.11n that have been built into the standard to provide backward compatibility. They are PHY Protection and MAC Protection.

### PHY Protection

In the legacy mode, the signal field contains information from a transmitting packet that indicates the length of the packet and at what data rate it is being sent. All other stations that hear this information can then correctly calculate how long it's going to take to send the packet out over the air – in other words, this information lets stations know how long to stay off the air.

With the new 802.11n high-throughput mode, a legacy packet is sent out at a legacy data rate in

the signal field, and then a high-throughput packet is sent using some of the new data rates that the 11n standard defines. The high-throughput mode still uses the same legacy data rates, but the length of the packet is increased. So, even though they're using a new 11n data rate, legacy stations will still understand how long to stay off the air.

### MAC Protection

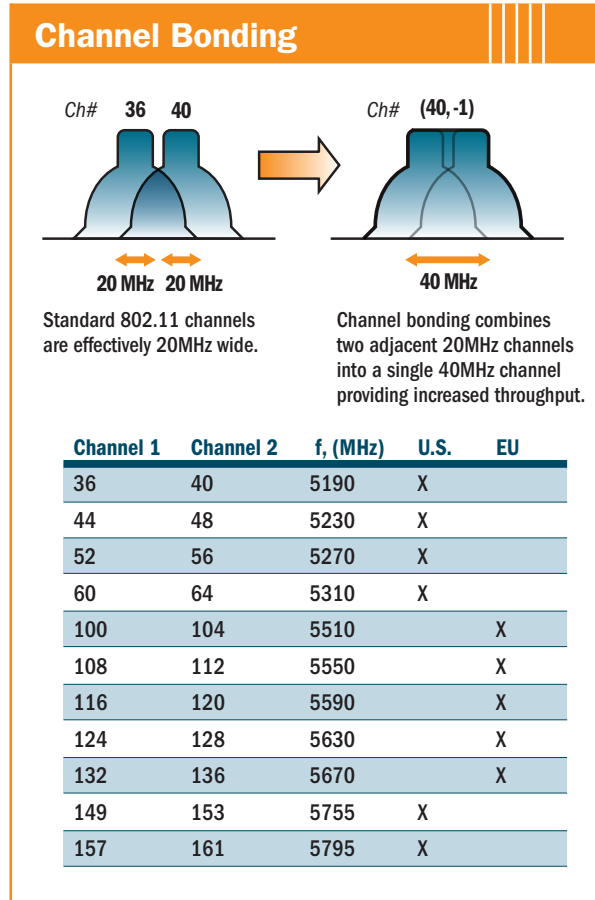
MAC Protection is used to span multiple packets being sent in sequence. This is done in the same way that it's done with 11b and 11g. The current 802.11 standard states that the presence of an 11b station within range of an 11g access point forces the access point to invoke a Request to Send/Clear to Send (RTS/CTS) or CTS-to-self protection mechanism. This protected mode prevents simultaneous transmission by devices using legacy 802.11 standards, which would result in collisions and retransmissions.

## Channel Bonding

Channel bonding is the last piece that makes up the new 11n data rates. Channel bonding is not new to the industry. In fact, some vendors today employ channel bonding in some of their proprietary products. Channel bonding bonds two adjacent 20MHz channels together to form a single 40MHz channel. This slightly more than doubles the bandwidth that is available today, thereby doubling the data rates that can be achieved.

There are some drawbacks to channel bonding, however. One of these is that channel bonding can only be performed when there are enough channels available to be bonded. For example, the 2.4GHz band has only three non-overlapping channels, so only two channels can be bonded to create one 40MHz channel. Secondly, channel bonding may not be available worldwide.

Lastly, if there are a number of standards-based devices today operating in different channels, channel bonding will recognize and respect those devices, and will not perform the channel bonding function in the presence of those legacy devices.



*Channel bonding can be used to double the bandwidth that is available today.*

## Obtaining Higher Data Rates

The new 802.11n standard will achieve higher data rates by using a combination of higher encoding rates, the spatial streams mentioned earlier (MIMO spatial multiplexing), channel bonding, and finally, by using an optional feature called Short Guard Interval.

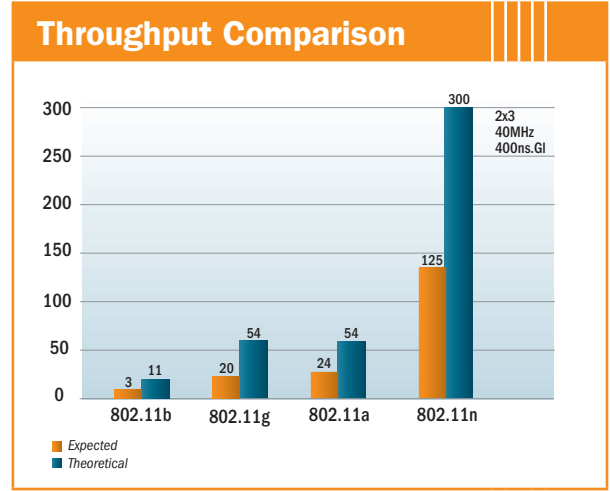
Short Guard Interval squeezes out more guard band between signals that are being sent out over the air, thereby decreasing transmit times (between 400 to 800 ns), which in turn produces higher throughput.

This works by employing a new base modulation encoding rate, then optionally multiplying it by the number of spatial streams that are being used. Using channel bonding the data rate can then be doubled, with even more throughput to be gained finally by using Short Guard Interval. All of these methods combined will be used to create the new, higher 11n data rates.

## Throughput Comparison

As the diagram illustrates, data rates went from 11Mbps with 802.11b to 54Mbps with 802.11a and g and will go to hundreds of Mbps with 802.11n. The 300Mbps listed here is based on a 2x3 transmit/receive using 40MHz band with 400 ns. Guard Interval.

Theoretically, the raw throughput can range from 6.5Mbps with 1x1 to 600Mbps with 4x4. Most of this capacity in 11n will be in the 5GHz band. In fact, due to the lack of 40MHz channels in 2.4GHz, it is recommended that only 802.11b and g are used for legacy devices and that only 5GHz is used for 11n. Even today, 11a is far better than 11n in the 2.4GHz band – it is cleaner and has more non-overlapping channels to utilize.

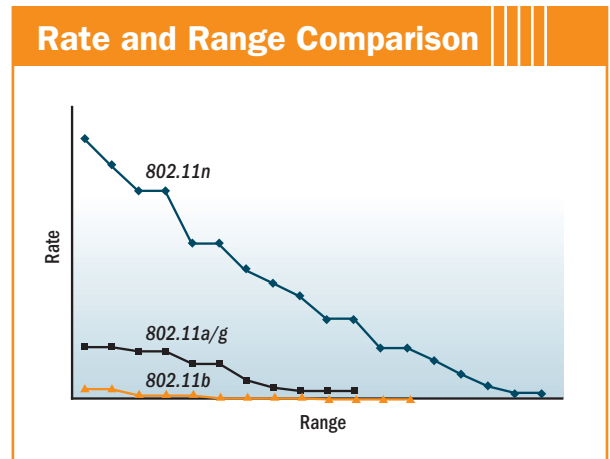


Data rate comparison of 802.11a/b/g & 802.11n

## Rate and Range Comparison

This figure illustrates rate and range, which are critical in all wireless networks. Generally speaking, one must choose between higher data rates, or longer range at lower data rates. The higher data rates will require you to have an 11n client on both sides of the link.

In order to achieve these higher data rates, MIMO-enabled, or 11n-enabled access points must be used together with 11n-enabled clients. Since cell sizes can only be as large as their legacy clients allow, all of the stations in that cell must be upgraded to support MIMO or 11n.



Rate and Range comparison of 802.11a/b/g & 802.11n

## Status of 802.11n

As mentioned earlier, Draft 2.0 of 802.11n has been approved and released. The final draft (expected to be version 3.0) is slated to be ratified sometime in the beginning of 2009. Most Pre-n and Draft 2.0-n products available today do have good performance, but have significant interoperability issues.

Since 11n works best in the 5GHz band, due to the limitations and noise in the 2.4GHz band that were discussed earlier, we can expect to see a gradual phasing out of 2.4GHz networks.

Legacy 802.11a/g clients will see a slight increase in performance when attached to an 11n network since they will communicate with more antennas, however, to truly get the bump in performance, 11n must be used on both sides. This means more than one spatial stream on both the transmitter and receiver must be used.

## Network Readiness

There are several things to keep in mind when planning for 11n:

802.11n access points will require Gigabit Ethernet interfaces, which means that the wired network infrastructure will need to be upgraded to Gigabit Ethernet.

Legacy controller-based Wi-Fi architectures will need to be replaced as well, since they cannot handle the Gigabit speeds required from dual 802.11n access points. Deploying these controllers deep in the network core will create bottlenecks for 802.11n along with latency and jitter, which is detrimental for video and voice applications.

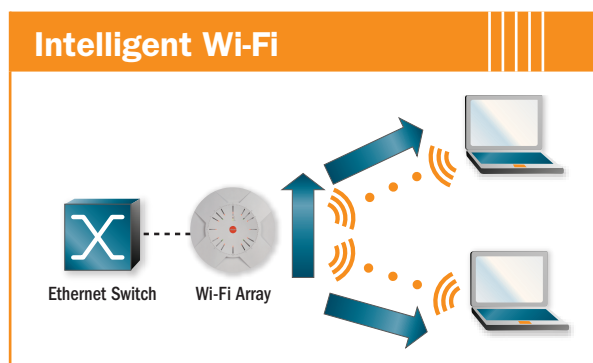
By early 2009 we will begin to see a phase-out of a/b/g products and can expect to see only 802.11n products shipping by the leading chip manufacturers.

---

## Recommendations

The following recommendations will help network managers achieve the highest performing network today, with an easy upgrade path to 802.11n when the standard is ratified and available for mass deployment:

- Wait for the final version of 802.11n to be ratified by the IEEE committee.
- Wait for the Wi-Fi Alliance's interoperability testing to be completed.
- Upgrade to Gigabit Ethernet to prepare for higher data rates of 11n.
- Deploy 802.11n at 5GHz, not 2.4GHz, to take advantage of performance and avoid degrading the capabilities of 11g radios. It's best to keep them separated. 11n can be phased-in gradually — no need to swap out everything all at once.
- Move the Wi-Fi Controller to the edge of the network so that packets can be locally switched at the edge, rather than deep in the core.
- The Wi-Fi controllers should be integrated or local to the access point.
- Be sure to use access points that support 802.1p and 802.1Q tagging at the edge of the wireless network for end-to-end QoS. With more voice and video traffic being sent wirelessly, it is imperative that wired QoS can be mapped to wireless QoS.
- Lastly, make sure to select a Wi-Fi solution today that provides an upgrade path to 802.11n.

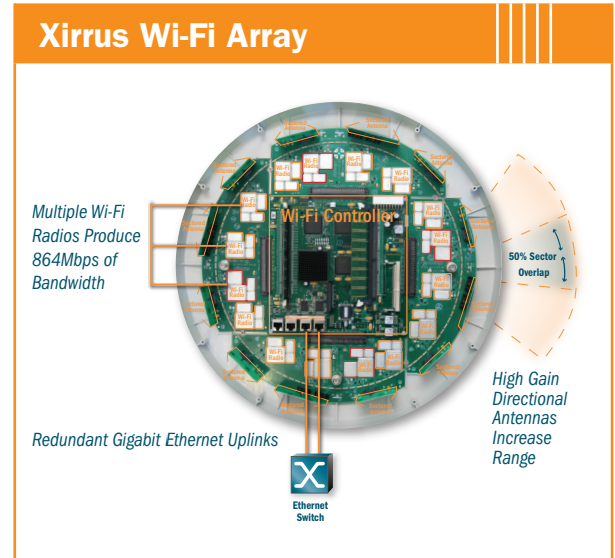


*By moving the intelligence to the network's entry point, Wi-Fi networks are capable of delivering greater performance, control, and flexibility.*

## 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.



*No other current-generation Wi-Fi technology can deliver the bandwidth or throughput of Xirrus Wi-Fi Arrays.*

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.

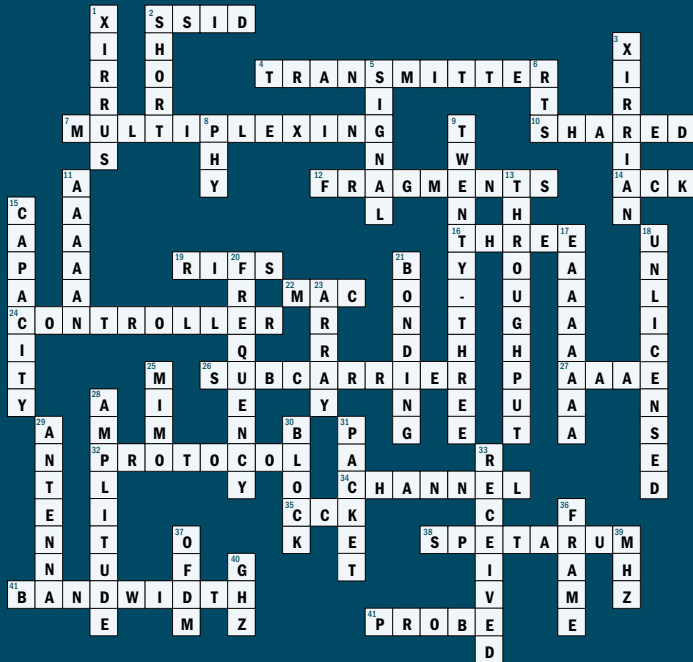
## About Xirrus

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.



## 802.11n Demystified Crossword Puzzle—Answer Key



### Across

2. Service identifier
4. Receiver antonym
7. Combine multiple streams into one
10. 802.11 medium
12. Files divided and scattered
14. Acknowledgement
16. Number of 802.11b/g non-overlapping channels
19. Improvement to SIFS
22. Improved in 802.11n
24. Circuitry to interpret and execute
26. Carried on top of carrier
27. Institute of engineers
32. Format for transmitting data
34. Path for signals
35. Complementary Code Keying
38. Contiguous frequencies
41. Pipe diameter
42. Requesting information

### Down

1. Only Wi-Fi Power Play
2. 802.11n guard interval
3. Xirrus language
5. Conveys data between points
6. Request to Send
8. Lowest level of OSI network model
9. Number of 802.11a non-overlapping channels
11. Targets at least 100Mbps of throughput
13. Amount of data sent in a given time
15. Maximum amount of users
17. Converting code
18. Public use
20. Rate at which a repeating event occurs
21. Combining two adjacent channels
23. Highest performing access device
25. Multiple antennas to improve rate and range
28. Height of a crest
29. Receive/send radio signal
30. Group of bits or bytes
31. Fragment of data
33. Transmitter antonym
36. Manages addressing and protocol information
37. Splits one band into many
39. One-million cycles per second
40. 109 Hz

Xirrus, Inc.

www.xirrus.com  
sales@xirrus.com

2101 Corporate Center Drive  
Thousand Oaks, CA 91320, USA

1.800.947.7871 Toll Free in the USA  
+1.805.262.1600 Sales  
+1.805.262.1601 Fax

Copyright© 2008, Xirrus, Inc. All Rights Reserved. Xirrus and the Xirrus logo are trademarks of Xirrus, Inc. All other trademarks belong to their respective owners. Protected by patent #US D526,973 S. Other patents pending.