Wi-Fi CERTIFIED™ 802.11n draft 2.0: Longer-Range, Faster-Throughput, Multimedia-Grade Wi-Fi® Networks

Executive summary

Wi-Fi CERTIFIED 802.11n draft 2.0 is a certification program for products based upon the IEEE draft 2.0 802.11n specification. At this writing, the final 802.11n amendment to the IEEE 802.11 standard is expected to be released in the second half of 2008. 802.11n is a major next step in the evolution of WLAN technology and represents more than just a new physical layer.

The 802.11n amendment has introduced substantial enhancements in Wireless Local-Area Network (WLAN) performance, efficiency and robustness of the 802.11 physical (PHY) and medium access control (MAC) layers. The draft 802.11n products currently on the market demonstrate a significantly higher throughput and improved range. The 802.11n standard promises to achieve as much as 5x the throughput and up to double the range over legacy 802.11 a/b/g technology.

At this level of throughput and range performance, 802.11n is expected to support multimedia applications in the home, with the ability to transport multiple high-definition (HD) video streams through the house, while at the same time accommodating Voice over Internet Protocol (VoIP) streams and data transfers for multiple users with high Quality of Service (QoS) and latest generation security protections in place. In enterprise, campus and municipal networks, 802.11n offers the robustness, throughput, security and QoS capabilities that IT managers have come to expect from wired Ethernet networks.

The IEEE 802.11n specification is now stable and converging. Many vendors have stated that their Wi-Fi CERTIFIED 802.11n draft 2.0 products are planned to be software-upgradeable to the eventual IEEE 802.11n standard. The industry now needs assurance that these new products interoperate with each other and that they are backwards compatible with and friendly to the legacy 802.11a/b/g systems. The Wi-Fi CERTIFIED program delivers this assurance.

Devices eligible for certification implement most of the mandatory capabilities in the IEEE 802.11n Draft 2.0 specification. In addition, certain optional capabilities are covered under the certification testing, if implemented in the device. The certification defines and verifies out-of-box behavior of draft 802.11n devices. It also tests for backwards compatibility with and protection of legacy 802.11a/b/g networks from potential disruption by 802.11n. Security and QoS testing are mandatory for the Wi-Fi CERTIFIED 802.11n draft 2.0 products.

About Wi-Fi Alliance

The Wi-Fi Alliance is a global, non-profit industry association of more than 300 member companies devoted to promoting the growth of wireless Local Area Networks (WLANs). With the aim of enhancing the user experience for mobile wireless devices, the Wi-Fi Alliance's testing and certification programs ensure the interoperability of WLAN products based on the IEEE 802.11 specification. Since the introduction of the Wi-Fi Alliance's certification program in March 2000, more than 3,500 products have been designated as Wi-Fi CERTIFIED™, encouraging the expanded use of Wi-Fi products and services across the consumer and enterprise markets. Apple, Broadcom, Cisco, Conexant, Dell, Intel, Microsoft, Motorola, Nokia, Sony, and Texas Instruments serve as Sponsor members of the Alliance, and a complete list of members is found at www.wi-fi.org.

Table of Contents

Introduction

The new generation of IEEE 802.11n-based Wi-Fi technology is expected to pick up significant market momentum in 2008. Draft 2.0 of the 802.11n amendment to the standard is now widely considered stable, with only minor changes from draft 1.0.

Tests conducted by vendors and independent test labs show that draft 802.11n products reach up to twice as far and are as much as five times as fast as legacy 802.11a/b/g technology. The currently available draft 802.11n technology can comfortably cover a typical house with sufficient bandwidth to support video, gaming, data and voice applications.

In the enterprise environment, 802.11n is expected to support mission-critical applications with the throughput, QoS and security capabilities comparable to Ethernet.

The next logical step for the industry is interoperability. Wi-Fi CERTIFIED 802.11n draft 2.0 is the industry-wide interoperability certification program for products based on the IEEE 802.11n draft 2.0 standard.

Certified products from different manufacturers have passed tests to verify their interoperability with other products, including backward compatibility with legacy Wi-Fi CERTIFIED products. Wi-Fi CERTIFIED 802.11n draft 2.0 products will also have the Wi-Fi Alliance security and QoS certifications – WPA/WPA2 and WMM – bringing security and high performance to mission critical applications in the enterprise and to bandwidth hungry multimedia applications in the home.

The developing IEEE 802.11n standard is based on MIMO (multiple-input multiple-output) air interface technology. MIMO is a significant innovation and a technology that is being adapted for use by several non-802.11 wireless data communications standards, including 4G cellular. MIMO employs a technique called spatial multiplexing to transport two or more data streams simultaneously in the same frequency channel. Spatial multiplexing is central to 802.11n and has the potential of doubling the throughput of a wireless channel when two spatial streams are transmitted. Generating multiple spatial streams requires multiple transmitters, multiple receivers and distinct, uncorrelated paths for each stream through the medium. Multiple paths can be achieved using antenna polarization or multipath in the channel.

Multipath is a common phenomenon in wireless channels, where the signal reflects from walls and objects, such as furniture. Reflections combine, distorting the signal at the receiver. While the legacy 802.11a/b/g radios work to overcome the effects of multipath, the multi-transmitter MIMO radios use multipath to advantage. Receivers in MIMO systems are able to consistently process each multipath component, thereby eliminating the mixture of out-of-phase components which sometimes result in signal distortion.

Spatial multiplexing capability is mandatory for Wi-Fi CERTIFIED 802.11n draft 2.0 products, except for handheld devices. Certification requires that least 2 spatial streams must be supported. Under most conditions 2-stream spatial multiplexing can achieve double the data rate of a single stream.

While the legacy networks operate in a 20 MHz channel, 802.11n defines the use of 20 and 40 MHz channels with up to 4 spatial streams per channel. The Wi-Fi 802.11n draft 2.0 certification program presently confines the use of 40 MHz channels to the 5 GHz band. With 4 spatial streams in a 40 MHz channel the maximum transmission data rate is 600 Mbps.

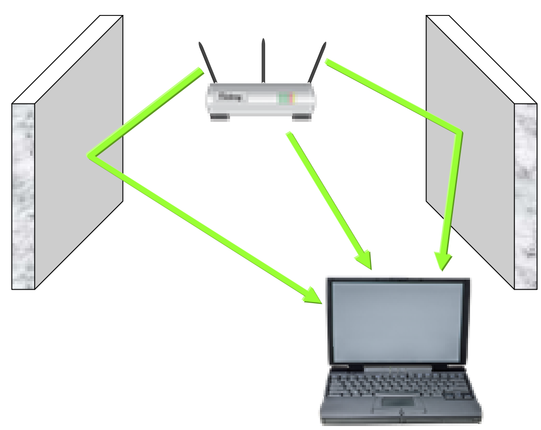
Current products can transmit at up to 300 Mbps using 2 spatial streams in a 40 MHz channel (table 1). The use of multiple streams and 40 MHz channels is optional.

	20 MHz Channel		40 MHz Channel	
	1 stream	2 streams	1 stream	2 streams
	Data Rate, in Mbps			
802.11b 2.4 GHz	1, 2, 5.5, 11			
802.11a 5 GHz	6, 9, 12, 18, 24, 36, 48, 54			
802.11g 2.4 GHz	1, 2, 6, 9, 12, 18, 24, 36, 48, 54			
802.11n GI[1]=800ns 2.4 GHz	6.5, 13, 19.5, 26, 39, 52, 58.5, 65	13, 26, 39, 52, 78, 104, 117, 130		
802.11n GI[2]=800ns 5 GHz	6.5, 13, 19.5, 26, 39, 52, 58.5, 65	13, 26, 39, 52, 78, 104, 117, 130	13.5, 27, 40.5, 54, 81, 108, 121.5, 135	27, 54, 81, 108, 162, 216, 243, 270
802.11n, GI=400ns 2.4 and 5 GHz	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2	14.4, 28.9, 43.3, 57.8, 86.7, 115.6, 130, 144.4	15, 30, 45, 60, 90, 120, 135, 150	30, 60, 90, 120, 180, 240, 270, **300**

Table 1: 802.11 a/b/b/n data rates, Mbps. *Shaded regions indicate optional capabilities. 600 Mbps data rate is achievable in a 40 MHz channel using GI of 400 ns and 4 streams.*

A MIMO system has some number of transmitters (N) and receivers (M), as depicted in figure 1. Signals from each of the N transmitters can reach each of the M receivers via a different path in the channel. MIMO works best if these paths are spatially distinct, resulting in received signals that are uncorrelated. Multipath helps decorrelate the channels and thus enhances the operation of spatial multiplexing.

Fig 1: An NxM MIMO system *has N transmitters and M receivers. Signals from each transmitter can reach the target receiver via a unique path, allowing for spatial multiplexing – a technique of sending multiple data streams in the same channel, thereby multiplying the throughput of a single stream.*



Aside from spatial multiplexing, 802.11n devices can also use the traditional styles of receiver spatial diversity, such as Maximum Ratio Combining (MRC). The standard also introduces transmitter spatial diversity techniques, such as Space Time Block Coding (STBC) and Cyclic Shift Diversity (CSD), to improve reception by spreading the spatial

[1] GI = Guard Interval, period within an OFDM symbol allocated to letting the signal settle prior to transmitting the next symbol. Legacy 802.11a/b/g devices use 800ns GI. GI of 400ns is optional for 802.11n.
[2] GI = Guard Interval, period within an OFDM symbol allocated to letting the signal settle prior to transmitting the next symbol. Legacy 802.11a/b/g devices use 800ns GI. GI of 400ns is optional for 802.11n.

streams across multiple antennas or transmitting the same signal with different cyclic shifts. On the transmit side, Beamforming is also specified as an optional feature.

The 802.11n standard has also introduced efficiency improvements in the MAC (media access control) protocol in the form of frame aggregation and block acknowledgements.

In the legacy 802.11 a/b/g systems an acknowledgment (ACK frame) is sent from the receiving station to the transmitting station to confirm the reception of each frame. If the transmitter does not receive an ACK, it retransmits the frame until an ACK is received. The ACK mechanism is also used in rate adaptation algorithms so that if too many retransmissions are required, the transmitting station drops to a lower data rate. The ACK mechanism adds robustness to 802.11 and ensures that all transmitted frames eventually get to the receiver, but this robustness comes at the price of protocol efficiency since for each transmitted frame, an additional ACK frame is also sent.

The block acknowledgement mechanism – a protocol for sending a single block ACK frame to acknowledge several received frames – can significantly improve protocol efficiency and throughput. While the block ACK protocol has been defined for legacy systems, it has not been extensively deployed. The block ACK mechanism is expected to be widely used in the 802.11n networks. The 802.11n draft has reduced the size of the block ACK frame from the legacy 128 bytes to 8 bytes, which represents a significant improvement in airlink efficiency considering the frequency of the ACK frames on the airlink.

Another area where 802.11n has improved MAC layer efficiency is through reducing the protocol overhead due to frame headers and inter-frame gaps. The shorter the frames, the lower the efficiency of transport due to the overhead of headers and inter-frame gaps. Voice traffic, composed of short frames (132-250 bytes, depending on the codec), is inherently inefficient and aggregating multiple voice frames into one has the potential of significantly increasing the efficiency of the voice service. Video traffic, too, can benefit from being transported using maximum size aggregate frames since video traffic sends many frames to the same destination. 802.11n maximizes the MAC layer transport efficiency through the frame aggregation protocol. The Aggregated MAC Service Data Unit (A-MSDU) mechanism increases the maximum size of the 802.11 MAC frames from the legacy 2304 bytes to 8k bytes. The Aggregated MAC Protocol Data Unit (A-MPDU) mechanism increases the maximum size of the 802.11 frames transported on the air link from the legacy 2304 bytes to 64k bytes.

Wi-Fi CERTIFIED 802.11n draft 2.0 products are required to pass the Wi-Fi WMM (Wi-Fi Multimedia) QoS certification, bringing prioritization to latency-sensitive streams (e.g. voice, video) to help avoid performance degradation.

The developing IEEE 802.11n standard incorporates many forward-looking capabilities that will serve different types of devices, including phones, personal digital assistants (PDAs), video game consoles, printers and other specialized platforms that are increasingly adopting Wi-Fi.

Table 2 summarizes the factors that contribute to improvements in throughput and range performance of 802.11n.

802.11n throughput enhancement technique	Description	Potential throughput enhancement over legacy 802.11 a/b/g
Spatial multiplexing	With 2 spatial streams throughput can be double that of a single stream.	100%
40 MHz channel width	Doubling the channel width over the legacy 20 MHz channel can double the throughput.	100%
More efficient OFDM	With 52 data sub-carriers vs. 48 for the legacy networks, the highest data rate per stream is 65 Mbps vs. the 802.11a/g 54 Mbps	20%
Shorter GI	The short GI of 400 ns allowed by 802.11n reduces the symbol time from 4 microseconds to 3.6 microseconds thereby increasing the symbol rate by 10%.	10%
Frame aggregation and Block ACK	A-MPDU has increased the maximum size of the frames on the airlink from the legacy 2.3k to 64k bytes. A-MSDU has increased the maximum size of the frames transported between MAC and LLC from 2.3k to 8k bytes. Block ACK protocol improves efficiency by enabling back-to-back frame transmissions. Frame aggregation and block ACK protocols provide significant efficiency gains, particularly for voice traffic where inter-frame gaps and ACK frames sent for every short voice frame make traditional voice streams highly inefficient. Frame aggregation also improves the efficiency of continuous traffic, such as video or large file transfers.	Up to 100% is possible, depending upon traffic

Table 2: Throughput enhancement techniques of 802.11n. *While the new MIMO PHY increases throughput in well-defined ways, the new MAC layer features improve protocol efficiency at upper layers and their impact is traffic pattern dependent.*

The Promise of 802.11n

Analyst firm ABI Research forecasts that 802.11n chipset shipments will increase from 93 million units in 2007 to about 1.1 billion units in 2012, dominating overall Wi-Fi shipments of 1.2 billion units.

This considerable rate of growth reflects the fact that 802.11n promotes expansion of Wi-Fi into new market segments and applications in the home and in the enterprise.

Home Environment

With its increased coverage and throughput, 802.11n enables HD video and audio-visual (AV) multimedia applications in the home environment. Increased throughput and WMM capabilities enable more reliable transport of simultaneous voice and multimedia sessions.

WMM certification helps ensure high quality of Wi-Fi calls, while the increased throughput and coverage of 802.11n provides sufficient bandwidth to transport multiple video streams to Wi-Fi enabled set-top boxes or TV sets around the house.

The high bandwidth and QoS of Wi-Fi CERTIFIED 802.11n draft 2.0 systems helps ensure that an internet connection can be reliably shared by the increasing number and type of Wi-Fi enabled devices in the home without degradation of service. Higher data rates of 802.11n also increase the throughput capacity of overlapping Wi-Fi networks.

The increased range of 802.11n provides coverage of the entire house, reaching farther than the legacy technology and reducing “dead spots” or low-rate areas in the home. Even single-antenna mobile devices, such as Wi-Fi phones, will enjoy the benefits of increased range and throughput of Wi-Fi CERTIFIED 802.11n by virtue of the transmit diversity capabilities, such as Space Time Block Coding (STBC), Cyclic Shift Diversity (CSD) and Transmit Beamforming.

Most network transactions, including voice and data services, will benefit significantly from the 802.11n frame aggregation technology. Printing files from PCs to printers, transferring files between PCs and network drives and sharing files between PCs, laptops and other devices on the network becomes more efficient with 802.11n thanks to frame aggregation.

Enterprise Environment

802.11n is enterprise-grade technology that will provide IT managers with nearly the same reliable service they have come to expect from their Ethernet networks. Mission-critical enterprise applications, such as Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP) access, collaboration tools, voice and video conferencing, will all benefit from the increased throughput and range of 802.11n.

The new efficiencies and enhancements of 802.11n on the MAC and PHY layers, combined with the WMM QoS capabilities, serve to improve the quality of VoIP and to increase the number of simultaneous calls on the airlink. Physical layer transmission enhancements of 802.11n, such as Space Time Block Coding (STBC), improve reception even for single receiver Wi-Fi phones by virtue of transmitting multiple copies of a data stream via multiple antennas. Multiple versions of the signal reaching the phone are received and processed with specialized decoding techniques to provide redundancy of signaling and optimize reception.

Of significant benefit to the Enterprise is lower density of APs, made possible by the improved efficiencies in the MAC, enhancements in the PHY operation and longer reach. Due to faster physical layer transmissions, stations get on and off the air faster, improving the airlink efficiency. The MAC layer mechanisms such as block ACK and frame aggregation also improve the airlink efficiency by reducing the overhead of packet headers, inter-frame gaps and ACK transmissions.

Legacy stations in the 802.11n network can benefit from better coverage provided by the 802.11n APs’ CSD and MRC techniques and they can also gain increased access to the airlink as the new 802.11n devices get on and off the air faster.

Campus and Municipal Networks

Campus and municipal networks typically operate in challenging environments where range is the biggest issue. 802.11n is well-equipped to improve the operating range even for single-antenna handheld devices used in such outdoors networks. Increased range of handheld devices is achieved through AP transmit and receive diversity mechanisms. Transmit diversity of APs, including STBC and transmit Beamforming, improves the downlink range performance. Receive diversity of APs, including MRC, reciprocate the transmit diversity and thus maintain the range for both the uplink and the downlink directions.

Improvements in Voice Performance

The handheld devices operating in the enterprise, campus and municipal networks enjoy improvements in VoIP performance and efficiency through protocols like, block ACK and frame aggregation. The required WMM part of the certification ensures that voice streams get priority over other classes of traffic and thus further enhances the voice service.

Given the significant improvements in throughput, efficiency and range offered by 802.11n, home users and IT managers planning new Wi-Fi deployments in the indoor or outdoor networks should give careful consideration to Wi-Fi CERTIFIED 802.11n draft 2.0 products over legacy equipment.

Wi-Fi CERTIFIED for 802.11n Draft 2.0

The Wi-Fi CERTIFIED for 802.11n program tests and certifies products based upon IEEE 802.11n Draft 2.0 [1], WFA WMM [2] and WPA [3] documents.

The key features of the baseline certification are listed in Table 3:

Feature	Explanation	Type
Support for 2 spatial streams in transmit mode	Required for an AP device	Mandatory
Support for 2 spatial streams in receive mode	Required for an AP and a client device, except for handheld devices	Mandatory
Support for A-MPDU and A-MSDU	Required for all devices	Mandatory
Support for block ACK	Required for all devices	Mandatory
2.4 GHz operation	Devices can be 2.4 GHz only, 5 GHz only or dual-band. For this reason, both frequency bands are listed as optional.	Tested if Implemented
5 GHz operation		Tested if Implemented
40 MHz channels in the 5 GHz band	40 MHz operation is only supported by the Wi-Fi Alliance in the 5 GHz band. In the 2.4 GHz band, heavily used by legacy installations and with only 3 non-overlapping channels, 40 MHz operation poses risk of interfering with operational legacy networks. The protocol for allowing 40 MHz operation in the 2.4 GHz band is still being debated at the IEEE and may be supported by the Wi-Fi Alliance at a later time, once consensus is reached.	Tested if Implemented
Greenfield preamble	Greenfield preamble cannot be interpreted by legacy stations. It is shorter than the mixed mode or legacy mode preamble and improves efficiency of the 802.11n networks with no legacy devices.	Tested if Implemented
Short Guard Interval (Short GI), 20 and 40 MHz	Short GI is 400 nanoseconds vs. the traditional GI of 800 nanoseconds. Short GI reduces the symbol time from 4 microseconds to 3.6 microseconds to improve throughput by 10%.	Tested if Implemented
Concurrent operation in 2.4 & 5 GHz bands	This mode is tested for APs only	Tested if Implemented

Table 3: Summary of key Baseline Certification features

Devices may also include optional features for which the Wi-Fi Alliance has no defined tests. These are known as *optional untested* features. One of the requirements of Wi-Fi Alliance certification is that optional untested features must not in any way disrupt the Wi-Fi CERTIFIED features and expected functionality.

Protection protocols defined by the 802.11n standard are designed to protect existing 802.11a/b/g installations from possible detrimental impact by the 802.11n transmissions that legacy devices may be unable to receive or interpret. 802.11n devices must employ protection protocols if legacy networks or devices are within range.

Protection mechanisms, such as mixed-mode preamble and non-HT (non-high-throughput) duplicate mode, are designed to protect legacy networks from potential disruption by the new MIMO protocols. The legacy part of mixed mode preamble is readable by both HT and non-HT devices, and contains the MIMO frame duration. In the non-HT mode, two frames with identical legacy frames are sent by the Wi-Fi CERTIFIED 802.11n draft 2.0 equipment on both 20 MHz halves of the 40 MHz channel simultaneously. The non-HT duplicate frame is used to announce the Network Allocation Vector (NAV) in a way readable by both 20 MHz HT (high throughput) and non-HT devices. This sets up a time period during which legacy stations should keep off the air. Following protection established by those mechanisms, the Wi-Fi CERTIFIED 802.11n draft 2.0 devices can use the new 802.11n protocols without disrupting the legacy networks.

Overlapping Legacy BSS Condition (OLBC) exists when a legacy BSS is located in proximity of an 802.11n BSS so that the 802.11n AP can hear beacons from the neighboring BSS that indicate the presence of legacy devices. Protection protocols must be used in the OLBC case.

Out of the box (OOB) settings of the certified device must be set up so that the device can detect the scenarios described in Table 4 and operate as indicated. OOB settings should only have 20 MHz operation enabled in the 2.4 GHz band.

Scenario	Out of the box behavior
Scenario A: All devices are 802.11n capable, no OLBC exists	• Mandatory features are used • Optional features may be used • No protection protocols are used, unless device detects a protection protocol being used
Scenario B: All devices are 802.11n capable and an OLBC exists	• Mandatory features are used • Protection protocols are used • Efficiency enhancing features of 802.11n, such as spatial multiplexing, 40 MHz channels, frame aggregation and other techniques, can be used only with protection protocols, such as the non-HT mode
Scenario C: A combination of 802.11n and legacy 802.11a/b /g stations are present in a BSS	• Mandatory features are used • Protection protocols are used • Efficiency enhancing features of 802.11n, such as spatial multiplexing, 40 MHz channels, frame aggregation and other techniques, can be used only with protection protocols, such as the non-HT mode

Table 4: Required out of the box behavior for baseline certification

Support for 2.4 GHz or 5 GHz band or both is at the vendor’s discretion. Certified devices may support either one or both bands. APs can optionally be tested in the concurrent 2.4 and 5 GHz operating mode.

Wi-Fi CERTIFIED 802.11n draft 2.0 products that support 5 GHz operation will undergo the Wi-Fi Alliance 802.11a certification. Wi-Fi CERTIFIED draft 802.11n products that support 2.4 GHz will undergo the Wi-Fi Alliance 802.11b/g certification. In both cases, certification for the legacy operating modes is mandatory.

Although the IEEE 802.11n draft supports 40 MHz operation in the 2.4 GHz band, this mode presents some issues and is the subject of ongoing discussions. Since only 70 MHz is available in the 2.4 GHz band, already crowded with the legacy 802.11b/g networks, 40 MHz operation of 802.11n poses a possibility of disrupting existing installations. This issue was addressed by introducing new coexistence protocols that include methodology for detecting WLAN activity in the band, for sharing the secondary channel (the second 20MHz channel comprising the 40 MHz channel) with adjacent networks and for switching channels when necessary to avoid interference. These are complex protocols requiring coordinated periodic scanning of all available channels and the 802.11 working group may still refine them. At a later time, if the IEEE reaches a level of comfort with the 40 MHz operation in the 2.4 GHz band, the Wi-Fi Alliance may consider including this mode in the certification.

The Wi-Fi CERTIFIED testing sets as its primary goal to help ensure interoperability of the certified devices. The Wi-Fi Alliance does not do benchmarking for range or throughput performance.

Wi-Fi Alliance Certification Testing Approach

The test approach is to verify the operation of clients under test with at least 4 APs, representing chipsets from at least 3 different vendors, and to verify the operation of an APs under test against at least 4 clients using different chipsets. This is depicted in figure 2 below.

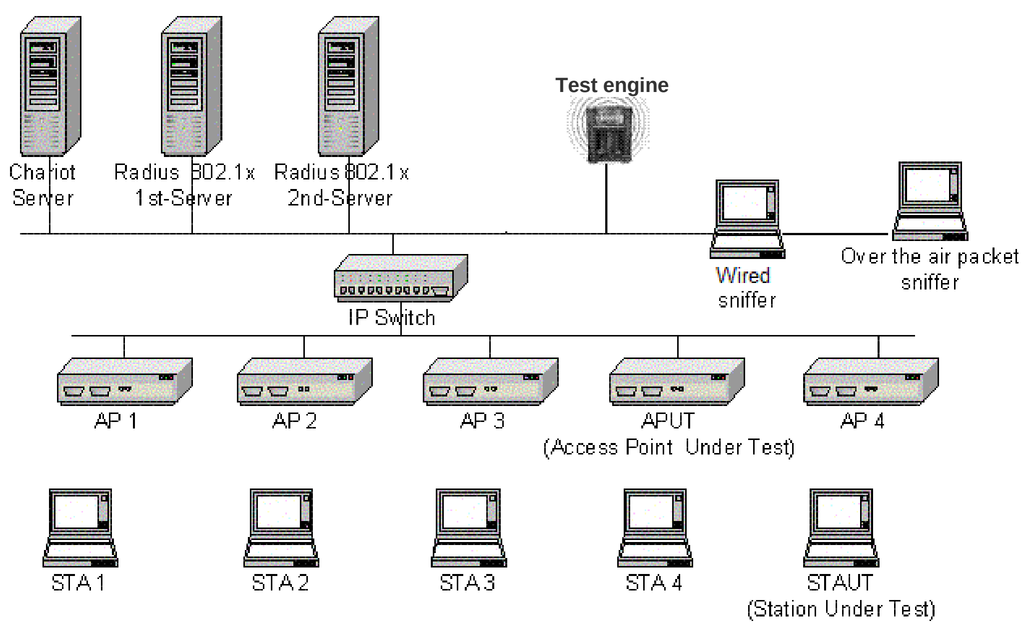


Fig 2: Typical over-the-air certification test bed *tests a client against 4 APs or an AP against 4 clients. Devices in the test bed are based on silicon from different vendors.*

The testing is performed over the air at close range. In addition to interoperability, some performance testing is performed with the goal of ensuring proper operation of the devices. Such performance testing is used for functionality and interoperability verification and does not set competitive thresholds on performance.

The test bed for Wi-Fi CERTIFIED 802.11n draft 2.0 incorporates legacy devices for verifying backwards interoperability of the device under test. Legacy devices, 802.11a/b/g, can also be tested in the 802.11n draft 2.0 test bed to verify forward compatibility with 802.11n. The forward compatibility testing is not required and can be performed at the vendor's discretion.

The Wi-Fi CERTIFIED 802.11n draft 2.0 testing includes verification of the legacy 802.11a/b/g modes of operation. QoS and security certification to the existing Wi-Fi Alliance standards – WMM™ and WPA/WPA2 with Extended EAP – is a requirement.

The WMM Power Save certification will become an important requirement in the future as battery powered handheld devices start incorporating draft 802.11n. The WMM Power Save test ensures proper support for sleep mode operation of handheld devices. This test is not required as part of 802.11n draft 2.0 testing, but is highly recommended for battery-powered stations and all AP devices.

Identifying Wi-Fi CERTIFIED Products

The Wi-Fi Alliance Wi-Fi CERTIFIED logo has been updated to accommodate draft 2.0-based certified products and indicate backward compatibility with 802.11 a/b/g gear. The a, b, g and n elements of the logo indicate physical layer compatibility when present.

Fig 3: Wi-Fi CERTIFIED Logo *with SIIs for 802.11 a, b, g and draft n physical layers*

In addition, some manufacturers will ship products with an Interoperability Certificate issued by the Wi-Fi Alliance which articulates every certification completed. A sample of the certificate follows as Figure 4.

Wi-Fi® Interoperability Certificate

Certification ID: WFA4853

CERTIFIED®

This certificate indicates the capabilities and features that successfully completed interoperability testing by the Wi-Fi Alliance. You may find detailed descriptions of these features at www.wi-fi.org/certification_programs.php.

Certificate Date:	April 30, 2007
Category:	Reference Design (please select secondary categories)
Company:	White Lion
Product:	product_name
Model/SKU #:	model_number/sku

This product has the following Wi-Fi Certifications:

IEEE Standard	Security	Multimedia	Special Features
IEEE 802.11a IEEE 802.11b IEEE 802.11g IEEE 802.11n draft 2.0 IEEE 802.11h IEEE 802.11d	WPA™ - Personal WPA2™ - Personal	WMM™ WMM Power Save	Wi-Fi Protected Setup™ PIN PBC

For more information: www.wi-fi.org/certification_programs.php

Fig 4: Interoperability Certificate

The Wi-Fi Alliance Web site, www.wi-fi.org, provides an up-to-date listing of all Wi-Fi CERTIFIED products. Users can search via product category or by a variety of criteria such as manufacturer, certification type, etc., and can view the Interoperability Certificate for products which have been certified.

A Look Ahead

The baseline Wi-Fi CERTIFIED 802.11n program is the first step in the 802.11n certification process and is optimized for PC devices. As diverse platforms increasingly adopt 802.11n, the certification program is expected to expand to accommodate the specialized market requirements of various types of device. The Wi-Fi Alliance is planning the development of a Handheld (HH) Profile and a Consumer Electronics (CE) Profile.

The optional Profile testing will focus on testing the features that may be specifically appropriate for the target device class, such as handheld VoIP terminals or CE equipment such as video servers, set-top boxes, displays and cameras.

When the 802.11n standard is ratified by the IEEE (expected in late 2008) the Wi-Fi Alliance plans to update its certification testing accordingly.

Additional Resources

For additional information on the Wi-Fi Alliance please consult www.wi-fi.org where you can find a listing of Wi-Fi CERTIFED products, white papers and Frequency Asked Questions.

Glossary

802.11a/b/g	IEEE specifications for a wireless networks that operate at 2.4 GHz (b, g) or 5 GHz (a) with rates up to 11Mbps (b) or 54 Mbps (a, g).
802.11n	IEEE draft amendment to 802.11 standard defining MIMO operation on the physical layer and incorporating improvements on the MAC layer. 802.11n is expected to have the throughput of greater than 100 Mbps.
Access Point (AP)	Often a Wi-Fi router, a device that connects wireless devices to a network.
ACK frame	A short frame sent by the receiving station to the transmitting station to confirm the receipt of the frame. If the transmitter doesn't receive an ACK, it retransmits the frame until an ACK is received. After a few unsuccessful retransmission attempts, the transmitter may reduce the data rate.
Beamforming	A technique of using several antenna elements to spatially shape the emitted electromagnetic wave to beam the energy into the receiver by adjusting the magnitude and phase from each transmit antenna. Beamforming requires the transmitting and receiving stations to perform channel sounding to optimize the shape and direction of the beam. Beamforming can be used in conjunction with spatial multiplexing or by itself when only a single path is available between the radios.
Block acknowledgement (Block ACK)	The method of sending a single acknowledgement frame to confirm receipt of multiple frames
Basic Service Set (BSS)	A network consisting of an AP and its associated clients
Client	Any device connected to a network that is able to request files and services (files, print capability) from the server or other devices on the network.
Codec	Coder/decoder – an algorithm implemented either in software or in hardware to encode the digitized voice, video or image data for optimum transmission over the network.
Customer Relationship Management (CRM)	An Enterprise data system used for a variety of customer support, customer communications or analysis functions.
Cyclic Shift Diversity (CSD)	A type of transmit diversity; a signal shaping technique incorporated into the 802.11n specification that spreads the spatial streams across multiple antennas by transmitting the same signal with different phase shifts
Device	An independent physical or logical entity capable of communicating with other devices across a Local Area Network (LAN) or Wireless Local Area Network (WLAN).
Downlink	Transmission direction from the AP to the stations
Enterprise Resource Planning (ERP)	An Enterprise data system for managing critical Enterprise operation including financial systems, payroll, purchasing,

	manufacturing, sales and other functions.
Frame Aggregation	A protocol for combining several frames into a single frame, thereby eliminating some inter-frame gaps and improving efficiency on the airlink.
Guard Interval (GI)	A period at the end of each OFDM symbol allocated to letting the signal dissipate prior to transmitting the next signal. This prevents overlaps between two consecutive symbols. Legacy 802.11a/b/g devices use 800ns GI. GI of 400ns is optional for 802.11n.
Header	Frame header, or packet header, is a field at the start of a packet. Headers can serve different protocol layers. MAC headers typically include the source and destination MAC address of the packet and include the protocol information necessary to process the packet.
High Throughput (HT)	Typically referrers to draft 802.11n devices that offer higher throughput than legacy 802.11 a/b/g devices
Inter-frame gap	Or inter-packet gap, is a quiet time between packets transmitted on the network.
Local Area Network (LAN)	A system of connecting PCs and other devices within the same physical proximity in order to share resources, such as an Internet connection, printers, files and drives. When Wi-Fi is used to connect the devices, the system is known as a wireless LAN or WLAN.
Logical Link Control (LLC)	Protocol layer between MAC and Layer 3, which is typically IP Transport layer, such as TCP/IP or UDP/IP.
Maximum Ratio Combining (MRC)	A technique used by a wireless receiver that's working with two or more diversity antennas to optimally combine signals received by these antennas, taking into account the SNR of each of the received signals.
Network Allocation Vector (NAV)	An indicator, maintained by each station, of time periods when transmission onto the wireless medium will not be initiated by the station. NAV information can be derived from the announcements by other stations of how long they intend to occupy the medium. NAV is the central mechanism in collision avoidance protocol.
Network Name	A name used to identify a wireless network referred to as the service set identifier, or SSID.
Non High Throughput (non-HT) duplicate mode	Method to protect legacy networks from disruption by the new 802.11n protocols designed to improve efficiency – protocols such as frame aggregation or STBC that legacy stations are unable to interpret. In non-HT mode, prior to the use of new efficiency protocols, two packets are sent on both halves of the 40 MHz channel simultaneously announcing the NAV to tell legacy stations how long to stay off the network.
Space Time Block Coding	A transmitter diversity technique of spreading the transmit

(STBC)	signal over multiple antennas to improve reception. STBC also incorporates FEC (Forward Error Correction) coding.
Uplink	Transmission direction from the stations to the AP
Wi-Fi	A term developed by the Wi-Fi Alliance to describe WLAN products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 (a,b,g, draft n) standards.
Wi-Fi CERTIFIED	Word mark used by product(s) passing certification testing requirements developed and governed by the Wi-Fi Alliance.
Wi-Fi CERTIFIED 802.11n draft 2.0	Certification for new generation Wi-Fi equipment designed to the IEEE 802.11n draft 2.0 specification
Wi-Fi Network	A Wireless Local Area Network
Wireless Router	A wireless router is device that accepts connections from wireless devices to a network and includes a network firewall for security, and provides local network addresses.
Wireless Local Area Network (WLAN)	A Wi-Fi network.
WMM	Wireless Multi Media, the Wi-Fi Alliance QoS protocol and certification defining different priority levels for voice, video, background and best effort traffic. WMM is based on the 802.11e amendment that has been incorporated into the 802.11/2007 edition of the standard.
Wi-Fi Protected Access (WPA):	An improved security standard for wireless networks that provides strong data protection and network access control
Wi-Fi Protected Access version 2 (WPA2)	A next-generation security protocol/method for wireless networks that provides stronger data protection and network access control than WPA

Abbreviations

A-MPDU	Aggregate MAC Protocol Data Unit
A-MSDU	Aggregate MAC Service Data Unit
AP	Access Point
BSS	Basic Service Set
CE	Consumer Electronics
CSD	Cyclic Shift Diversity
CRM	Customer relationship management
ERP	Enterprise Resource Planning
GI	Guard Interval
HT	High Throughput
LLC	Logical Link Control
MAC	Medium Access Control
MIB	Management Information Base
MIC	Message Integrity Code
MIH	Media Independent Handover
MP	Mesh Point
MPDU	MAC Protocol Data Unit
MRC	Maximum Ratio Combining
MSDU	MAC Service Data Unit
NAV	Network Allocation Vector
OFDM	Orthogonal Frequency Division Multiplexing
RCPI	Received Channel Power Indicator
RSSI	Receive Signal Strength Indicator
SAP	Service Access Point
SG	Study Group
SII	Standard Indicator Icon
STBC	Space Time Block Coding
TG	Task Group
TPC	Transmit Power Control
WG	Working Group
WFA	Wi-Fi Alliance
WLAN	Wireless Local Area Network
WMM	Wireless Multi Media

References

1. IEEE P802.11n™/D2.0,"Draft STANDARD for Information Technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements. Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment 4: Enhancements for Higher Throughput".

2. Wi-Fi Alliance – WMM™ (including WMM™ Power Save Specification) Version 1.1

3. Wi-Fi Alliance – Wi-Fi Protected Access (WPA) Version 3.1