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

September 2009

Executive Summary

The Wi-Fi CERTIFIED n interoperability test program certifies products based on the 802.11n amendment to the IEEE 802.11 standard (802.11n). 802.11n is the latest step in the evolution of Wireless Local Area Network (WLAN) technology. This paper provides an overview of 802.11n technology and describes the Wi-Fi CERTIFIED n program in detail.

The 802.11n amendment introduces substantial enhancements in Wi-Fi performance. Today's Wi-Fi CERTIFIED n devices can deliver five times or more throughput and more robust connections at up to twice the range of legacy 802.11 technology. This improved performance is available today in a broad and growing range of products addressing diverse market requirements. As manufacturers incorporate key 802.11n capabilities into their products, the full potential of 802.11n will become evident. Fully featured Wi-Fi CERTIFIED n products have the ability to transport 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). Wi-Fi CERTIFIED n devices also have the latest generation security protections. In enterprise, campus and municipal networks, 802.11n offers the robustness, throughput, security and QoS capabilities that IT managers seek.

The Wi-Fi CERTIFIED n program is an update to the Wi-Fi CERTIFIED 802.11n draft 2.0 program which was released in June 2007 (draft-n program). The baseline requirements of the program are unchanged, and the updated program adds support for some optional features included in the standard. The Wi-Fi CERTIFIED n program preserves interoperability with more than 700 products certified under the draft-n program, including computers, consumer electronics such as televisions and media servers, and consumer networking devices. The success of the draft-n program extended deeply into the enterprise segment, with more than 100 enterprise-grade access point/switch devices certified. Since all products certified under the draft-n program meet the core requirements of, and interoperate with, the updated program, they are eligible to use the Wi-Fi CERTIFIED n logo without retesting**.**

About the Wi-Fi Alliance

The Wi-Fi Alliance is a global non-profit industry association of hundreds of leading companies devoted to the proliferation of Wi-Fi technology across devices and market segments. With technology development, market building, and regulatory programs, the Wi-Fi Alliance has enabled widespread adoption of Wi-Fi worldwide.

The Wi-Fi CERTIFIED™ program was launched in March 2000. It provides a widely-recognized designation of interoperability and quality, and it helps to ensure that Wi-Fi enabled products deliver the best user experience. The Wi-Fi Alliance has completed more than 6,000 product certifications to date, encouraging the expanded use of Wi-Fi products and services in new and established markets.

Table of Contents

Executive Summary 2
About the Wi-Fi Alliance 2
Introduction 4
802.11n Technology 4
    Throughput 5
    Range and Reliability 5
    Multiple Antennas or MIMO 5
    Channelization 6
    Efficiency Measures 7
Estimating Feature Impact on Throughput 8
Mandatory and Optional Features in Wi-Fi CERTIFIED n Testing 9
Frequency Bands and Protection Protocols 10
Wi-Fi Alliance Certification Testing Approach 11
Identifying Wi-Fi CERTIFIED n Products 12
The Promise of 802.11n 14
    Home Environment 14
    Enterprise Environment 15
    Campus and Municipal Networks 15
    Improvements in Voice Performance 15
Summary 15
Glossary 16
Abbreviations 18
References 18

Introduction

The Wi-Fi Alliance has updated its Wi-Fi CERTIFIED n program coinciding with the ratification of the 802.11n amendment to the IEEE 802.11 standard [1] (802.11n). The Wi-Fi Alliance certification program based on draft 2.0 of the IEEE standard (draft-n program) was introduced in 2007, and has propelled the adoption of 802.11n products in homes, in the enterprise and in other markets. More than 700 products were certified under the draft-n program. Among them are more than 100 enterprise-grade access point/switch devices along with consumer networking devices, computers, and consumer electronics including televisions and media servers.

The mandatory baseline requirements for the updated Wi-Fi CERTIFIED n program are the same as in the draft-n program, so devices certified under draft-n are fully compliant with Wi-Fi CERTIFIED n. The updated program incorporates testing for some optional features from the ratified standard which have begun to see wider deployment in the marketplace.

Wi-Fi CERTIFIED n products are tested to verify their interoperability, including backward compatibility with legacy Wi-Fi CERTIFIED products. Wi-Fi CERTIFIED n products also have the Wi-Fi Alliance security and QoS certifications – WPA2 and WMM – bringing security and high performance to mission-critical applications in the enterprise and to bandwidth-hungry multimedia applications in the home.

802.11n Technology

802.11n is a major step in the evolution of Wi-Fi technology because unlike its predecessors 802.11a and 802.11g, 802.11n is more than a new physical layer protocol (PHY). Wi-Fi CERTIFIED n incorporates several significant enhancements that can deliver five times or more throughput and more robust connections at up to twice the range over legacy technology. 802.11n technology can easily cover a typical house with sufficient bandwidth to support video, gaming, data and voice applications. The leap in performance and network robustness is easily experienced and measured when users upgrade from legacy networks to 802.11n.

The technology enhancements in the 802.11n standard are sophisticated. The benefits of individual features are often expressed in more than one way. The Wi-Fi CERTIFIED n program incorporates the most important of these features to deliver throughput and range improvements. They are depicted in Figure 1 and described below.

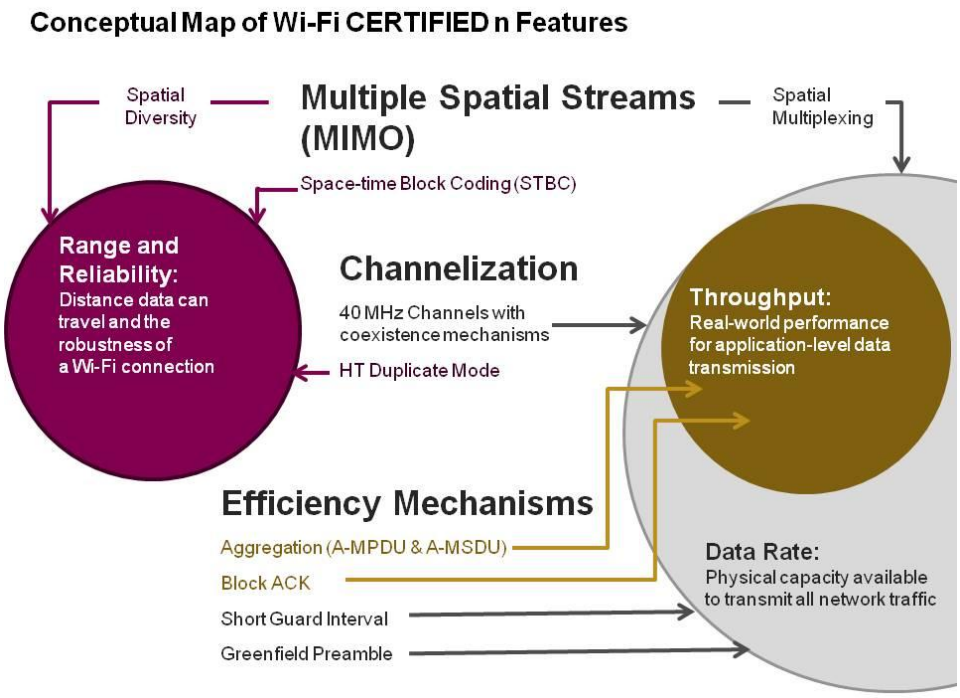

***Figure 1: Conceptual map** of optional features in Wi-Fi CERTIFIED n program*

Throughput

Throughput is the "real" measure of performance. It is what the user perceives as a device's performance as he uses it in everyday ways. Throughput is the transmission capability that is available to applications after the overhead required to address the needs of upper layer protocols has been addressed. By definition, throughput is a subset of a device's physical layer data rate (data rate). Data rate is an expression of a device's raw transmission capability at the lowest, physical layer. It is an essential contributor to device performance, but an end user will not experience performance equivalent to a device's data rate.

Range and Reliability

Range is the distance at which a device can operate effectively. Range incorporates elements of both throughput and robustness – that is the user's perception of a device's range combines distance with expectations about the speed and quality of the connection. The value of 802.11n's improved range is most clearly seen in applications like voice and video.

Multiple Antennas or MIMO

MIMO (multiple input multiple output) leverages multipath. Multipath is a phenomenon in wireless transmissions in which the signal reflects from walls and objects, such as furniture. Reflections can combine, distorting the signal at the receiver. While legacy 802.11a/b/g radios use techniques to overcome the negative effects of multipath, the IEEE 802.11n standard incorporates MIMO, which instead uses multipath to enhance communication.

A MIMO system has some number of transmitters (N) and receivers (M), as depicted in Figure 2. Signals from each of the N transmitters can reach each of the M receivers via a different path in the channel. A MIMO device with multiple antennas is capable of sending multiple spatial streams – spatially distinct data streams within the same channel. A MIMO device with multiple

antennas is capable of receiving multiple spatial streams. Multipath helps decorrelate the received signals enabling transmission of multiple data streams through the same MIMO channel – a technique called spatial multiplexing. MIMO can multiply data rate through a technique called spatial multiplexing - dividing a data stream into several branches and sending it as multiple parallel data streams simultaneously in the same channel.

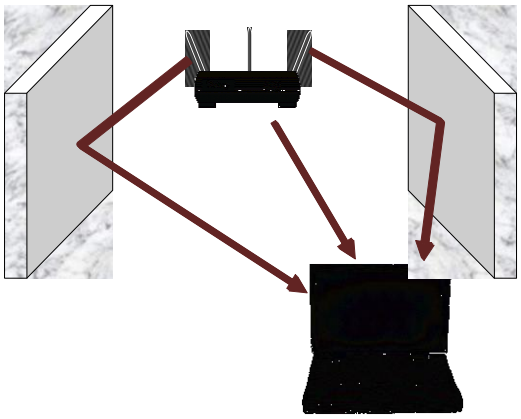

Figure 2: An NxM MIMO system has N transmitters and M receivers. Signals from each transmitter can reach the target receiver via a unique path, allowing for spatial multiplexing – a technique of sending multiple data streams in the same channel, thereby multiplying the data rate of a single stream.

MIMO can also be used to improve the robustness and range of 802.11n communications through a technique called spatial diversity. When the same data stream is transmitted across multiple spatial streams error rate can be reduced. An additional technique improving range and reliability called Space Time Block Coding (STBC) is also incorporated into Wi-Fi CERTIFIED n. STBC improves reception by coding the data stream in blocks which are distributed for transmission across multiple transmitting antennas and across time. At the receiving antenna, the data is recombined in an optimal way making use of the coding. STBC requires multiple transmit antennas and delivers benefits to devices with the ability to receive one or more data streams.

Channelization

In addition to the benefits reaped from spatial multiplexing in MIMO, 802.11n technology employs several other techniques to support faster data rates by enabling the use of wider channels.

While 802.11 a/b/g networks operate in a 20 MHz channel, 802.11n defines the use of 20 and 40 MHz channels. 40 MHz channels allow doubling of the data rate to 150 Mbps. All 802.11 devices send a packet over the air as a sequence of symbols. Devices using 40 MHz channels can encode and transmit more data in each symbol. Depending on the degree of complexity that the environment can support, 802.11 devices choose an appropriate data rate for use over the air. For example, the IEEE 802.11b standard supports data rates of 1, 2, 5.5 and 11 Mbps.

Table 1 shows the range of data rates for different 802.11 technologies.

	20 MHz Channel				40 MHz Channel			
	1 stream	2 streams	3 streams	4 streams	1 stream	2 streams	3 streams	4 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 2.4 and 5 GHz	6.5, 13, 19.5, 26, 39, 52, 58.5, 65	13, 26, 39, 52, 78, 104, 117, 130	19.5, 39, 58.5, 78, 117, 156, 175.5, 195	26, 52, 78, 104, 156, 208, 234, 260	13.5, 27, 40.5, 54, 81, 108, 121.5, 135	27, 54, 81, 108, 162, 216, 243, 270	40.5, 81, 121.5, 162, 243, 324, 364.5, 405	54, 108, 162, 216, 324, 432, 486, 540
802.11n, SGI enabled 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	21.7, 43.3, 65, 86.7, 130, 173.3, 195, 216.7	28.9, 57.8, 86.7, 115.6, 173.3, 231.1, 260, 288.9	15, 30, 45, 60, 90, 120, 135, 150	30, 60, 90, 120, 180, 240, 270, 300	45, 90, 135, 180, 270, 360, 405, **450**	60, 120, 180, 240, 360, 480, 540, **600**

Table 1: 802.11 a/b/g/n data rates, Mbps. *Optional features, such as spatial multiplexing and 40 MHz channels, can increase data rates up to a maximum of 600 Mbps.*

Efficiency Measures

The improved throughput of 802.11n comes through two paths. Several features increase data rate in the physical layer, with some proportion of that effect visible in throughput increases. 802.11n also includes innovations that reduce overhead and improve efficiency of transmissions – directly contributing to improved throughput.

As discussed previously, MIMO and channelization both directly affect a device's data rate. In addition, an 802.11n technique called Short Guard Interval (SGI) can also improve data rate by reducing the size of the gap between symbols.

Much of the throughput improvement in 802.11n comes from aggregation techniques. Frame aggregation improves the efficiency of 802.11n systems by reducing the protocol overhead required for transmitting protocol frames. Video traffic can benefit from being transported using maximum size aggregate frames since video traffic sends many frames to the same destination.

The Aggregated Medium Access Control Service Data Unit (A-MSDU) mechanism increases the frame size used in transmitting Medium Access Control (MAC) protocol frames. The Aggregated MAC Protocol Data Unit (A-MPDU) mechanism increases the maximum size of the 802.11 frames transported on the air from the legacy 2304 bytes to 64k bytes.

Another efficiency improvement is in the area of streamlined acknowledgements. The block acknowledgement mechanism – a protocol for sending a single block acknowledgement (ACK) frame to acknowledge several received frames – can significantly improve protocol efficiency and throughput by reducing the amount of overhead dedicated to acknowledgements. While the block ACK protocol was also defined for legacy systems, it was not extensively deployed. The 802.11n standard has reduced the size of the block ACK frame from the legacy 128 bytes to eight bytes, which also yields a significant improvement in efficiency.

Estimating Feature Impact on Throughput

Industry performance numbers cited for throughput calculations, measurements and comparisons are typically based on transmission of the TCP/IP protocol suite. Figure 3 shows how optional features may contribute to improvements in throughput of Wi-Fi CERTIFIED n devices.

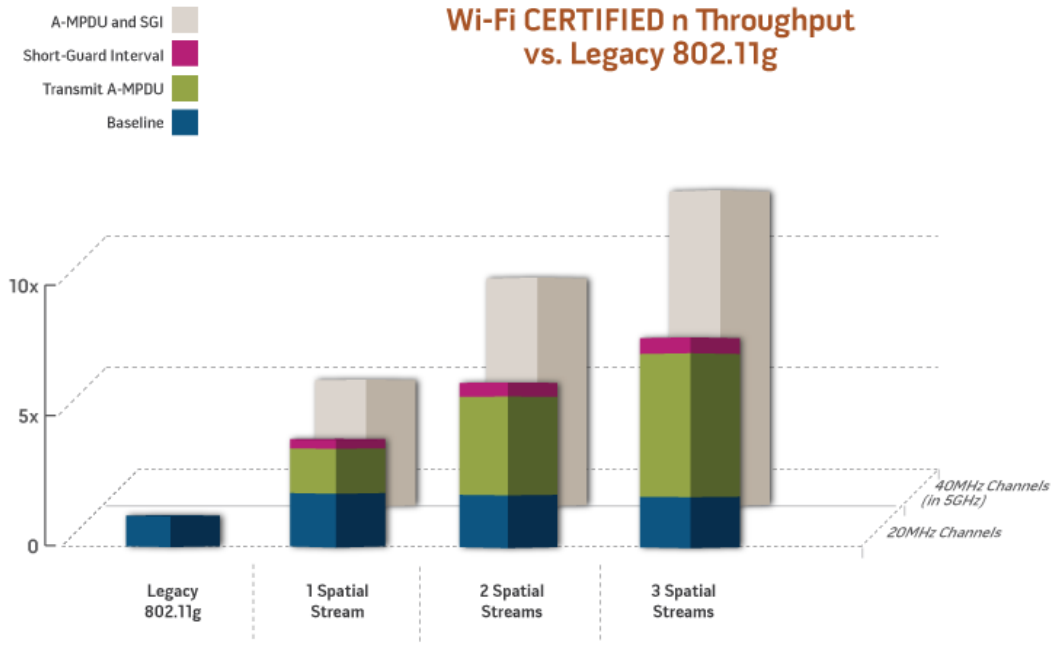

Figure 3: Throughput improvement in Wi-Fi CERTIFIED n. *Depiction of simulator-generated TCP/IP throughput rates for Wi-Fi CERTIFIED n devices. The simulation assumes the use of maximum data rates and optimal source traffic conditions. These numbers are estimates and informational - the Wi-Fi Alliance does not benchmark throughput performance.*

While MIMO increases over-the-air data rates in well-defined ways, the impact of aggregation techniques on throughput is dependent on traffic pattern. The impact of all features is dependent on the environment in which the equipment is used, equipment configuration and proximity.

Mandatory and Optional Features in Wi-Fi CERTIFIED n Testing

The Wi-Fi CERTIFIED n program tests and certifies critical features of the IEEE 802.11n standard [1], and the Wi-Fi Alliance WMM (Wi-Fi Multimedia) [2] and Wi-Fi Protected Access 2 (WPA2) [3] specifications. The key features of the 802.11n specification that are included in the Wi-Fi CERTIFIED n program are listed in tables below.

Table 2: Wi-Fi CERTIFIED n Mandatory Features

Feature	Description	Requirement
Spatial Streams	Systems that transmit and receive two spatial streams can double the data rate versus traditional one-stream operation.	Access points are required to transmit and receive at least two spatial streams. Client devices are required to transmit and receive at least one spatial stream. Access points supporting one spatial stream are not included in the 802.11n standard, and are not tested as Wi-Fi CERTIFIED n devices. Under the draft-n program, client devices (excluding hand held devices) were required to support one spatial stream for transmit and two for receive.
Aggregation Protocols in receive mode A-MPDU and A-MSDU	Frame aggregation protocols improve throughput by increasing frame size and reducing the overhead associated with headers and inter-frame gaps.	Access points and clients must be capable of receiving aggregated frames.
Block ACK Protocol	Sends a single block acknowledgement (ACK) frame to acknowledge several received frames. 802.11n has reduced the size of the block ACK frame from the legacy 128 bytes to eight bytes.	Access points and clients must be support block acknowledgements.

Table 3: Wi-Fi CERTIFIED n Optional Features *(Tested if Implemented)*

Feature	Description
Three Spatial Streams**	Transmission of three data streams simultaneously provides three times the data rate of a single spatial stream when both access point and client support three spatial streams. Alternatively spreading one data stream over three transmitters improves error rates.
2.4 GHz Operation	Devices can support 2.4 GHz, 5 GHz, or both frequency bands (dual-band). Access points capable of operating in both 2.4 & 5 GHz frequency bands simultaneously are certified as "concurrent dual-band".
5 GHz Operation	
40 MHz Channels in the 5 GHz Band	Bonding of two adjacent 20 MHz channels to create a single 40 MHz channel. A 40 MHz provides twice the data rate of a 20 MHz channel.
20/40 MHz Coexistence Mechanisms in the 2.4 GHz Band**	Allows access points to sense nearby legacy Wi-Fi networks and coordinate move to network default to 20 MHz channels. 20/40 coexistence mechanisms are required if an access point supports 40 MHz channels in the 2.4 GHz band. Wi-Fi CERTIFIED n devices are configured for 20 MHz operation in 2.4 GHz out-of-box.
Greenfield Preamble	A technique that enables an 802.11n network to use a shorter preamble to improve the efficiency and power consumption of 802.11n networks. Legacy devices and some 802.11n devices cannot interpret Greenfield preamble, so it is not recommended in mixed networks.
Short Guard Interval (SGI), 20 and 40 MHz Channels	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. Improves data rate by 10%.
Space Time Block Coding (STBC) (Transmit)**	Improves reception by coding the data stream in blocks which are distributed for transmission across multiple transmitting antennas and across time. At the receiving antenna, the data is recombined in an optimal way making use of the coding. STBC requires multiple transmit antennas and delivers benefits to devices with the ability to receive one or more data streams. Access Points can be certified for Transmit STBC.
HT Duplicate Mode (MCS 32)	Allows an access point to send the same packet simultaneously on each 20 MHz channel in 40 MHz mode, leading to a more robust transmission. This feature can be particularly beneficial at the edge of the Wi-Fi network's coverage footprint.
A-MPDU (Transmit mode)**	Aggregates MPDUs to include more information in each exchange and reduce header and inter-frame gap overhead at the MAC layer. Increases throughput and reduces power.

*** Optional features added in the updated 802.11n program released in Fall 2009.*

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 Wi-Fi CERTIFIED functionality.

Frequency Bands and Protection Protocols

Wi-Fi CERTIFIED n devices can operate in either or both of the 2.4 GHz and 5 GHz frequency bands and will interoperate with other Wi-Fi CERTIFIED devices that operate in the same frequency band. Access points can optionally be tested in the concurrent 2.4 and 5 GHz operating mode. Wi-Fi CERTIFIED n products that support 5 GHz operation are also required to pass Wi-Fi CERTIFIED 802.11a testing. Wi-Fi CERTIFIED n products that support 2.4 GHz are required to pass Wi-Fi CERTIFIED 802.11b/g testing.

802.11n networks operating in the 2.4 GHz band must share the frequency with legacy 802.11b/g networks. To help ensure that neighboring 802.11 legacy networks can continue to operate as

users expect, the default out-of-box (OOB) behavior for Wi-Fi CERTIFIED n devices is 20 MHz channels in the 2.4 GHz band.

If a user configures his 2.4GHz device for 40 MHz channels, coexistence protocols in Wi-Fi CERTIFIED n devices sense and respond to any proximal 802.11g activity in the channel by coordinating changeover of the Wi-Fi CERTIFIED n network to 20 MHz operation.

Wi-Fi Alliance Certification Testing Approach

The test approach verifies that a tested client device operates with at least four access points from different manufacturers that are based on chipsets from a minimum of three different semiconductor vendors. Tested access points are verified to operate with at least four clients using different chipsets.

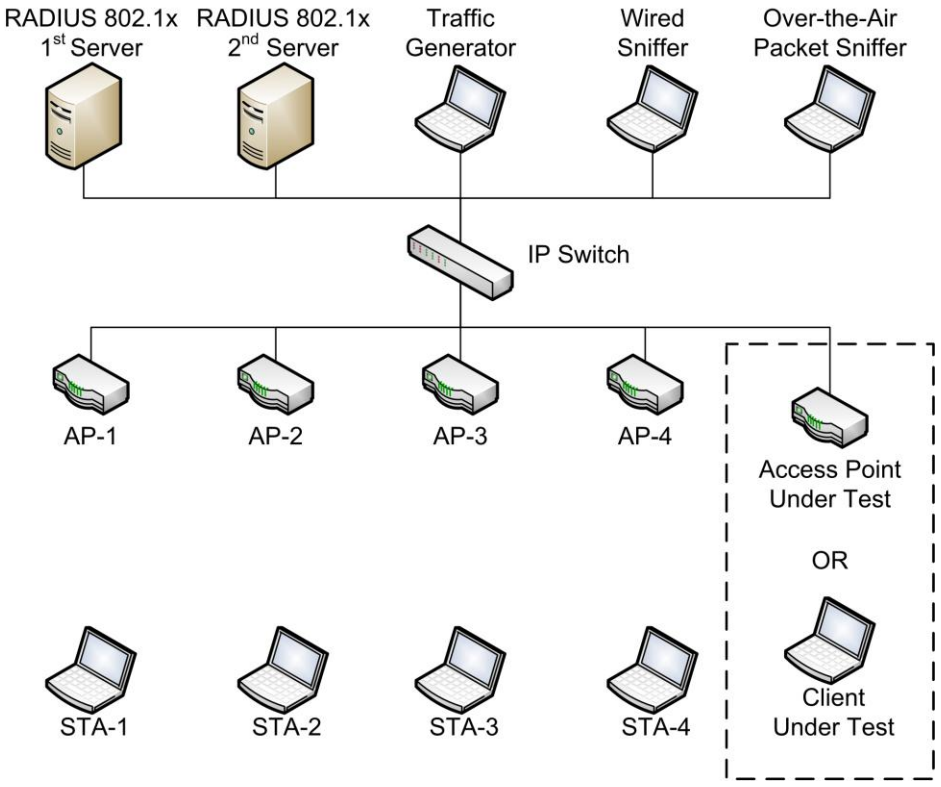

Figure 4: Typical over-the-air Wi-Fi CERTIFIED test bed

Testing is performed over the air at close range. If a tested device implements any of the optional features included in the Wi-Fi CERTIFIED n program, testing verifies the interoperability of each implemented feature. Testing is mandatory for all optional features implemented on the device.

Wi-Fi CERTIFIED n devices must also pass the following Wi-Fi CERTIFIED programs:

- Wi-Fi CERTIFIED 802.11a, Wi-Fi CERTIFIED 802.11b/g (depending on frequency bands supported) to verify legacy modes of operation,
- Wi-Fi Multimedia (WMM) to verify the device implements essential QoS mechanisms, and
- WPA2 security including EAP types (extensible authentication protocol) for the latest generation of security protections.

Identifying Wi-Fi CERTIFIED n Products

The Wi-Fi CERTIFIED logo provides a simple indication of products which work together - the a, b, g and n components of the Wi-Fi CERTIFIED logo indicate physical layer compatibility. Because 802.11n technology has become quite complex, and most vendors offer a variety of products with differing feature sets, the Wi-Fi Alliance has developed some additional branding elements for Wi-Fi CERTIFIED n products to help consumer users differentiate products and understand their capabilities.

***Figure 5: Wi-Fi CERTIFIED Logo** with SIIs (standard indicator icons) for 802.11 a, b, g and n physical layers*

An optional set of identifying taglines and a graphical matrix can be used on product marketing materials and packaging to help consumers identify Wi-Fi CERTIFIED n devices that implement these features. While the interoperability certificate provides a detailed look at the features tested for a certified product, the logo and tagline graphics are meant to distinguish products with a richer feature in a retail environment.

Logo / Tagline	Eligible Client Devices	Eligible AP Devices
Wi-Fi CERTIFIED n	All Wi-Fi CERTIFIED n devices	
Wi-Fi CERTIFIED n dual-stream n	• Two spatial streams (receive) – 1 transmit, 2 receive – 2 transmit, 2 receive – 2 transmit, 3 receive • Transmit A-MPDU • 40 MHz channels in 5 GHz (if 5GHz supported)	• Two spatial streams (transmit and receive) – 2 transmit, 2 receive • Transmit- A-MPDU • 40 MHz channels in 5 GHz (if 5GHz supported) • Transmit STBC
Wi-Fi CERTIFIED n multi-stream n	• Three or more spatial streams (transmit and receive) – 3 transmit, 3 receive – 3 transmit, 4 receive – 4 transmit, 4 receive • Transmit A-MPDU • 40 MHz channels in 5 GHz (if 5GHz supported)	• Three or more spatial streams (transmit and receive) – 3 transmit, 3 receive – 4 transmit, 4 receive • Transmit- A-MPDU • 40 MHz channels in 5 GHz (if 5GHz supported) • Transmit STBC

Figure 6: Optional taglines *for eligible Wi-Fi CERTIFIED n devices*

There is also a simple matrix for member use which incorporates essential information about the capabilities of Wi-Fi CERTIFIED n devices. This matrix includes the Wi-Fi CERTIFIED logo appropriate to the device, a tagline (if the device qualifies and the vendor wishes to include it) and a summary of the frequency bands and spatial stream configurations tested. The matrix may be displayed on packaging or supporting materials at the vendor's discretion.

Figure 7: Optional matrix *for eligible Wi-Fi CERTIFIED n devices*

The interoperability certificate is a record of certification testing and includes a listing of optional features that were tested. Figure 8 is a sample of the certificate.

Figure 8: Sample Wi-Fi CERTIFIED interoperability certificate

An up-to-date listing of all Wi-Fi CERTIFIED products can be found at the Wi-Fi Alliance website, www.wi-fi.org. Users can search via product category or criteria including manufacturer, certification date, etc., and can view the interoperability certificate for certified products. For detailed information for consumer and enterprise users, including video tutorials, shopping guides, and a glossary of terms see www.11nbasics.org.

The Promise of 802.11n

ABI Research forecasts that shipments of 802.11n semiconductors will represent 45 percent of the total market in 2009 and grow to nearly 60 percent in 2012.[4] This considerable rate of growth reflects the fact that 802.11n and the Wi-Fi CERTIFIED n program promote 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, Wi-Fi CERTIFIED n 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 multimedia applications, while the increased throughput and coverage 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 n 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.

The increased range of Wi-Fi CERTIFIED n provides coverage to 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, can reap the benefits of increased range and throughput of Wi-Fi CERTIFIED n by implementing transmit diversity capabilities, such as STBC.

Most network transactions, including voice and data services, will benefit significantly from 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 thanks to frame aggregation.

Enterprise Environment

Wi-Fi CERTIFIED n is enterprise-grade technology that provides IT managers with the reliable, secure service they have come to expect. Mission-critical enterprise applications, such as Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP) access, collaboration tools, voice and video conferencing, all benefit from the increased throughput and range while relying on the next generation security protections.

The efficiencies and enhancements in the features included in Wi-Fi CERTIFIED n, combined with the WMM QoS capabilities, serve to improve the quality of Voice over Wi-Fi (VoWi-Fi) and to increase the number of simultaneous calls on the air link. Transmission enhancements based on MIMO and STBC, improve reception even for single receiver Wi-Fi phones by reducing error rates and improving range.

Enterprise networks benefit from the improved throughput and longer reach of Wi-Fi CERTIFIED n devices. Faster transmissions allow stations to get on and off the air more quickly. Legacy clients in the network can benefit from better coverage provided by the 802.11n access points and they can also gain increased access as the new 802.11n devices transfer their data faster.

Campus and Municipal Networks

Campus and municipal networks typically operate in challenging environments where range is the biggest issue. Wi-Fi CERTIFIED n 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 access point transmit and receive diversity mechanisms. Transmit diversity of access points, including STBC, improves the downlink range performance. Receive diversity of access points reciprocate the transmit diversity and thus maintain the range for both the uplink and the downlink directions.

Improvements in Voice Performance

Handheld devices operating in enterprise, campus and municipal networks enjoy improvements in Voice over Wi-Fi. The required WMM component of the certification ensures that tagged voice streams get priority over other classes of traffic and thus further enhances the voice service.

Summary

The Wi-Fi CERTIFIED n interoperability test program extends the improved throughput and range of 802.11n to a wide range of devices. Today's Wi-Fi CERTIFIED n devices can deliver five times or more throughput and more robust connections at up to twice the range of legacy 802.11 technology.

The strong adoption of 802.11n in the wake of the Wi-Fi Alliance's draft-n program in 2007 is a strong indication of the potential of the technology. The updated Wi-Fi CERTIFIED n program including security protections and quality-of-service testing will catalyze broader adoption of 802.11n by expanding the optional feature set enabling significant performance gains for a broad and growing range of devices.

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 amendment to 802.11 standard defining MIMO operation on the physical layer and incorporating improvements on the MAC layer.
Access Point (AP)	A device that connects wireless devices to a network. Often includes the functionality of a router.
ACK frame	A short frame sent by the receiving station to the transmitting station to acknowledge 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.
Block acknowledgement (Block ACK)	The method of sending a single acknowledgement frame to acknowledge receipt of multiple frames
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.
Customer Relationship Management (CRM)	An Enterprise data system used for a variety of customer support, customer communications or analysis functions.
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).
Enterprise Resource Planning (ERP)	An enterprise data system for managing critical operations 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.
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 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.
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 (STBC)	A transmitter diversity technique of spreading the transmit signal over multiple antennas to improve reception. STBC also incorporates FEC (Forward Error Correction) coding.
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, 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 n	Certification for new generation Wi-Fi equipment designed to the IEEE 802.11n specification
Wi-Fi Network	A Wireless Local Area Network based on 802.11 technology that is Wi-Fi CERTIFIED.
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.
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 2 (WPA2)	A next-generation security protocol/method for wireless networks that provides strong data protection and network access control.

Abbreviations

A-MPDU	Aggregate MAC Protocol Data Unit
A-MSDU	Aggregate MAC Service Data Unit
AP	Access Point
BER	Bit Error Rate
BSS	Basic Service Set
CRM	Customer relationship management
ERP	Enterprise Resource Planning
GI	Guard Interval
HT	High Throughput
MAC	Medium Access Control
MPDU	MAC Protocol Data Unit
MSDU	MAC Service Data Unit
SGI	Short Guard Interval
SII	Standard Indicator Icon
STBC	Space Time Block Coding
WFA	Wi-Fi Alliance
WLAN	Wireless Local Area Network
WMM	Wireless Multi Media

References

[1] IEEE P802.11n™," 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 5: Enhancements for Higher Throughput".

[2] Wi-Fi Alliance – WMM™ (including WMM™ Power Save Specification)

[3] Wi-Fi Alliance – Wi-Fi Protected Access (WPA)

[4] ABI Research – 3Q 2009, "Wi-Fi IC Market Data".