WiGig® and the future of seamless connectivity

Wi-Fi Alliance®

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Executive summary

WiGig[®] technology, based on the IEEE 802.11ad specification, was originally developed by the Wireless Gigabit (WiGig) Alliance. The WiGig MAC and PHY Specification was contributed to IEEE in 2010, and the WiGig Alliance merged with Wi-Fi Alliance[®] in 2013.

WiGig technology uses the 60 GHz band to support data rates up to 7 Gbps, and it enables devices to transparently switch to other supported frequency bands if needed. Other features include support for beamforming, low-power, and security protection.

This paper is a revision of a version originally published by the WiGig Alliance in 2010.

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Introduction

The widespread availability and use of digital multimedia content has led to the need for continuous innovations in wireless connectivity. The demand for fast speeds, high capacity, and low latency are the driving forces behind a new technology that complements the capabilities of traditional Wi-Fi®. The technology, WiGig, uses the 60 GHz frequency band to achieve multi-gigabit speeds to support advanced applications.

In 2013, the WiGig Alliance, the organization which developed the WiGig MAC and PHY Specification, unified with Wi-Fi Alliance, consolidating all technology and certification development within Wi-Fi Alliance to deliver closely-harmonized connectivity and application-layer solutions. Members of Wi-Fi Alliance are developing the WiGig CERTIFIED™ program to deliver product interoperability validation. The program is expected to begin product interoperability testing in 2014, and certified products will bear the certification mark WiGig CERTIFIED and an associated logo.

The technology is based on IEEE 802.11ad, the standard wireless communications in 60 GHz. The 60 GHz band has more spectrum available than the 2.4 GHz and 5 GHz bands, allowing for wider channels to support faster data rates of up to 7 Gbps using low power modulation schemes, making it ideal for in-room connectivity to support demanding multimedia applications.

> ### WiGig and IEEE 802.11ad
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> IEEE 802.11ad is an amendment to the 802.11 standard that enables multi-gigabit wireless communications in the 60 GHz band. The WiGig MAC and PHY Specification was contributed to the IEEE 802.11ad standardization process, and was confirmed in May 2010 as the basis for the 802.11ad draft standard. 802.11ad was approved by IEEE in late 2012. In this paper, the terms WiGig MAC/PHY Specification and 802.11ad are used interchangeably.

802.11ad is an amendment to the existing IEEE 802.11 standard, which is at the core of billions of Wi-Fi products available worldwide. The specification enables a broad range of advanced uses, including

wireless docking and connection to displays, as well as virtually instantaneous wireless backups, synchronization, and file transfers between computers and handheld devices. WiGig technology complements Wi-Fi, extending into new usages and delivering more completely on the Wi-Fi Alliance vision of seamless connectivity without wires or cables.

Specification overview

The WiGig/IEEE 802.11ad specification includes key features to maximize performance, minimize implementation complexity and cost, harmonize with existing Wi-Fi, and provide advanced security. Key features include:

- Support for data transmission rates up to 7 Gbps; all devices based on the specification will be capable of gigabit data transfer rates
- Unique design to support low-power handheld devices such as cell phones, as well as high-performance devices such as computers; includes advanced power management
- Support for networking implementations similar to Wi-Fi, enabling devices to transparently switch between 802.11 networks operating in any frequency band, including 2.4 GHz, 5 GHz and 60 GHz
- Support for beamforming, maximizing signal strength and enabling robust communication at distances beyond 10 meters
- Advanced security protection using the Galois/Counter Mode of the AES encryption algorithm
- Support for high-performance wireless implementations of HDMI, DisplayPort, USB and PCIe

WiGig architecture

The WiGig/IEEE 802.11ad specification defines Physical (PHY) and Medium Access Control (MAC) layers, and is an amendment to IEEE 802.11. It enables native support for IP networking over 60 GHz and makes it simpler to produce devices that can communicate over both 60 GHz and existing Wi-Fi using radios which operate in 2.4 GHz, 5 GHz, and 60 GHz.
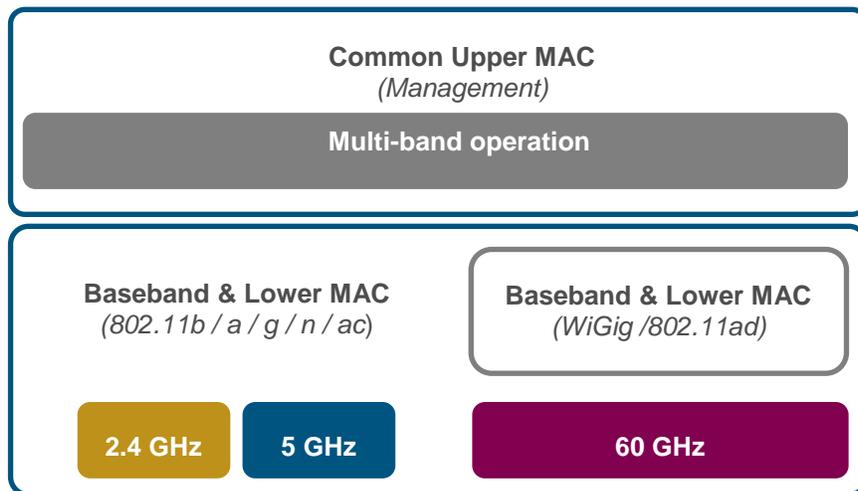

Figure 1. WiGig architecture

Several Protocol Adaptation Layers (PALs) support specific data and display standards over 60 GHz. PALs allow wireless implementations of these standard interfaces that run directly on the MAC and PHY, as shown in Figure 2. The initial PALs are audio-visual (A/V), which defines support for HDMI and DisplayPort, and input-output (I/O), which defines support for SD, USB and PCIe.
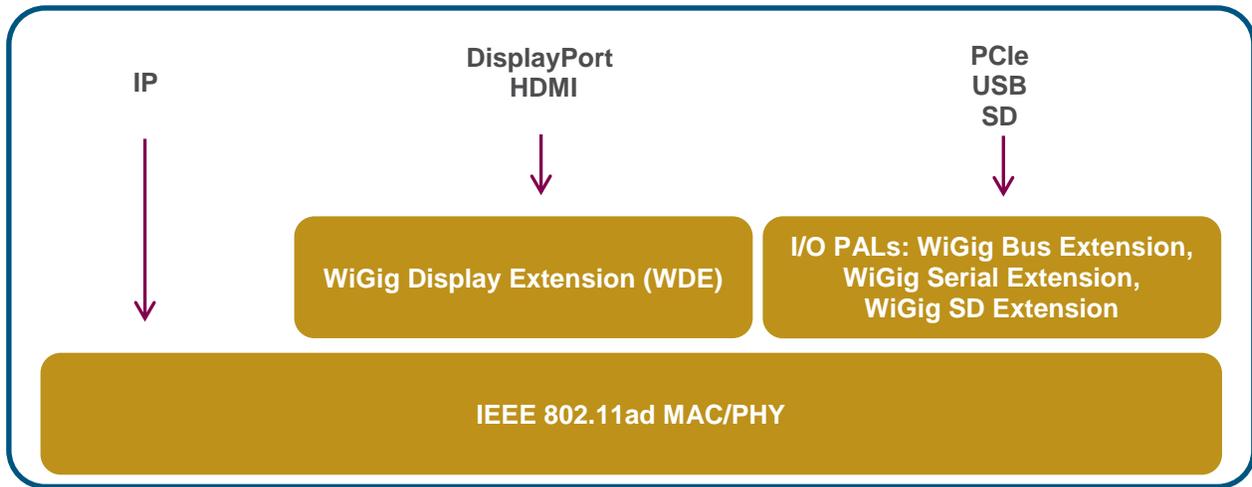

IP

**DisplayPort
HDMI**

**PCIe
USB
SD**

WiGig Display Extension (WDE)

I/O PALs: WiGig Bus Extension, WiGig Serial Extension, WiGig SD Extension

IEEE 802.11ad MAC/PHY

Figure 2. Protocol Adaptation Layers (PALs)

Physical layer (PHY)

Similar to the 2.4 GHz and 5 GHz bands used by Wi-Fi, the 60 GHz band is unlicensed and widely available. Within the 60 GHz band, there is variation in the spectrum available in different countries, as shown in Figure 3.

In general, the 60 GHz band has much more spectrum available than the 2.4 GHz and 5 GHz bands – typically 7 GHz of spectrum, compared with 83.5 MHz in the 2.4 GHz band. As with the 2.4 and 5 GHz bands, 60 GHz spectrum is divided into multiple channels. The 802.11ad specification defines four channels, each 2.16 GHz wide – 50 times wider than the channels available in 802.11n.

These wide channels enable 60 GHz devices to support applications that require extremely fast communication with low power consumption, such as uncompressed video transmission and wireless docking.
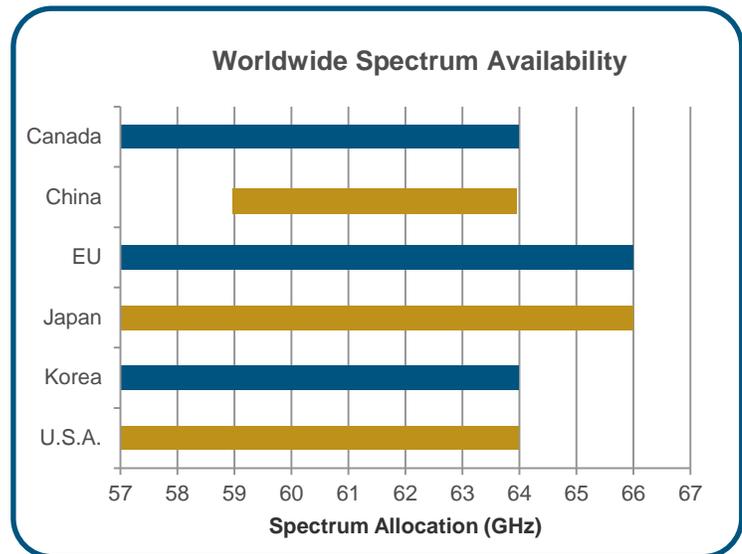

Worldwide Spectrum Availability

Canada, China, EU, Japan, Korea, U.S.A.

Spectrum Allocation (GHz)
57 58 59 60 61 62 63 64 65 66 67

Figure 3. Worldwide spectrum availability in the 60 GHz band

Modulation & Coding Scheme (MCS)
The specification supports two types of modulation and coding schemes, which provide different benefits:

- Orthogonal frequency-division multiplexing (OFDM) supports communication over longer distances with greater delay spreads, providing more flexibility in handling obstacles and reflected signals. Furthermore, OFDM allows the greatest transmission speeds of up to 7 Gbps.
- Single carrier (SC) typically results in lower power consumption, so it is often a better fit for small, low- power handheld devices. SC supports transmission speeds up to 4.6 Gbps.

The two types of schemes share common elements such as preamble and channel coding. This reduces implementation complexity for manufacturers of WiGig devices. All WiGig CERTIFIED devices will be required to support SC and some will also support OFDM. An MCS capabilities exchange and negotiation at session initiation will help ensure that all WiGig CERTIFIED devices can connect to one another.

Medium Access Control (MAC) layer

The MAC layer of the WiGig/802.11ad specification includes new features that support advanced usage models, facilitate integration with Wi-Fi networks, reduce power consumption, and provide strong security.

Network architecture
The specification defines a new network architecture that enables two devices to communicate directly with each other, allowing new uses such as rapidly synchronizing two devices and transmitting audio-visual data to a projector or TV. In addition, the specification also supports existing 802.11 network architectures, including the use of a shared access point as in today's Wi-Fi networks.

Seamless multi-band operation
A communication session can be rapidly and seamlessly transferred between a 60 GHz channel and any lower-frequency Wi-Fi channel, including channels in the 2.4 GHz or 5 GHz band. This innovation enables seamless fallback to 2.4 GHz or 5 GHz Wi-Fi if 60 GHz connectivity is not available.

Multi-band operation provides a greatly improved user experience. Users with Wi-Fi/WiGig integrated devices will be able to continue connectivity without interruption if their device switches from a 60 GHz to a lower-frequency Wi-Fi channel. The user will experience high performance, and will be able to automatically take advantage of the additional speed in 60 GHz whenever it is available.

Power management
WiGig CERTIFIED devices will take advantage of a new scheduled access mode to reduce power consumption. Two devices communicating with each other via a directional link may schedule the periods during which they communicate; in between those periods, they can sleep to save power. This advanced capability allows devices to more precisely tailor their power management to their actual traffic workload, and it is especially important for cell phones and other handheld battery-powered devices.

Advanced security
The IEEE 802.11ad specification builds on the strong security mechanisms defined in IEEE 802.11. WiGig CERTIFIED devices will use Galois/ Counter Mode, a highly-efficient mode of encryption that is designed to support higher communication speeds. Encryption is based on the government-grade Advanced Encryption Standard (AES), and can be implemented in hardware for performance and efficiency.

Beamforming in 60 GHz

Use of the 60 GHz band allows extremely fast communication, but also presents the challenge that propagation loss is higher than in the 2.4 GHz and 5 GHz bands. Signals in the 60 GHz band are more susceptible to disruption from physical barriers than at lower frequencies.

The IEEE 802.11ad specification addresses this challenge using adaptive beamforming, a technique that enables robust multi-gigabit communications at distances greater than 10 meters. Beamforming uses directional antennas to reduce interference and focus a signal between two devices into a concentrated "beam," allowing faster data transmission over longer distances.

Support for beamforming is defined within the PHY and MAC layers of the IEEE 802.11ad specification. During the beamforming process, two devices establish communication and then fine-tune their antenna settings to improve the quality of directional communication until there is enough capacity for the desired data transmission.

Another key benefit of beamforming is that if an obstacle blocks the line of sight between two devices - if someone walks between them, for example - the devices can quickly establish a new communications pathway. In Figure 4, the devices use beams that reflect off walls to maintain communication.

Figure 4. Beamforming

Protocol Adaptation Layers (PALs)

PALs allow wireless implementations of key computer and consumer electronics interfaces over 60 GHz networks, making it easier to produce devices with built-in support for specific uses such as wireless connections to displays.

PALs enable highly efficient implementations because they are defined directly on the IEEE 802.11ad MAC and PHY, rather than layered on other protocols, and can be built in hardware. This maximizes performance and reduces power consumption. PALs defined to date are:

- **Audio-Visual: WiGig Display Extension (WDE)**
  WDE allows wireless transmission of audio-visual data. An example might be transmitting movies from a computer or digital camera to a TV set or projector. This PAL supports wireless implementations of High-Definition Multimedia Interface (HDMI®) and DisplayPort® interfaces, as well as the High-bandwidth Digital Content Protection (HDCP) scheme used to protect digital content transmitted over those interfaces. It scales to allow transmission of both compressed and uncompressed video.

- **Input-Output (I/O) PALs: WiGig Bus Extension, WiGig SD Extension, and WiGig Serial Extension**
  The Input-Output PALs define high-performance wireless implementations of widely used computer interfaces over 60 GHz. There are three I/O PALs defined today: WiGig Bus Extension (PCIe), WiGig SD Extension (Secure Digital I/O), and WiGig Serial Extension (USB).
    o **WiGig Bus Extension:** PCIe is typically used within computers to connect the CPU and memory to I/O controllers that support storage, network cards and other interfaces. It is also used to connect to media and visual processors to enhance picture quality or offload processing from the CPU. Implementation of the PAL enables multi- gigabit wireless synchronization between devices and connection to storage and other high speed peripherals.
    o **WiGig SD Extension:** SD memory is widely adopted in mobile devices to store various files, such as documents, photos, and AV contents. The WiGig SD Extension is designed to directly access an SD memory equipped in a remote device from a host device, for instance a smart phone from a notebook PC. The WiGig SD Extension is suitable for resource-limited, battery-operated devices because of its simple implementation that is optimized to memory access and its ability to achieve multi-gigabit file transfer speeds with significant power savings.
    o **WiGig Serial Extension:** USB is typically used to connect external peripherals and other devices to a host; the USB PAL enables multi-gigabit wireless connectivity between USB devices, and facilitates the development of products such as USB docking stations. The WiGig Serial Extension has been transferred from Wi-Fi Alliance to the USB Implementers Forum (USB-IF) to use as a foundation of a Media-Agnostic Serial Bus Specification.
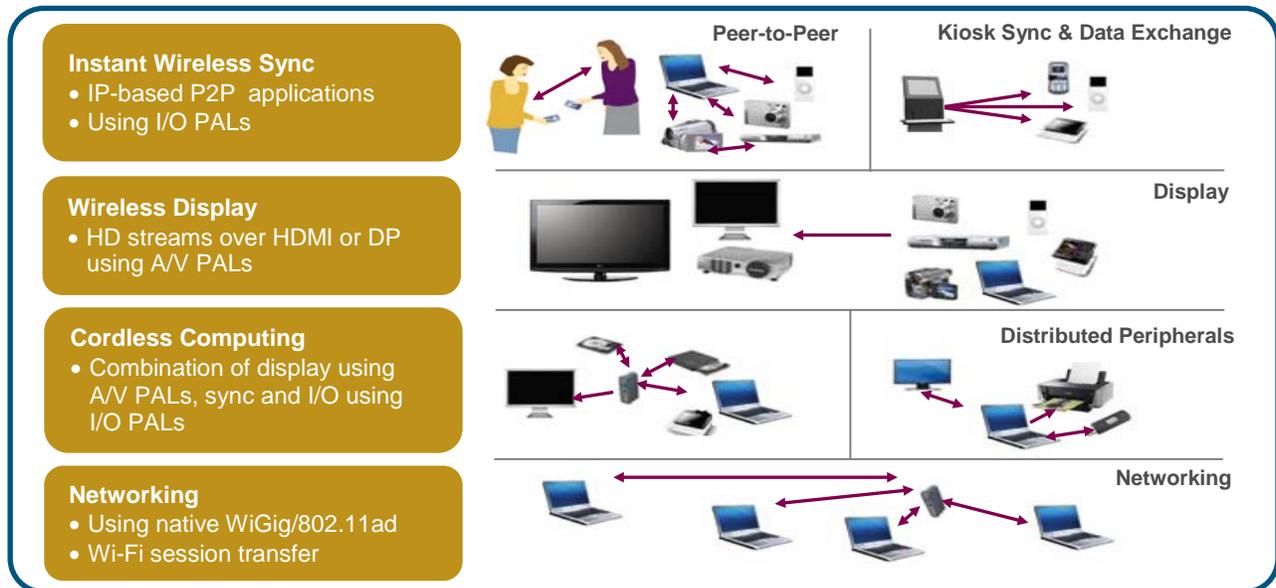
Usage models

| Instant Wireless Sync | Peer-to-Peer | Kiosk Sync & Data Exchange |

- **Instant Wireless Sync**
  - IP-based P2P applications
  - Using I/O PALs

- **Wireless Display**
  - HD streams over HDMI or DP using A/V PALs

- **Cordless Computing**
  - Combination of display using A/V PALs, sync and I/O using I/O PALs

- **Networking**
  - Using native WiGig/802.11ad
  - Wi-Fi session transfer

Peer-to-Peer

Kiosk Sync & Data Exchange

Display

Distributed Peripherals

Networking

Figure 5. Usage models

The 802.11ad specification and WiGig PALs enable multi-gigabit wireless implementations of a broad range of new and existing usage models, as shown in Figure 5.

Wi-Fi Alliance is developing the WiGig CERTIFIED program for interoperability certification of devices incorporating 802.11ad. The program is expected to launch in 2014.

Summary

WiGig uses the unlicensed 60 GHz band worldwide to provide data rates up to 7 Gbps. Based on the 802.11ad standard, it includes native support for networking over 60 GHz; products with both Wi-Fi and WiGig integration will be able to transparently switch among 2.4 GHz, 5 GHz and 60 GHz networks ensuring optimal performance. Wi-Fi Alliance is also developing interoperability programs based on WiGig PALs that define wireless implementations of A/V and I/O interfaces, facilitating advanced applications such as wireless docking, high-speed synchronization and connection to displays.

About Wi-Fi Alliance

Wi-Fi Alliance® is a global non-profit industry association of hundreds of leading companies devoted to seamless connectivity. With technology development, market building, and regulatory programs, 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. Wi-Fi Alliance has certified more than 15,000 products, encouraging the expanded use of Wi-Fi products and services in new and established markets.

Wi-Fi®, Wi-Fi Alliance®, WMM®, Wi-Fi Protected Access® (WPA), WiGig®, Wi-Fi Direct®, the Wi-Fi CERTIFIED logo, the Wi-Fi logo, the Wi-Fi ZONE logo and the Wi-Fi Protected Setup logo are registered trademarks of Wi-Fi Alliance. Wi-Fi CERTIFIED™, Wi-Fi Protected Setup™, Wi-Fi Multimedia™, WPA2™, Wi-Fi CERTIFIED Passpoint™, Passpoint™, Wi-Fi CERTIFIED Miracast™, Miracast™, Wi-Fi ZONE™, WiGig CERTIFIED™, and the Wi-Fi Alliance logo are trademarks of Wi-Fi Alliance.

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Further information resources

The Wi-Fi CERTIFIED products database on Wi-Fi Alliance's website (www.wi-fi.org) contains an up-to-date list of certified products, where users can search for Wi-Fi CERTIFIED equipment by multiple criteria, including product category, manufacturer, certification date and features supported, and can view the interoperability certificate for certified products.

For further information on Wi-Fi Alliance certification programs and for white papers on Wi-Fi–related topics, please visit Wi-Fi Alliance's website (www.wi-fi.org).