



Wireless Gigabit Alliance

WiGig White Paper

Defining the Future of Multi-Gigabit Wireless Communications

WiGig 白皮書

定義 Multi-Gigabit 無線通訊的未來

2011



Introduction

簡介

The widespread availability and use of digital multimedia content has created a need for faster wireless connectivity that current commercial standards cannot support. This has driven demand for a single standard that can support advanced applications such as wireless display and docking, as well as more established usages such as network access.

數位多媒體內容的普及與廣泛運用，推升了對高速無線連接性的需求，而這是現行商業化標準所無法支援的。這使得業界需要一種可同時支援無線顯示、無線擴充基座(docking)等先進應用，以及既有網路存取使用模式的單一標準，來因應市場的最新發展趨勢。

The Wireless Gigabit (WiGig) Alliance was formed to meet this need by establishing a unified specification for wireless communication at multi-gigabit speeds; this specification is designed to drive a global ecosystem of interoperable products.

無線Gigabit(WiGig)聯盟的成立便是為了透過制定一個統一數Gigabit級無線通訊規範以滿足這項業界需求。此規範的制定，將有助於推動互通產品的全球生態系統建立。

The WiGig MAC and PHY Specification enables data rates up to 7 Gbps, more than 10 times the speed of the fastest Wi-Fi networks based on IEEE 802.11n. It operates in the unlicensed 60 GHz frequency band, which has much more spectrum available than the 2.4 GHz and 5 GHz bands used by existing Wi-Fi products. This allows wider channels that support faster transmission speeds.

WiGig MAC和PHY 規範可實現最高達 7 Gbps 的數據傳輸率，此速度較目前最快的IEEE 802.11n Wi-Fi 網路快了十倍以上。WiGig 是在免授權 (unlicensed) 的 60GHz 頻帶上執行，可較現行 Wi-Fi 產品使用的 2.4GHz和5 GHz 頻帶擁有更多可用頻譜，因此能提供更寬的通道，以支援更高的傳輸速度。

The WiGig specification is based on the existing IEEE 802.11 standard, which is at the core of

hundreds of millions of Wi-Fi products deployed worldwide. The specification includes native support for Wi-Fi over 60 GHz; new devices with tri-band radios will be able to seamlessly integrate into existing 2.4 GHz and 5.GHz Wi-Fi networks.

WiGig規範是以現行的 IEEE 802.11 標準為基礎，這亦是目前全球已部署數億台 Wi-Fi產品的核心技術。此規範包括 Wi-Fi在 60 GHz 頻帶的原生支援；因此，具備三頻無線電的新款裝置將能無縫地與現有的 2.4 GHz 和 5.GHz Wi-Fi 網路整合。

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. For the first time, consumers will be able to create a complete computing and consumer electronics experience without wires.

此規範能實現多樣化的先進應用，包括無線擴充基座 (wireless docking)、無線連接顯示器、以及可讓電腦和手持裝置間幾乎以瞬時完成無線備份、同步作業、以及檔案傳輸。消費者將能在電腦和消費電子裝置之間建立一個前所未聞的完整無線體驗。

WiGig and IEEE 802.11ad

IEEE 802.11ad is an amendment to the 802.11 standard that enables multi-gigabit wireless communications in the 60 GHz band. The WiGig 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.

WiGig以及IEEE 802.11ad

IEEE 802.11ad是802.11標準的修訂版，使其能在60 GHz頻帶實現數Gigabit級的無線通訊。WiGig規範已提交至 IEEE 802.11ad 標準化過程，並於 2010年5月被確認為802.11ad草案標準的基礎。

Specification Overview

規範概要

The WiGig specification includes key features to maximize performance, minimize implementation complexity and cost, enable compatibility with existing Wi-Fi and provide advanced security. Key features include:

WiGig規範中包括了可將效能增至最大，以及將建置複雜度與成本降至最低的重要特性，使其能與既有Wi-Fi相容，並提供先進的安全性。其重要特性包括：

- Support for data transmission rates up to 7 Gbps; all devices based on the WiGig specification will be capable of gigabit data transfer rates
- 支援最高達7 Gbps的數據傳輸率；所有以WiGig規範為基礎的裝置都將具備數Gigabit級的資料傳輸能力。
- Designed from the ground up to support low-power handheld devices such as cell phones, as well as high-performance devices such as computers; includes advanced power management
- 專為多種應用所設計，從手機等低功耗手持裝置，到電腦等高效能裝置，均能適用，並具備先進電源管理功能。
- Based on IEEE 802.11; provides native Wi-Fi support and enables devices to transparently switch between 802.11 networks operating in any frequency band including 2.4 GHz, 5 GHz and 60 GHz
- 以IEEE 802.11為基礎；提供原生Wi-Fi支援，並可讓裝置在2.4 GHz、5 GHz、和60 GHz各種不同頻帶運作的802.11網路間實現通透切換。
- Support for beamforming, maximizing signal strength and enabling robust communication at distances beyond 10 meters
- 支援束波成形(beamforming)，可提升訊號強度，以實現距離超過10公尺的強韌通訊能力。

- Advanced security using the Galois/Counter Mode of the AES encryption algorithm
- 採用Galois/Counter模式的AES加密演算法以提供先進安全性。
- Support for high-performance wireless implementations of HDMI, DisplayPort, USB and PCIe
- 支援HDMI、DisplayPort、USB和PCIe等介面的高效能無線建置。

Structure 架構

The WiGig specification defines Physical (PHY) and Medium Access Control (MAC) layers and is based on IEEE 802.11. This enables native support for IP networking over 60 GHz. It also makes it simpler and less expensive to produce devices that can communicate over both WiGig and existing Wi-Fi using tri-band radios (2.4 GHz, 5 GHz and 60 GHz).

WiGig規範是以IEEE 802.11標準為基礎，並定義了實體層(PHY)和媒體存取控制(MAC)層，以提供對60 GHz的IP網路原生支援。同時，也能以簡單、低成本的方式開發可同時在WiGig和現有Wi-Fi網路上進行通訊的三頻無線電(2.4 GHz、5 GHz、和60 GHz)裝置。

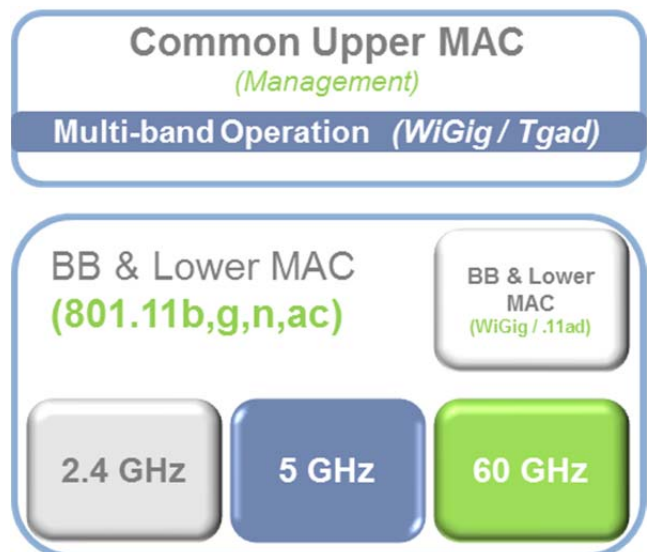


Figure 1. WiGig architecture enables tri-band communications

圖一：WiGig架構可實現三頻通訊

The WiGig Alliance is also defining Protocol Adaptation Layers (PALs) that support specific data and display standards over 60 GHz.

WiGig聯盟也定義了協定適配層(PAL)，以支援60 GHz頻帶上的特定數據和顯示標準。

PALs allow wireless implementations of these standard interfaces that run directly on the WiGig MAC and PHY, as shown in Figure 2, and can be implemented in hardware. The initial PALs are audio-visual (A/V) or the WiGig Display Extension (WDE), and input-output (I/O) that includes the WiGig Serial Extension (WSE) and WiGig Bus Extension (WBE).

如圖二所示，PAL能允許這些標準介面直接在WiGig MAC和PHY上執行，以實現無線建置，同時能以硬體方式設計。初期的PAL涵蓋音訊/視訊(A/V),如WiGig 視訊延伸(WiGig Display Extension，WDE),以及支持輸入/輸出(I/O)介面的WiGig序列延伸(WiGig Serial Extension，WSE)和WiGig匯流排延伸(WiGig Bus Extension，WBE)。

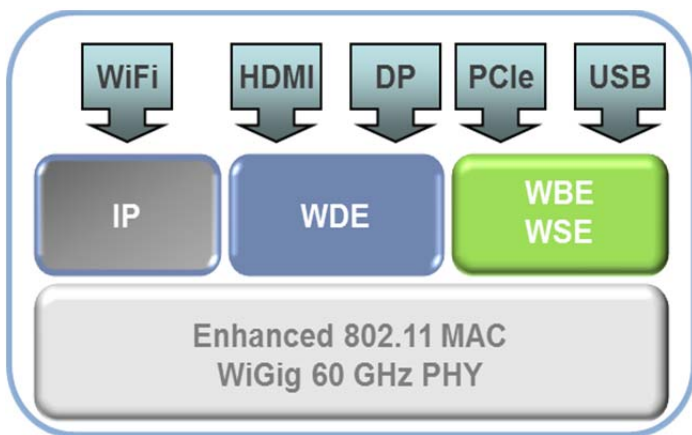


Figure 2. WiGig Protocol Adaptation Layers (PALs)
圖二：WiGig協定適配層(PAL)

Physical Layer (PHY)

實體層(PHY)

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

與Wi-Fi使用的2.4 GHz和5 GHz頻帶相同，WiGig使用的60 GHz頻帶是無需授權的，而且全球都可取得。在60 GHz頻帶中，不同國家可用的頻譜並不完全相同，請參見圖三所示。

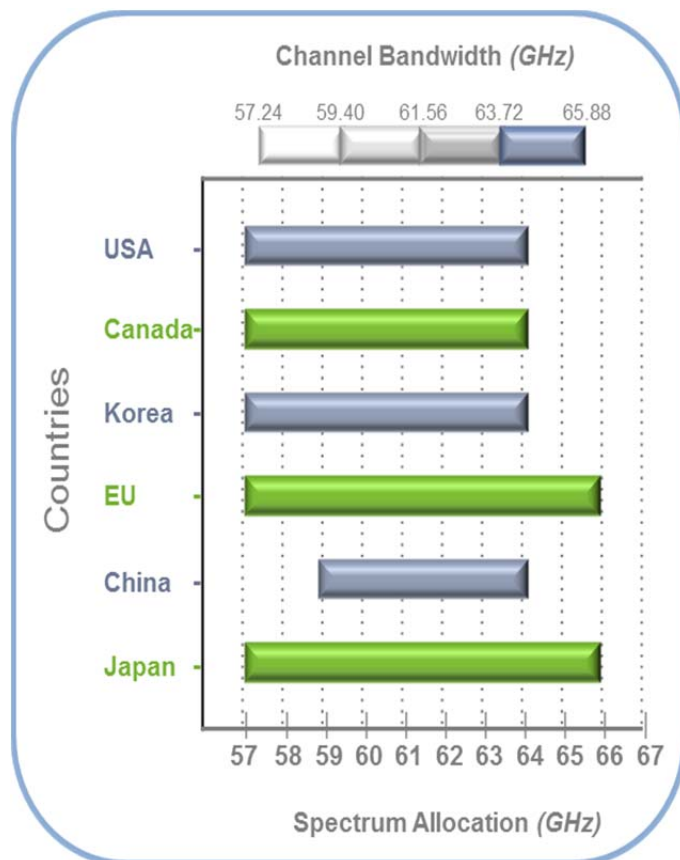


Figure 3. Worldwide spectrum in the 60 GHz band used by WiGig
圖三：全球各地WiGig所使用的60 GHz頻帶可用頻譜

Worldwide, 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.

在全球各地，60 GHz頻帶擁有的可用頻譜較2.4 GHz和5 GHz頻帶為多——一般為7 GHz寬的頻譜，而2.4 GHz頻帶的頻寬為83.5 MHz。

This spectrum is divided into multiple channels, as in the 2.4 GHz and 5 GHz bands. Because the 60 GHz band has much more spectrum available, the channels are much wider, enabling multi-gigabit data rates. The WiGig specification defines four channels, each 2.16 GHz wide – 50 times wider than the channels available in 802.11n.

與2.4 GHz和5 GHz頻帶相同，此頻譜會被分割為多個通道。因為60 GHz的可用頻譜較多，因此通道更寬，有助於實現數Gigabit級的數據傳輸率。WiGig規範定義了四個通道，每個都是2.16 GHz寬，這較802.11n的可用通道寬度提升了50倍。

These wide channels enable WiGig to support applications that require extremely fast communication, such as uncompressed video transmission.

這些較寬的通道能讓WiGig支援需要非常高速的通訊應用，像是未壓縮視訊傳輸。

Modulation & Coding Scheme (MCS) 調變與編碼方式(MCS)

The specification supports two types of modulation and coding schemes, which provide different benefits:

此規範支援兩種調變與編碼方式，可分別提供不同的效益：

- 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.
- 正交分頻多工(OFDM)由於具備較大的延遲擴展(delay spread)，因此可支援長距離傳輸，在處理障礙和反射訊號時可提供最佳的彈性。此外，OFDM可實現最高達7 Gbps的傳輸速度。
- 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.
- 單載波(SC)的功耗較低，因此較適用於小型、低功耗手持式裝置。單載波最高可支援4.6 Gbps的傳輸速度。
- The two types of schemes share common elements such as preamble and channel

coding. This reduces implementation complexity for manufacturers of WiGig devices.

- 這兩種技術有共通之處，像是前序(preamble)和通道編碼，因此可減少開發WiGig裝置的複雜度。

Medium Access Control (MAC) Layer 媒體存取控制(MAC)層

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

WiGig規範定義的媒體存取控制(MAC)層，包括可支援先進使用模式的新特性，有助於與Wi-Fi網路整合、降低功耗、並提升安全性。

Network Architecture 網路架構

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.

WiGig規範中定義了新的網路架構，可實現兩個裝置間的直接通訊，因此可開創出新的使用模式，例如裝置間的快速同步化作業，以及將影音內容傳送到投影機或電視。此外，WiGig規範亦支援現有802.11網路架構，像是與Wi-Fi網路相同，可採用共享的存取點(AP)。

Seamless Multi-band Operation 無縫多頻帶運作

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 WiGig connectivity is not available.

一個通訊會談(communication session)能在60 GHz通道和2.4 GHz或5 GHz的Wi-Fi通道間快速、且無縫地被轉送。此創新設計能夠在沒有60 GHz WiGig網路存在時，無縫地回到2.4 GHz或5 GHz Wi-Fi網路。

Multi-band operation provides a greatly improved user experience. Users with multi-band devices will be able to continue accessing the network, without interruption, if their device switches from a 60 GHz to a lower-frequency Wi-Fi channel. They will always experience

performance that is at least as good as today's Wi-Fi products, and will be able to automatically take advantage of the additional speed of 60 GHz WiGig whenever it is available.

此多頻帶運作可顯著提升使用者體驗。擁有多頻帶裝置的使用者，若其裝置從60 GHz切換到較低頻的Wi-Fi通道，仍能夠不被中斷地持續存取網路。對使用者來說，他們總是希望至少能擁有與現今Wi-Fi產品一樣的效能，若可能的話，還能自動切換到更高速的60 GHz WiGig網路。

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.

The WiGig specification addresses this challenge using adaptive beamforming, a technique that enables robust multi-gigabit communications at distances greater than 10 meters.

雖然60 GHz頻帶可提供高速傳輸，但同時也帶來較2.4 GHz 和5 GHz頻帶更高的傳播損失(propagation loss)挑戰。對此，WiGig規範採用適應性束波成形(adaptive beamforming)技術來克服這個問題，可實現距離10公尺以上的強韌數Gigabit級通訊。

Beamforming employs directional antennas to reduce interference and focus the signal between two devices into a concentrated "beam." This allows faster data transmission over longer distances.

束波成形技術採用方向性天線以降低干擾，並將兩個裝置間的訊號集中為一個「束波」(beam)，以實現高速的更長距離傳輸。

Support for beamforming is defined within the PHY and MAC layers of the WiGig 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.

對於束波成形的支援，已定義在WiGig規範的PHY和MAC層。在束波成形的過程中，兩個裝置將建立通訊，然後微調其天線設定，以提升方向性通訊的品質，直至達到足夠的數據傳輸容量為止。

Another key benefit 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 using, for example, beams that reflect off walls, as shown in Figure 4.

束波成形的另一個重要效益是，如果兩個裝置間有東西阻礙其直視性(LOS)，例如有人走過兩個裝置間，這時裝置會快速建立新的通訊路徑—舉例來說，利用反射到牆壁的束波，如圖四所示。



Figure 4. Beamforming
圖四：束波成形

Power Management

電源管理

WiGig devices can 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 is especially important for cell phones and other handheld battery-powered devices.

WiGig裝置能利用新的排程存取模式(scheduled access mode)來降低電源消耗。兩個裝置透過方向性鏈結(directional link)彼此通訊時，可設定它們將會通訊的期間，在其他時間，兩個裝置可設定為休眠或省電模式。此一先進功能可更精密地依照實際的流量負荷設定電源管理模式，這對手機和其他以電池供電的手持裝置來說，是非常重要的。

Advanced Security

先進安全性

The WiGig specification builds on the strong security mechanisms used in IEEE 802.11. WiGig uses Galois/Counter Mode, a highly-efficient mode of operation that is designed to support communication speeds of 10 Gbps and above, provides strong encryption based on the Advanced Encryption Standard (AES), is government-recommended, and can be implemented in hardware for performance and efficiency.

WiGig規範是以IEEE 802.11中所使用的強大安全性機制為基礎。WiGig採用Galois/Counter模式，這是專為支援10 Gbps以上通訊速度所設計的高效操作模式，能提供以政府推薦先進加密標準(AES)為基礎的強大加密功能，同時允許具更佳效能與效率的硬體建置方式。

Protocol Adaptation Layers (PALs)

協定配適層(PAL)

PALs allow wireless implementations of key computer and consumer electronics interfaces over 60 GHz WiGig networks. PALs make it easier for implementers to produce devices with built-

in support for specific uses such as wireless connections to displays.

PAL可讓主要的電腦和消費電子介面建置無線的60 GHz WiGig網路。PAL能使建置更為簡易，可開發具備內建支援的裝置，以實現例如無線顯示器連接等特定應用。

PALs enable highly efficient implementations because they are defined directly on the WiGig MAC and PHY, rather than layered on other protocols and can be implemented in hardware. This maximizes performance and reduces power consumption.

因為是直接定義於WiGig MAC和PHY層之上，而不是更高層的協定層中，再加上能建置於硬體中，因此 PAL可實現高效建置。這能帶來最佳效能並降低功耗。

Audio-Visual (A/V)

訊/視訊(A/V)

The WiGig Display Extension (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 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.

WiGig視訊延伸(WDE)可允許音訊/視訊數據的無線傳輸。舉例來說，可從電腦或數位相機將影片傳送到電視或投影機。此PAL可支援HDMI和DisplayPort介面的無線建置，同時也支援用來保護數位內容在這些介面上傳輸的高頻寬數位內容保護(HDCP)標準。WDE PAL並可擴充性的允許壓縮過和未壓縮的視訊傳輸。

Input-Output (I/O)

輸入/輸出(I/O)

The I/O PAL defines high-performance wireless implementations of computer interfaces over 60 GHz. Definitions exist for WiGig Serial Extension (WSE) and for WiGig Bus Extension (WBE).

I/O PAL對電腦介面在60 GHz上的運作，提供了高效能無線建置的定義。現已完成的定義有WiGig序列延伸(WSE)和WiGig匯流排延伸(WBE)。

WSE PAL is similar to USB and is typically used to connect external peripherals and other devices to a host; the WSE PAL enables multi-gigabit wireless connectivity between WSE devices, and facilitates the development of products such as WSE docking stations.

WSE PAL 與USB類似，通常是用來將外部週邊或其他裝置與主機相連，WSE PAL可實現WSE 裝置間的數Gigabit級無線連接性，同時亦有助於開發像是WSE 基座等各種產品。

PCIe Bus 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 WBE PAL that is similar to PCIe enables multi-gigabit wireless synchronization between devices and connection to storage and other high speed peripherals.

PCIe匯流排通常被用在電腦中，將CPU和記憶體與支援儲存、網路卡、以及其他介面的I/O控制器相連。它也能被用來與媒體和繪圖處理器相連，以增強圖片品質或卸載CPU的處理負荷。建置與PCIe類似的WBE PAL能實現裝置間的數Gigabit級無線同步化作業，並能與儲存和其他高速週邊相連。

Usage Models 使用模式

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

WiGig規範和PAL能為多種創新、以及既有的使用模式帶來數Gigabit級的無線建置方式，如圖五所示。

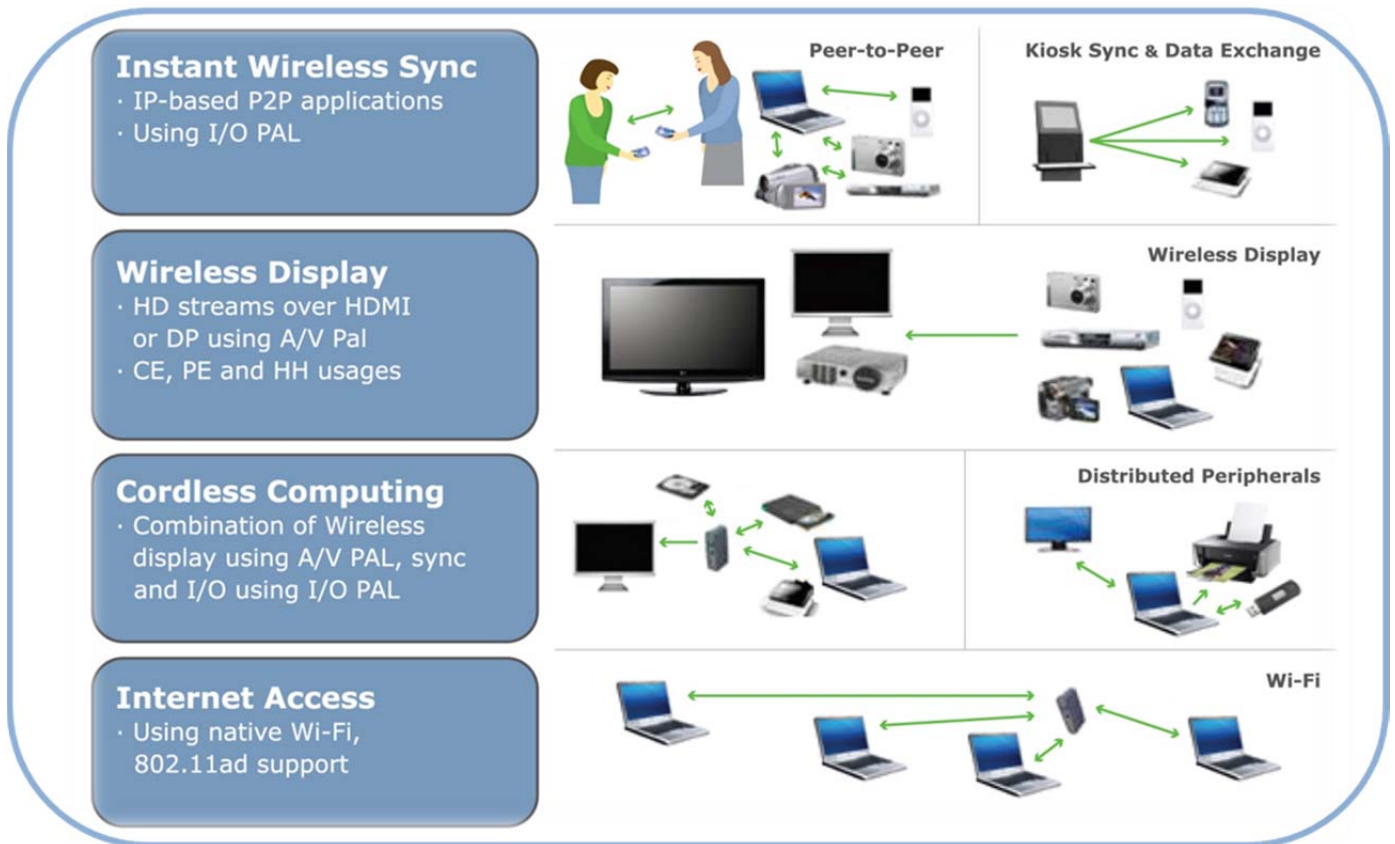


Figure 5. WiGig Usage Model
圖五：WiGig使用模式

Summary

結論

The WiGig specification utilizes the unlicensed 60 GHz band worldwide to provide data rates up to 7 Gbps. Based on the 802.11 standard, it includes native support for Wi-Fi over 60 GHz; products with tri-band radios will be able to transparently switch among 2.4 GHz, 5 GHz and 60 GHz networks ensuring optimal performance. The WiGig Alliance is also specifying 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.

WiGig規範利用全球免授權的60 GHz頻帶，最高可提供7 Gbps的數據傳輸率。它是以802.11標準為基礎，包括了對Wi-Fi在60 GHz的原生支援；具三頻無線電的產品能在2.4 GHz、5 GHz 和60 GHz網路間無縫切換，以確保最佳效能。WiGig聯盟同時也定義了可用

來實現A/V和I/O介面無線建置的PAL，將可推動像是無線基座、高速同步化作業、和無線顯示器等先進應用。

The publication of the specification enables manufacturers to create a global ecosystem of interoperable WiGig products. The specification is available to members of the WiGig Alliance, who are able to develop next-generation wireless products under royalty-free terms. For more information, including how to become a member, visit www.wigig.org.

此規範的發佈將能使製造商建立具互通性WiGig產品的全球生態系統。所有WiGig聯盟成員均可取得此規範，聯盟成員能夠根據免權利金條款，開發下一代無線產品。若欲得知更多訊息，包括如何成為會員，請瀏覽網站：www.wigig.org。