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# Wi-Fi Industry Adopts 802.11ad for High Performance

*RF & Wireless Components (RFWC)*

## Report Snapshot

802.11ad products have been on the market since 2013, but until recently volumes remained low, with products consisting mainly of wireless docking stations for premium laptop PCs. Demand for very fast downloads, 4K UHD video, Cloud storage and other data-intensive applications have changed this, with 802.11ad now coming into its own at the high-performance end of Wi-Fi in mobile devices and infrastructure.

Components

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# Executive Summary

**802.11ad, also referred to as multi-gigabit Wi-Fi or WiGig, has emerged as a high-performance complement to 802.11ac Wave 2.** Consumers will use 802.11ad in smartphones for sharing video content, and from there applications will expand to include point-of-sale kiosks for downloading multimedia content, residential, enterprise and public venue Wi-Fi infrastructure, virtual reality devices, and front haul and back haul for small cells.

**Key attributes of 802.11ad include:**

- 802.11ad adds an incredible 7 GHz of bandwidth at 60 GHz to today's Wi-Fi to provide a huge lift in data rates and local wireless capacity.
- At 60 GHz, radio signals do not penetrate most objects, but contrary to popular belief, 802.11ad is not limited to line of sight (LOS) applications. In most cases, the use of multiple antennas allows 60 GHz to take multiple paths between NLOS points without interruption from objects in the line of sight.
- 802.11ad enhances the Wi-Fi user experience, and will help equipment OEMs and Internet service providers to differentiate their offerings with ultra-high-rate Wi-Fi for new applications.

**The first infrastructure and smartphones using 802.11ad will start to ship early this year,** outstripping early shipments over the past three years in docking stations for laptop PCs.

**The new Qualcomm-Intel interoperability testing collaboration means that almost all 802.11ad devices that ship in 2016 will work together.** Intel and Qualcomm lead in share and in market clout in 802.11ad chips; Intel is promoting 802.11ad in tablets and docking stations, while Qualcomm is mainly promoting its chips for smartphones, laptops, and Wi-Fi infrastructure. Other 60 GHz chip specialists will have to scramble to match Intel and Qualcomm in 802.11ad, but they could potentially work with cellular chipset providers MediaTek and Spreadtrum in the future.

# Analysis

In 2015, 802.11ac Wave 2 emerged as the newest version of Wi-Fi to reach consumers in mobile devices and routers. This year, 802.11ad, an even higher performance standard, offers an even better Wi-Fi user experience. 802.11ad supplements 802.11ac Wave 2 by adding a 60 GHz radio for breathtakingly high data rates over modest ranges.

## Advantages of 802.11ad

**The 60 GHz portion of 802.11ad complements 802.11ac Wave 2 with additional bandwidth and in-room coverage for data transfer with very high speed and extremely low latency.** As shown in Exhibit 1, 802.11ad can transfer a full-length, two hour 4K Ultra HD movie to or from a device in 2.3 minutes or less, far faster than possible with 802.11n or even 802.11ac today*.[i]

Exhibit 1 Estimated File Transfer Times for Typical Content Using 802.11ad

| Content Type | Size | 802.11ad Transfer Time (@ 4.7 Gbps) |
|---|---|---|
| 4K UHD movie | 60 GB | 2.3 min |
| HD movie | 5 GB | 12.1 sec |
| SD movie | 1.5 GB | 3.6 sec |
| 4K movie trailer | 1.2 GB | 3.0 sec |
| Picture library | 1 GB | 2.4 sec |
| E-magazine | 250 MB | 0.6 sec |
| HD movie trailer | 100 MB | 0.2 sec |

*Assumes no additional compression for transfer and, typical overheads. More aggressive compression can reduce the file sizes shown above for faster transfers. Source: Strategy Analytics.*

Client and infrastructure Wi-Fi devices that support 802.11ad will all ship with the latest 802.11ac radios for compatibility, forming a true tri-band (or multiband) configuration using 2.4 GHz, 5 GHz and 60 GHz Wi-Fi.

**Peak data rate.** 802.11ad supports 4.7 Gbps within a walled-in area or open space at ranges up to 10 meters using 60 GHz. This is sufficient for streaming 4K Ultra HD video using little or no compression. The 60 GHz component of 802.11ad does not penetrate most walls, but in unobstructed line of site applications, it can transmit and receive at 2 Gbps at ranges up to 40 meters, or 1 Gbps at ranges up to 130 meters. Future versions of 802.11ad could potentially reach peak data rates of an astounding 100 Gbps.

**Low latency.** 802.11ad operating at 60 GHz can attain latencies below 1 millisecond between clients and access points. Connecting to the Internet adds the latency of the core network, which today is typically on the order of 50 milliseconds or more, but within the local area network, nothing will beat 802.11ad for fast response.

**Robust links.** 802.11ad at 60 GHz today uses one spatial stream, 64-QAM modulation and a single channel. This means the signal-to-noise requirements are modest, resulting in robust, fault-tolerant links. Although 60 GHz can be blocked easily by large objects, Qualcomm has demonstrated that 60 GHz radios can use beam steering and take advantage of multipath using reflections from walls and table tops to maintain a strong signal even when the line of sight path is blocked. Future versions of 802.11ad will probably increase the number of antenna elements from today's 32 to as many as 128, and adopt massive MIMO techniques for higher peak data rates, capacity, and phenomenal NLOS performance.

**Capacity**. A single 60 GHz 802.11ad access point has access to 7 GHz of contiguous bandwidth, the equivalent of more than seven Wi-Fi access points operating in the combined 2.4 GHz and 5 GHz Wi-Fi bands. If using HEVC

video compression, a single 802.11ad access point can support *tens* of simultaneous 4K UHD streams within a room.

**Battery efficiency.** 802.11ad can transfer content with approximately the same power consumption as 802.11ac, but in *one fifth to one sixth the time*. This means that the total power consumed for the transfer of a file is one fifth to one sixth that of 802.11ac. In portable devices such as smartphones and tablets, this translates directly into longer battery life between recharging.

## Demand for 802.11ad

The popularity of on-line video continues to grow rapidly, with much of the video now viewed over wireless networks, and increasing amount of it user-generated and uploaded to YouTube and social networking sites. **An increasing proportion of this content is 4K Ultra HD video, for which 802.11ad is especially well suited:**

- In 2015, more than 800 million smartphones shipped with ≥ 8 megapixel cameras capable of 30 fps or better 4K UHD video. The Consumer Electronics Association defines "4K Ultra HD" as video with a minimum resolution of 3840×2160 pixels.

- By 2020, more than 1.5 billion phones will ship with 4K UHD video support according to the Strategy Analytics Wireless Device Strategies service.

- Ten percent of North American households will own a 4K UHD television by the end of 2018 according to a 2015 publication by the Strategy Analytics *Connected Home Devices* service. In retrospect viewed from early 2016, this is probably **too low**:

    - In late 2014, inhibitors to adoption included lack of 4K UHD content and the need to buy expensive 75-inch to 85-inch and above screens for optimum viewing in typical living rooms.

    - By the end of 2015, prices for 55-inch 4K UHD TVs had dropped to as low as $500, and available models had proliferated. We counted 24 4K UHD models on Best Buy's USA web site out of 44 TVs in total, or 55 percent of the models offered. Clearly, 4K UHD had taken off.

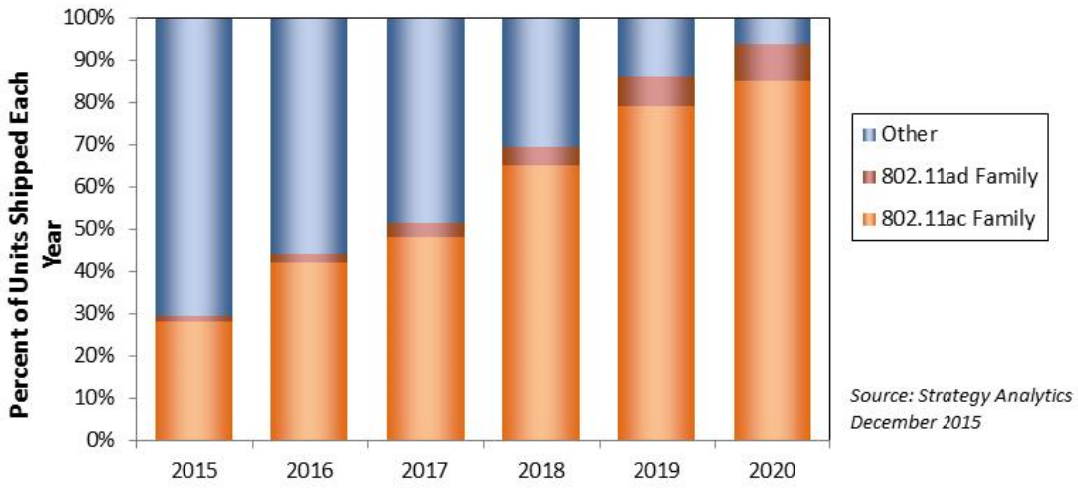
    - Today consumers buy 4K UHD TVs to have the best possible picture, and content is available from a growing number of on-demand sources including Netflix and Amazon.

        – With more 4K UHD TVs and quad HD and above phones, more consumers want to mirror the phone display on the big TV screen.
        – The new 4K UHD HDR (high dynamic range) video standard and spectacular new HDR TVs from Samsung, Sony, Panasonic and LG coming to market this year will **further stimulate demand,** and TV vendors have struck deals with content providers to provide new releases in true 4K UHD HDR format for availability on demand.

**Streaming 4K UHD video and getting the files on and off of devices is a big challenge.** Even a compressed two-hour 4K UHD movie can occupy 60 GB of disk space, which can take more than a half hour to transfer using 802.11n. We think 4K UHD video will be a big driver of 802.11ad, but not the only one.

Based on discussions with Wi-Fi equipment suppliers, 802.11ad (and its follow-on standard 802.11ay) will grow from a few percent of routers and related Wi-Fi infrastructure shipments in 2016 to about 10 percent in 2020 (see Exhibit 2). Penetration in client devices will exceed that of infrastructure initially with seeding by Qualcomm, Intel and others in smartphones, laptops, tablets and other client devices, creating demand for infrastructure.

Exhibit 2 802.11ad Family as a Percent of Infrastructure Shipments




This growth may not seem impressive at first, but it represents a shift from past niche applications for 802.11ad, mainly in docking stations, to wide acceptance as a very high-performance complement to 802.11ac (and follow-on versions such as ax), and acceptance as a mainstream Wi-Fi technology useful across a full range of applications.

## Applications

Today one can find 802.11ad mainly used in **wireless docking stations** for laptop PCs, for example as an option for Dell Latitude 5000 and 7000 model PC docking stations. HP also uses 802.11ad in its HP Advanced Wireless Docking Station and as option for the HP Elite x2 1011 business laptop PC. If Intel pushes this application successfully, volumes could reach many tens of millions of units per year in a high proportion of dockable PC devices. See Exhibit 3.

Exhibit 3 Expected Evolution of 802.11ad Applications


Given that 802.11ad can support streaming tens of 4K UHD video streams, we expect **cable replacement** in home entertainment video system to emerge as another major application. In a typical home video system, multiple HDMI cables interconnect set top boxes, DVRs, Blu-ray players, TVs, smartphones, tablets and PCs, making something of a rats nest around and behind the television. Consumers really would like to eliminate the clutter and complication of all the cables, and 802.11ad could help immensely.

Many **premium-tier smartphones and tablets** will ship with 802.11ad starting in 2016 driven by Qualcomm and Intel. We think that consumers will really like 802.11ad for device-to-device screen mirroring and content transfers between mobile devices.

- The first phone announced with 802.11ad, the Le Max Pro from LeTV, can pair with the Blade 65-inch TV from LeTV. The TV uses Qualcomm's APQ8094 applications processor and a Qualcomm 802.11ac/ad chipset. The phone, actually a phablet, uses Qualcomm's flagship Snapdragon 820 and an 802.11ac/ad chipset from Qualcomm.
- In May 2015, SiBEAM (a Lattice Semiconductor subsidiary) announced that its "UltraGig" 60 GHz chipset had been designed into LeTV's Le Max phablet, the predecessor to the Le Max Pro. UltraGig is a proprietary air interface that does not comply with 802.11ad, but the latest chipsets from SiBEAM add 802.11ad support.

Device-to-device transfers such as display mirroring and virtual reality (VR) do not require 802.11ad access points as intermediaries, but we think that 802.11ad in mobile devices will stimulate wider adoption in infrastructure as consumer try to extend fast file transfers and display mirroring to other devices on the home network. As in the case of 802.11ac Wave 2, the timing of Apple's adoption of 802.11ad in iPhones will surely have a big impact on the market.

Another application expected to emerge in 2016 is the **point-of-sale kiosk** for purchasing content such as downloadable movies and e-books. Today one can purchase downloadable content at the airport, but transfers can take so long that you are likely to miss your flight or have to leave the content behind. Kiosks equipped with 802.11ad can solve this problem by providing the content in as little as a few seconds. Qualcomm demonstrated an 802.11ad-equipped kiosk last year; the first commercial kiosks with 802.11ad will probably ship in 2016.

Exhibit 4 TP-Link 802.11ad Multiband Wi-Fi Router

Once OEMs, consumers and equipment makers experience the benefits of 802.11ad, we expect wider adoption in Wi-Fi access points as a means of enhancing access to local storage as well as the Internet and Cloud access:

- High-performance **residential routers** will ship with 802.11ad starting in early 2016, and should these should provide a boost to Cloud access and storage at least in regions with higher wired broadband speeds.
    - **TP-Link** announced its Talon AD7200 multi-band Wi-Fi router with 802.11ad at ICES in January '16, claimed to be the first commercially available 802.11ad router. The router supports 802.11n, ac Wave 2 and ad, and can seamlessly change among these should a wall block the 60 GHz signal. Qualcomm supplies the 802.11ac Wave 2 and 60 GHz ad radio chips. See Exhibit 4.
    - **EC** and **Elecom** also announced 802.11ad routers due to ship in 2016.
    - **Internet service providers** (ISPs) have a strong interest in new premium-tier services and how 802.11ad-equipped wired broadband modems can support these. Services could include ultra-high-rate Internet access, Cloud storage and 4K video. 802.11ad offers ISPs an opportunity to provide new, revenue-generating, differentiated offerings, which could become quite compelling as 802.11ad reaches consumers in smartphones in 2016.
- 802.11ad can provide benefits to **enterprises** for downloading video and mass distribution of data in open office environments. Use in enterprise infrastructure could start in late 2016 or early to mid-2017. 802.11ad will also appear in shopping malls, stadiums and airports, where open spaces can allow unobstructed access over tens of meters, and in these environments 802.11ad can relieve congestion typical in the LTE, 2.4 GHz and 5 GHz Wi-Fi bands. Multi gigabit Ethernet (2.5 GbE and above) will be required on the wired side to make full use of 802.11ad in many of these applications.
- By 2017, 802.11ad will appear in **wireless virtual reality headsets and glasses**. The low latency of 802.11ad and ability to support UHD video at 60 to 90 frames per second eliminates the dizziness and difficulty of controlling motion experienced by users relying on higher-latency links in the past. Exciting applications for VR include multi-player games, psychotherapy, drone control and education.

- 802.11ad can provide high-speed **front haul and back haul** to small cells, and will probably find use in these applications as 5G launches in 2019 and 2020. One equipment supplier speculated that Google may have a strong interest in 802.11ad for backhaul.

Exhibit 5 lists commercial 802.11ad systems that have shipped so far and those expected to ship in 2016 as of publication of this Insight.

Exhibit 5 Commercial 802.11ad Devices

| Brand | Application | Model | Ship Date | Comments |
|---|---|---|---|---|
| **Dell** | Wireless Mini PCIe card | DW1601 | 2013? | Qualcomm QCA9005: Wilocity Wil6120, Atheros AR9462. |
| **Dell** | Wireless dock | Wireless Dock D5000 | 2013 | Original WiGig docking station (2013); Wilocity (Qualcomm). |
| **Dell** | Wireless docking | Latitude 5000 | 2013 | Optional WiGig. Wilocity. |
| **Dell** | Wireless dock | Dell Wireless Dock (452-BBUX) | May 2015 | Intel WiGig, VGA (1), Mini DisplayPort (1), HDMI (1), USB 2.0 (2), USB 3.0 (3), WAN (1) |
| **Dell** | Wireless dock | WLD15 452-BBUX CTKM5 for Latitude E7250, E7450, E5450, E5550, and E5250 | 2015 | Intel chipset. |
| **HP** | Wireless dock | HP Advanced Wireless Docking Station | 2015 | Intel chipset. |
| **HP** | Laptop PC | HP Elite x2 1011 | 2015 | Intel chipset. |
| **Le** | Phablet | Le Max | 2015 | SiBEAM. |
| **Le** | Phablet | Le Max Pro | 2016 | Qualcomm SD820 and Wi-Fi. |
| **Le** | 4K UHD TV | Le Blade | 2016 | Qualcomm Wi-Fi chipset including APQ8094 processor |
| **Lenovo** | Laptop & wireless dock | ThinkPad X1 Yoga, ThinkPad X1 Carbon | 2016 | Intel. |
| **TP-Link** | Wi-Fi router | Talon AC7200 | 2016 | Qualcomm APQ8064 apps processor with QCA9500 & 802.11ac chipset. |
| **Acer** | Laptop / networking | TravelMate P648 | 2016 | Qualcomm equipped. |
| **Asus** | Gaming laptop | ? | 2016 | Qualcomm equipped. |
| **NEC** | Wi-Fi router | Aterm 11ad | 2016 | Qualcomm equipped. |
| **Elecom** | Wi-Fi router | WRC-7133 GXBK | 2016 | Qualcomm equipped. |
| **IgniteNet** | Point-to-point backhaul | MetroLinq PTP60-35 and PTP60-19 | 2016 | Peraso X610 chipset with WiGig/802.11ad core. |

## Chipset Availability

Most chip suppliers use CMOS with a multiple emitter antenna array with up to 32 phase shifted elements for beam steering and gain. According to Broadcom, a chipset with a 16-element antenna array provides an Rx sensitivity of around -73 dBm per antenna port, and 27 dBm of antenna EIRP with a 3 dBm transmit element output. Future versions of 802.11ad, as mentioned above, might allow up to 128 emitters operating in support of massive MU-MIMO.

Of the listed companies, **Qualcomm, Intel, Peraso, Nitero, SiBEAM** and probably **Broadcom** will have 802.11ad chips on the market in 2016:

- **Qualcomm** uses 28 nm CMOS technology for its VIVE QCA9500 chipset, consisting of the QCA6320 baseband / MAC and QCA6310 transceiver, the latest chipset with roots in the acquisition of Wilocity. Qualcomm is shipping units in increasing volumes today, and will expand its sales along with the latest Snapdragon processors for smartphones and 4K Ultra HD. Wilocity and Qualcomm shipped the 802.11ad / ac chipsets used by Dell in the original D5000 docking station.

- **Intel** offered the Intel Wireless Gigabit Sink W13100 NGFF (M.2) card starting in 2014. The W13100 supports 60 GHz only and is used on the docking station side of a laptop to dock link. To go with the W13100, Intel offers the Tri-Band Wireless AC 17265 solution with Wireless Gigabit Antenna primarily for tablets, 2 in 1 computers and laptop PCs. Intel supplies the solution in an M.2 Type 3030 connectorized module (aka NGFF card).

  The company recently (2015) announced the Intel Wireless Gigabit 11000 (60 GHz only) for docks and the Intel Tri-Band Wireless-AC 18260 solution for laptops. These are apparently shipping in the latest docking stations and laptop PCs that use 802.11ad from Intel.

- **Broadcom** has done presentations about the advantages of 802.11ad, and has chipsets in development, however, the company had not yet announced parts as of late February 2016 when this report went to press. We expect Broadcom to launch its first 802.11ad chips later this year. Broadcom would seem well-positioned to supply 802.11ad for enterprise applications to equipment enterprise suppliers such as Cisco.

- **SiBEAM** (a Lattice Semiconductor company), a pioneer of 60 GHz technology, started shipping radio chipsets for its proprietary UltraGig / WirelessHD air interface mainly to HDTV makers in 2010 for HDMI cable replacement. Outside of a few premium models and prototypes, WirelessHD never took off.

  In early 2015, SiBEAM announced the SB6501 802.11ad-compliant network processor and SB6510 transceiver. Later in 2015, SiBEAM announced a design win in the LeTV Le Max phablet promoted as providing “a seamless, interactive experience from the phone to the TV,” but apparently LeTV shipped very few phones with SiBEAM’s chips. SiBEAM has said it would ship 802.11ad chips in adapters in 2016.

- **Peraso** offers two 60 GHz chipsets, the X610 for outdoor / infrastructure and the W110 for consumer electronics. The X610 uses a WiGig software stack with network management on top, and consists of the PRS4601

baseband and PRS1126 RF transceiver. The W110 for consumer electronics consists of the PRS4001 baseband and PRS1125 transceiver.

Peraso has the transceivers fabricated in SiGe-BiCMOS for RF output power up to 14 dBm, and uses one antenna element instead of the phased array emitter approach favored by CMOS providers. As a result, Peraso's initial chipsets do not support beam steering, however, the company has 16 emitter array transceivers in development.

IgniteNet uses the X610 chipset in their MetroLinq™ PTP60-35 and PTP60-19 point-to-point radios, now shipping. Peraso showed an 802.11ad USB dongle at MWC 2016, and said it would ship adapters interoperable with Qualcomm- and Intel-based 802.11ad products later this year.

- **Nitero** uses 28 nm CMOS from Samsung to fabricate the Nitero NT4600M, which Nitero claims consumes only 500 mW, a bit lower than competing solutions according to Nitero. Nitero has said it is targeting use in phones.

- **Samsung** announced in 2014 that it had developed a chipset for 60 GHz Wi-Fi and would ship the first production devices in n 2015. We have not heard any news since then. Samsung phones using the Samsung 60 GHz chipset could appear in smartphones in 2016, but we think using Qualcomm's solution in phones will provide faster time to market for 802.11ad for Samsung this year.

- **Tensorcomm** has in development low-power chips for 802.11ad. The company announced the TC2522-Y 60 GHz radio with 2.5 Gbps operation over four 60 GHz channels in February, 2014, but has been relatively quiet since then. The company has the chipset fabricated in 40 nm CMOS by TSMC, and can provide the chipset in a 17 mm x 11 mm x 0.5 mm module. Claimed peak power consumption is only 250 mW at 2.5 Gbps. The company is run by Patrick Sun, a wealthy businessman, and with his support in the mix should not be counted out.

- **Panasonic** is reported to have chips in development for near-field 60 GHz.

- **Hitachi** has chips in development.

- **Keyssa** has a near-field version of 60 GHz that would be suitable for kiosks in development.

- **Blu Wireless** demonstrated an 802.11ad chipset in 2015, but the company has said it intends to provide silicon IP for 60 GHz radio ICs, not complete chipsets.

- **Allegro DVT** has developed silicon IP for the WiGig Wireless Display Extension (WDE), which supports wireless audio and video streaming with lossless quality and latencies below 1 ms.

The success of 802.11ad with high chip volumes requires interoperability and performance testing, which will happen with plug-fests and range debug events to fine tune system and radio chip performance. API development and IP stack support is also still needed for applications beyond docking stations. Here the larger suppliers with extensive staffing such as Qualcomm, Intel and Broadcom have an advantage over the smaller suppliers.

### Qualcomm-Intel Collaboration

**In February, 2016, Intel and Qualcomm announced a partnership for interoperability and performance testing of 802.11ad chipsets and devices**:

- The agreement insures interoperability among virtually all infrastructure and client devices including routers, laptops, smartphones, docking stations, multimedia kiosks and other 802.11ad devices that will ship this year.
- The testing will help to build a vigorous ecosystem by assuring a positive user experience with 802.11ad and by removing uncertainties for OEMs considering adopting 802.11ad in new device designs.
- Intel and Qualcomm will probably supply more than 95 percent of the chipsets used in 802.11ad-equipped devices shipping in 2016. This underscores the importance of the collaboration for the success of 802.11ad.

**The two companies have already established interoperability with good performance.** Qualcomm and Intel said they worked for months prior to the announcement to complete performance and interoperability tests of Qualcomm and Intel equipped 802.11ad access points and client devices in various use-cases, starting with discovery and ranging through high-rate uploads and downloads in conventional networking and peer-to-peer situations. The tests included video streaming at multi-gigabit per second data rates.

## Implications & Conclusions

**802.11ad has emerged as a multi-gigabit complement to 802.11ac Wave 2.** Consumers will get to use 802.11ad this year in leading-edge smartphones and TVs, and from there applications will expand to include point-of-sale kiosks for downloading multimedia content, residential, enterprise and public venue Wi-Fi infrastructure, virtual reality devices, and front haul and back haul for small cells:

- The Intel-Qualcomm collaboration for interoperability testing removes a potentially serious impediment to rapid adoption of 802.11ad by OEMs, paving the way for new OEM devices:
    - Interoperability between Qualcomm and Intel 802.11ad radios will serve the needs of the market very well this year and well into 2017 if not beyond. Today, most devices that use 802.11ad either ship with Qualcomm or Intel 60 GHz radios, and this will probably not change through the end of 2016, although we expect Peraso, SiBEAM, and probably Broadcom to ship production 60 GHz chipsets this year.
    - Qualcomm and Intel are the only two chipset suppliers to offer complete bundles of cellular and Wi-Fi solutions so far, and it appears that smartphones will make up a high proportion of initial client devices using 60 GHz technology, creating demand pull for 802.11ad in infrastructure, multimedia kiosks, and other devices and applications.
- After a focus on 802.11ac Wave 2 in 2014 and 2015, many equipment OEMs have turned their attention to 802.11ad for premium, high performance Wi-Fi access points. TP-Link was the first to announce an 802.11ac/ad

router. Many of the coming 802.11ad access points will probably take the form of ISP-installed modems in support of ultra-high-rate Wi-Fi in tandem with premium-tier Internet service plans.

**The first pay-off for 60 GHz development efforts is here, and not just for Intel and Qualcomm**. As cellular and Wi-Fi converge and 5G approaches, 802.11ad will ship in an increasing proportion of smartphones, and we believe that cellular chipset suppliers MediaTek and Spreadtrum will have to offer 802.11ad. They can do this by acquiring or partnering with the lower-share 60 GHz specialists.

**802.11ad is a step toward 5G**, which will use mm-wave frequencies potentially as high as 100 GHz. OEMs and radio chips suppliers will gain experience from 802.11ad, and use this for developing new mm-wave capabilities for 5G.

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[i] *For more about 802.11ac and 802.11ac Wave 2 with MU-MIMO, which will ship with 802.11ad in most devices, see the Strategy Analytics report: *802.11ac Wave 2 with MU-MIMO: The Next Mainstream Wi-Fi Standard*.