HomePlug™ AV2 Technology

Raising the Bar for Sustained High-Throughput Performance
and Interoperability for Multi-stream Networking
Using Existing Powerline Wiring in the Home.

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EXECUTIVE SUMMARY

HomePlug AV2 provides a major step forward in high-bandwidth capabilities and interoperability for cost-effective "no new wires" networking that supports HD / 3D video and other bandwidth-hungry applications by leveraging existing power line wiring throughout the whole home.

HomePlug AV2 maintains full interoperability with HomePlug Alliance's other connected home technologies (HomePlug AV & HomePlug Green PHY) in order to facilitate a simple migration to next generation HomePlug Certified products. This is a key benefit as HomePlug Certified products are already found in millions of consumers' homes and widely available worldwide from service providers and retail stores.

HomePlug AV2 technology enables gigabit-class speeds to every electrical outlet in the home, making it ideal for Internet video, multi-room IPTV, online gaming, HD audio and other high demand home networking uses, particularly when using multiple HD devices simultaneously.

Key features enabled by HomePlug AV2 include:

- Gigabit-class PHY Rate
- Support for MIMO (multiple-input and multiple-output) PHY
- Whole home coverage with inherent repeater functionality
- Streaming multiple high-definition video and audio programs
- Interoperable with HomePlug AV, HomePlug Green PHY AND IEEE 1901 devices
- Power save with three modes of operation (Active, Standby and Idle)

Developed by a diverse group of industry-leading participants in the HomePlug Alliance Technical Working Group (see Figure 1), the HomePlug AV2 specification builds upon the extensive ecosystem of established HomePlug products and technologies, thereby ensuring both backward interoperability and forward-looking support for new applications that will be driven by the evolution of ultra-high-speed connectivity and services.

Figure 1 – AV Technical Working Group

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THE DRIVE FOR HIGHER PERFORMANCE IN-HOME NETWORKS

The convergence of voice, video and data within a variety of multi-function devices and new applications, along with the evolution of high-definition and 3D video, is driving the need for increased high throughput connectivity throughout the home while assuring a high level of reliability and sustained performance.

Home networks are now expected to support applications such as whole-home audio systems, interactive gaming, Smart Grid utilities management and security monitoring. The rise of HDTV, IPTV and multi-room HD DVR services are significantly raising the throughput requirements for home networking. (Figure 2)

Figure 2

In addition, the proliferation of connected devices and methods for accessing and consuming multimedia content within the home is requiring network technologies to both deliver more throughput and provide more adaptability to meet ad hoc configuration needs. For example, streaming services (Netflix, Hulu, Vudu, Amazon Prime, Pandora etc.) and diverse access devices such as iPads and Xbox, are giving users more options for using digital content within the home – and they do not want to be limited as to where and how they use it.

Despite the ongoing drive for convergence of video, voice and data, home networks often leave disconnected islands in the home (dead spots) where digital content is not available without pulling new cabling or hassling with the inherent coverage limitations of wireless networking. In contrast, standards-based powerline for fixed devices and a combination of powerline and Wi-Fi for mobile devices can deliver a truly comprehensive whole-home solution that bridges all of these digital islands into a comprehensive network of interconnected content for access and viewing anywhere, anytime, and on any screen.

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For example, HomePlug AV Certified products enable users to easily access streaming services from anywhere there is a power outlet. It also flexibly delivers high speed throughput to all HDTVs, Blu-ray players, DVRs, PCs and game consoles throughout the home. Combined with a hybrid (Wi-Fi and HomePlug) router or range extender, both stationary and mobile devices are readily supported. Using simple and secure setup with push button authentication, HomePlug can easily extend connectivity to that additional TV or game console in another room without running any new wires.

The introduction of HomePlug AV2 is the next major step forward in performance to support higher throughput for whole-home HD / 3D video, interactive gaming and other demanding multimedia applications; while simultaneously providing interoperability with the growing ecosystem of other applications such as Smart Grid and security functions that HomePlug Alliance addresses via its HomePlug Green PHY standard

OVERVIEW OF HOMEPLUG AV2 TECHNOLOGY

Building on a Proven Family of Standards

The widely-adopted HomePlug AV standard has now been enhanced to both extend the reach and throughput of the HomePlug AV2 solution. As shown in Figure 3, both HomePlug Green PHY and HomePlug AV2 are fully interoperable with HomePlug AV, while each provides a distinct set of capabilities for addressing different market requirements.

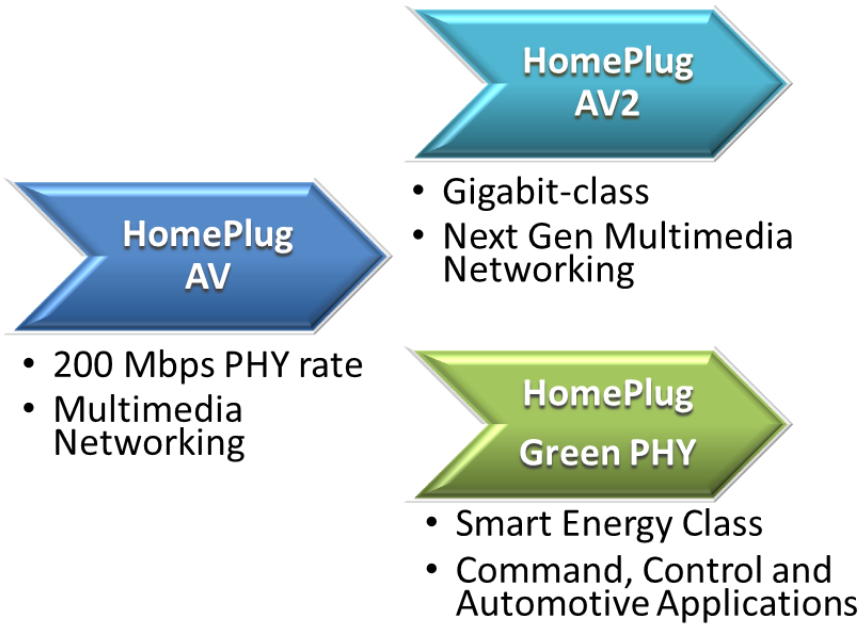

Figure 3 - Compatible Family of HomePlug Standards

Introduced in 2010, HomePlug Green PHY leveraged the HomePlug AV standard to deliver an energy-efficient and cost-effective networking option with optimized throughput for implementing a wide range of applications such as Smart Grid/Energy management, device automation/control, security monitoring, and other latency-

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tolerant machine-to-machine communications functions. HomePlug GP provides ample throughput for current and future Smart Grid/Energy applications, while offering reduced complexity and much lower power consumption.

Now, with the introduction of HomePlug AV2, the HomePlug AV architecture also has been extended upward to provide two to five times the performance of HomePlug AV. This enables HomePlug AV2 to provide both the throughput and coverage needed to support the escalating requirements of next-generation multimedia applications.

The following sections provide additional information on the similarities that provide interoperability between HomePlug AV and AV2 as well as the key differences that enable higher performance and coverage with HomePlug AV2.

Maintaining Architectural Interoperability with HomePlug AV

As illustrated in Figure 4 and Figure 5, HomePlug AV2 shares the same underlying architecture and communications hierarchy with HomePlug AV; thereby providing a solid foundation for achieving interoperability between all certified HomePlug AV, HomePlug AV2 and HomePlug Green PHY products

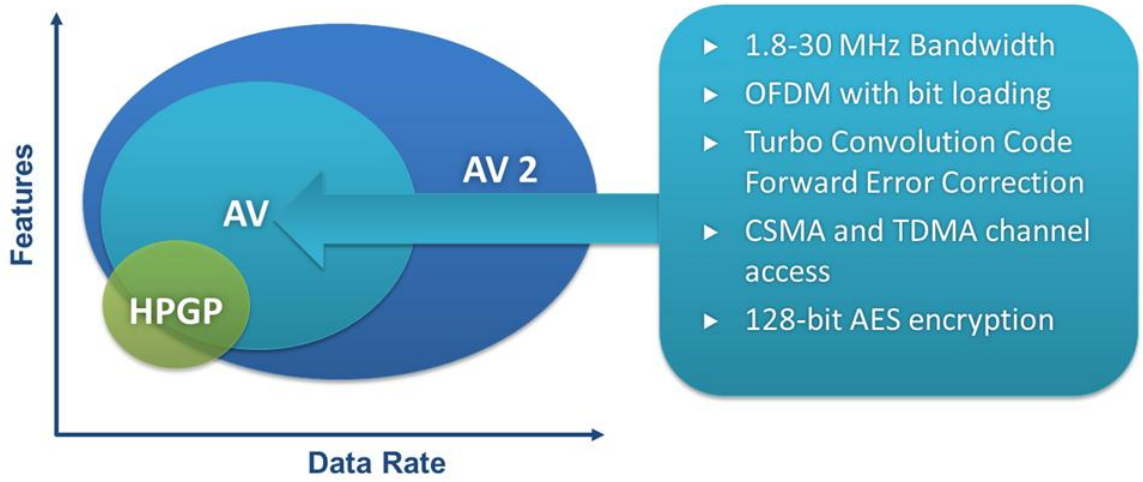

Figure 4 - HomePlug AV & AV2 Shared Attributes

Key Differentiating Features in HomePlug AV2

In addition to the compatibility between HomePlug AV and HomePlug AV2, there are a number of characteristics that differentiate HomePlug AV2 and provide for its higher bandwidth and coverage capabilities. These enhancements are shown in Figure 5 and are described in the following sections.

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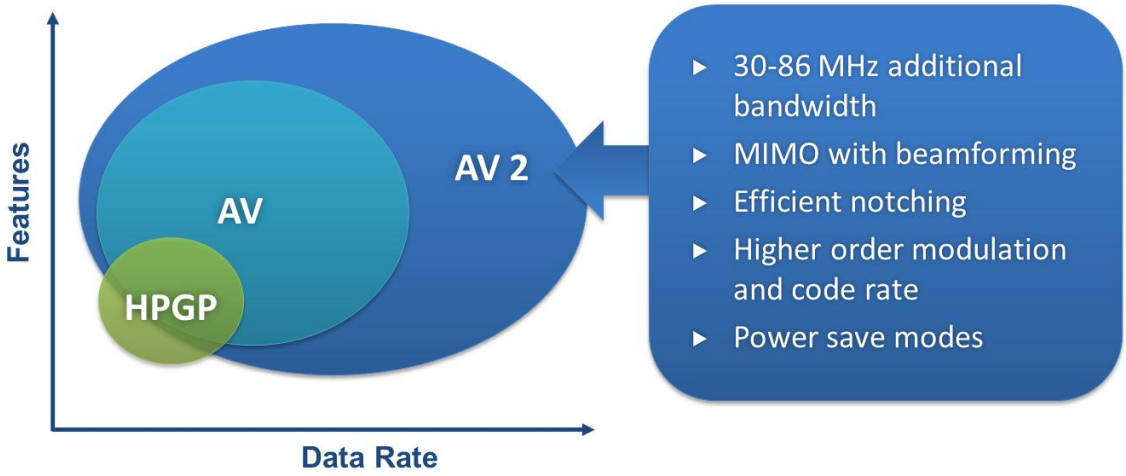

Figure 5 – Key Differences in HomePlug AV2

Additional Frequency Spectrum

HomePlug AV2 makes use of additional frequency spectrum (30 to 86 MHz) beyond the frequency used for HomePlug AV, which significantly increases HomePlug AV2 throughput for applications such as multiple HD streams. The additional spectrum also improves peak data rates and performance which is essential for achieving high performance over powerline.

Multiple-Input Multiple-Output (MIMO) Capabilities with Beamforming

The HomePlug AV2 specification also incorporates Multiple-Input Multiple-Output (MIMO) capabilities with beamforming, which offers the benefit of improved coverage throughout the home; particularly for previously hard to reach outlets. MIMO enables HomePlug AV2 devices to transmit on any two wire pairs within three-wire configurations. Whereas HomePlug AV always transmits on the Line-Neutral pair, HomePlug AV2 can transmit on any two pairs formed by the Line, Neutral or Ground wires (i.e., Line-Neutral, Line-Ground or Neutral-Ground). This allows for significantly improved peak data rates and performance. MIMO uses two independent transmitters and up to four receivers, with beamforming required to maximize the performance on the independent streams. Some regions and some homes do not have the third wire required to implement MIMO however HomePlug AV2 automatically switches to standard SISO operation whenever the third wire is not available.

High Efficiency PHY Protocol Data Unit (PPDU) Structure

HomePlug AV2 incorporates a high efficiency PPDU (or packet on the wire) structure that enables lower latency and increases network efficiency. The PPDU also improves packet efficiency by lowering overhead, thus exponentially increasing packet efficiency at higher data rates. HomePlug AV2 achieves greater efficiency in the PPDU primarily through the use of a Short Delimiter structure and Delayed Acknowledgements that enable very short response inter-frame spaces.

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Immediate Repeating

This feature in HomePlug AV2 expands coverage by repeating the signal on paths with better SNR (Signal to Noise Ratio) characteristics. Repeating is accomplished in a single channel access and segments are not stored at the repeater to minimize latency and resource usage. Also no reassembly and segmentation is required at the repeater.

Efficient Notching

HomePlug AV2 increases throughput by allowing devices to minimize the overhead incurred due to mandatory notching requirements. While in HomePlug AV the mechanism ("windowed OFDM") for creating the PSD notches is fixed and relatively conservative, AV2 devices may gain up to 20% in efficiency if they implement additional techniques to accommodate sharper PSD notches. Such devices gain additional carriers at the band edges and may utilize shorter cyclic extensions, which reduces the duration of the OFDM symbols.

Additional PHY Improvements

HomePlug AV2 also incorporates improved coding schemes in the PHY, which provide robust error correction and better peak data rates, while assisting with performance improvement on good paths at high data rates. The key improvements are higher order modulation (4096-QAM), higher Code Rates (8/9 code rate) and smaller guard intervals.

Power Save Modes

Another key innovation is improved energy efficiency when the device is in standby. HomePlug AV2 enables "sleep mode" for various intervals that are multiples of the beacon period in order to reduce power consumption. Using Power Save Modes that are identical to HomePlug Green PHY, the specification enables selectable "Sleep Window" and "Awake Window" durations. For example, a station can have a small "Awake Window" once every N Beacon Periods, an Awake Window for a portion of a Beacon Period or an "Awake Window" that is M Beacon Periods every N Beacon Periods. Management messages are exchanged so other stations can know when each station is Awake and only transmit to them during the Awake periods.

SUSTAINED PERFORMANCE FOR MULTI-STREAM NETWORKING

Field testing of HomePlug AV2 has confirmed the ability to deliver sustained performance for multiple stream networking environments, which exceed targets established in the original market requirements document (MRD) under the following conditions:

- Coverage performance was based on six home field tests in the US, all using combinations of four nodes in typical locations in each home.
- The full 2-85 MHz frequency band was tested and transmit power above 30 MHz was diminished by 30 dBm/Hz.

Key field test findings (Figure 6) are as follows:

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- For 1 stream test, the minimum targeted UDP throughput of 82 Mbps was achieved on 96% of all connections
- In the 3 stream tests, the minimum UDP throughput supported was measured on each of three streams from one source to threes clients. In all measured scenarios the minimum UDP throughput supported was at least 30 Mbps

These field test results show that HomePlug AV2 is able to consistently deliver levels of sustained performance for multi-stream HD / 3D video delivery at throughput levels as recommended by a range of telcos/operators/service providers who provided customer-centric input to development of the MRD.

AV2 Field Test Result	UDP Performance (Mbps)					
Coverage Percentage	99%	98%	96%	75%	5%	Peak PHY Rate
1 stream	59	67	82	138	493	1,256
3 equal streams, total throughput	90	93	99	141	367	1,256

Figure 6 – HomePlug AV2 Field Test Performance Results

LEVERAGING HOMEPLUG'S PROVEN TECHNOLOGY ECOSYSTEM

In addition to offering higher performance and backward compatibility, HomePlug AV2 benefits from the rich ecosystem of technologies and proven products that exist under the HomePlug Powerline umbrella. With 60 member companies, the HomePlug Alliance is the largest organization that creates specifications and certification programs for using existing powerlines to deliver reliable home networking, smart grid and smart energy applications. HomePlug already accounts for over 90% of the installed base for powerline networking and offers a rigorous certification process and a well-defined forward migration roadmap that are designed to lead the market through its next phase of growth.

Broad-based Participation in HomePlug AV2 Specification Development

Development of the HomePlug AV2 specification has been conducted by an active collaboration of industry-leading companies in the Technology Working Group, along with extensive inputs solicited from a wide range of key stakeholders, including OEMs, service providers, regulatory entities and other standards-setting organizations.

HomePlug AV2 Addresses Both Retail and Service Provider Segments

The deployment of expanded entertainment services such as HDTV, multi-room HD DVR services, and IPTV is being driven primarily from the top down by service providers. In order to maximize their service rollouts by deploying quickly and assuring a high level of customer acceptance, service providers need highly-reliable, standards-based home networking solutions that can support multiple HD video streams.

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When configuring and extending their home networks, end users also need to have solutions that are easy to install, reliable and hassle-free. From the perspective of end users, interoperability is critical because many users obtain add-on networking equipment through retail channels and they will simply expect it to work flawlessly within their heterogeneous home network environments.

HomePlug AV2 addresses the needs of both these key industry segments by offering solutions that deliver sustained performance and reliability in combination with ease of installation and interoperability with a broad ecosystem of proven HomePlug AV products available worldwide through major retailers such as Best Buy, Carrefour, Tesco and Wal-Mart. Over 30 leading service providers world-wide include HomePlug devices in their product offerings.

Multi-vendor Solutions with a Range of Certified Chipsets

With cumulative shipments of around 100 million HomePlug nodes at end of 2011 and a strong group of experienced silicon vendors producing 3rd and 4th generation chipsets, HomePlug AV2 benefits from an extensive and mature technology foundation. Four silicon vendors have developed HomePlug AV compliant chipsets with a full spectrum of design support tools and software development kits.

Extensive Testing and Certification Processes

Developers, end users and service providers throughout the world have come to expect excellence from HomePlug products. To a great degree, this confidence results directly from the rigorous product testing and certification methodologies that the HomePlug Powerline Alliance uses to assure the compliance and interoperability of all certified devices.

Interoperability with other Key Industry Standards

HomePlug AV2 also benefits from the extensive cross-standards collaboration between the HomePlug Alliance and other key industry organizations. Of primary importance is the relationship with IEEE and the inclusion of HomePlug AV within the IEEE 1901 global standard for interoperability of powerline networking technologies as well as inclusion in the IEEE 1905.1 hybrid networking standard. IEEE 1901 defines PHY and MAC specifications for powerline devices across the entire spectrum of In-Home, Transport and Smart Grid applications. IEEE 1905.1 utilizes widely adopted standards including Wi-Fi (IEEE 802.11), Ethernet (IEEE 802.3), HomePlug AV (IEEE 1901) and MoCA (coaxial cables) in a software abstraction layer that combines the performance and reliability of wired networks with the flexibility of wireless for mobile devices.

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Summary: Increased Performance, Coverage and Whole Home Integration

The explosion in demand for robust home networking is driving the need for standards based solutions that can deliver high speed throughput with sustained performance for multi-stream video and the ability to connect anywhere throughout the home. In addition, these solutions need to be easy to install and capable of seamlessly coexisting with other devices in the whole-home networking environment.

With the capability to deliver gigabit-class bandwidth over existing powerline wiring, HomePlug AV2 is the solution for taking whole-home networking to the next level of multimedia capabilities, while simultaneously providing interoperability with existing networks.

By providing a high bandwidth solution for multimedia applications that is fully interoperable with existing HomePlug AV and HomePlug Green PHY solutions, HomePlug AV2 now makes it possible to deploy truly unified whole-home networking that integrates everything from the HDTV to the game console to the Smart Energy system to the electric car charging station in the garage. All within a unified family of compatible standards that enable a broad ecosystem of seamlessly interoperable certified products. (Figure 7)

Figure 7

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