HomePlug AV2
Raising the Bar for Sustained Ultra-High-Bandwidth Performance and Interoperability for Whole-home Multi-stream Networking Using Existing Powerline Wiring

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Executive Summary

As the latest specification to be certified and released by the HomePlug® Powerline Alliance, 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 compatibility with existing HomePlug specifications and other industry networking standards in order to deliver an optimal blend of performance, interoperability and ease of use.

The new HomePlug AV2 technology enables significant performance increases of up to 1.8 Gbps physical rate for broadband networking over powerline wires while remaining fully interoperable with existing HomePlug AV, HomePlug GreenPHY and IEEE 1901 compliant products that are found in millions of consumers’ homes and widely available worldwide from service providers and retail stores.

HomePlug AV2 technology delivers gigabit-class broadband speeds, making it ideal for Internet video, multi-room IPTV, online gaming, HD audio and other high demand networking uses, particularly when using multiple HD devices simultaneously.

Key features of HomePlug AV2 include:
• Up to 1.8 Gbps PHY Rate
• Support for MIMO (multiple-input and multiple-output) PHY
• Whole home coverage with inherent repeater functionality
• High-definition video and audio support without noticeable dropouts or artifacts
• Interoperable with HomePlug AV and HomePlug Green PHY devices
• Power save: Active, Standby and Idle

Developed by a diverse group of industry-leading participants on the HomePlug AV Technical Working Group, the AV2 specification builds upon the extensive ecosystem of established HomePlug products and technologies, thereby ensuring both backward compatibility and forward-looking support for new applications that will be driven by the evolution of ultra-high-speed broadband access and services.

Figure 1 - AV Technical Working Group
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 bandwidth for in-home networking while also providing connectivity throughout the home and 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, security monitoring and other specialized communications requirements. In addition, the rise of HDTV, IPTV and multi-room HD DVR services are significantly raising the bandwidth requirements for home networking.

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

Despite the ongoing drive for convergence of video, voice and data, conventional networking technologies still can leave disconnected islands in the home 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 networking 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.

For example, HomePlug powerline technology enables users to easily access services such as Netflix, X box Live and Pandora from anywhere there is a power outlet. It also flexibly delivers high speed broadband to all HDTVs, Blu-ray players, DVRs, PCs and game consoles throughout the home. To support ad hoc requirements, HomePlug can easily connect that additional TV or game console in another room using simple and secure setup with push button authentication and without running any new wires. In a mixed network environment, HomePlug/Wi-Fi Range Extenders also can eliminate wireless dead spots to improve network reach and coverage.

The introduction of HomePlug AV2 is the next major step forward in performance to support higher bandwidth for whole-home HD / 3D video, interactive gaming and other demanding multimedia applications; while simultaneously providing cross-compatibility with the growing ecosystem of other applications such as Smart Grid and security functions that are already being deployed via HomePlug GreenPHY.
Overview of HomePlug AV2 Technology

Building on a Proven Family of Standards

The widely-adopted HomePlug AV standard has now been leveraged to extend the reach of powerline networking in two simultaneous directions. As shown in Figure 2, both HomePlug GreenPHY and HomePlug AV2 are compatible with HomePlug AV, while each provides a distinct set of capabilities for addressing different market requirements.

Introduced in 2010, HomePlug GreenPHY leveraged the HomePlug AV standard to deliver a lower-bandwidth, energy-efficient and cost-effective networking option for implementing a wide range of applications such as Smart Grids, security monitoring, and other latency-tolerant machine-to-machine communications functions. The HPGP peak PHY rate of 10 Mbps provides ample bandwidth for current and future Smart Grid applications, while offering reduced complexity and much lower power consumption.

Now, with the introduction of HomePlug AV2, the same basic architecture also has been extended upward to provide three times the bandwidth of HomePlug AV, 600 MB and a PHY rate of 1.8 Gbps. This enables HomePlug AV2 to provide both the bandwidth and coverage needed to support the escalating requirements of next-generation multimedia applications.

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

As illustrated in Figures 3 and 4, HomePlug AV2 shares the same underlying architecture and communications hierarchy with HomePlug AV; thereby providing a solid foundation for achieving interoperability between all certified products that meet the HomePlug AV, HomePlug AV2 and/or HomePlug GreenPHY specifications.

Figure 3 - HomePlug AV & AV2 Common Communications Architecture

Figure 4 - HomePlug AV & AV2 Shared Attributes
Key Differentiating Features in HomePlug AV2

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

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 on medium to good paths, which is essential for achieving Gbps level data rates 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 wires within three-wire configurations. Whereas HomePlug AV always transmits on Line-Neutral pairs, HomePlug AV2 can transmit on any pairing of Line, Neutral or Ground wires. This allows for significantly improved peak data rates and performance on both good and poor paths. MIMO uses two independent transmitters and up to four receivers, with beamforming required to manage the independent streams. Some regions (e.g. Japan) 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 Structure
HomePlug AV2 incorporates a high efficiency PPDU structure that enables faster time on wire, which lowers 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 (AKA Single OFDM Symbol Delimiter) structure and Delayed Acknowledgement that enables very short response inter-frame space.

Inherent 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 dynamically increases throughput by efficiently notching tones (while complying with regulatory requirements), which provides up to a 20% increase in the PHY rate throughput as compared with HomePlug AV. This is because HomePlug AV2 enables the transmitter to use approaches other than the “windowed OFDM” method that is used in HomePlug AV. By enabling the transmitter to specify the cyclic extension length and to negotiate notch boundaries, HomePlug AV2 significantly reduces the overhead associated with fixed 30 dB notches that are used in windowed OFDM.

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 similar 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.

ISP Coexistence Protocol
This capability allows peaceful coexistence between HomePlug AV2 and devices using other technologies, as defined in IEEE 1901.
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).

Key field test findings are as follows:

- Coverage performance (CVG) was based on six home field tests in the US, all using combinations of 4 nodes out of 5 “typical” locations in each home
- In the 2-85 MHz frequency band, transmit power was -50 dBm/Hz below 30 MHz, -80 dBm/Hz above 30 MHz, signal level based on a quasi-peak detector
- For 1 Stream test the minimum targeted UDP throughput was achieved with 96% of all connections supported at a UDP throughput of 86 Mbps or higher
- For 3 Stream tests the total UDP throughput of three equal data rate streams from one source to three client devices was achieved at 100% of all 3 simultaneous streams supported at 30 Mbps or higher

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<td>86</td>
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<td>96</td>
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<td>AV MRD</td>
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Figure 6 – HomePlug AV2 Field Test Performance Results

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 bandwidth levels as recommended by a range of service providers who were contacted for input prior to development of the MRD.

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 more than 70 member companies, the HomePlug Powerline Alliance is the oldest and 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 85% 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 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.

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 ramping up 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.

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 products available through retail channels. Over 30 leading service providers already include HomePlug devices in their product offerings and over 80 million HomePlug nodes have been shipped worldwide through the combination of retail and service provider channels.

Multi-vendor Solutions with a Range of Certified Chipsets

With cumulative shipments of over 80 million HomePlug nodes and a strong group of experienced silicon vendors producing 3rd and 4th generation chipsets, HomePlug AV2 benefits from an extensive and mature technology foundation. Six silicon vendors have already developed HomePlug AV certified 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 already 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 AV 2 also benefits from the extensive cross-standards collaboration between the HomePlug Powerline Alliance and other key industry organizations. Of primary importance is the relationship with IEEE and the inclusion of HomePlug AV within the IEEE 1901 specification, which defines the global standards for interoperability of broadband powerline networking technologies.

IEEE 1901 defines PHY and MAC specifications for powerline broadband devices across the entire spectrum, including In-Home, Access Broadband, Transport and Smart Grid implementations. In addition, IEEE 1901 establishes the standards for coexistence between different powerline network communications (PLC) systems.
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 ultra-high speed broadband 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 more than a gigabit of bandwidth over existing powerline wiring and to provide sustained performance of 600 Mbs, 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 an ultra-high bandwidth solution for multimedia applications that is fully compatible with existing HomePlug AV and GreenPHY 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.