ISSI *AMS*

Analog Mixed Signal Division

G.hn Prime:
The Right Choice
Ensuring The Home
Network's Quality

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Preface

ISSI AMS' continuously exchanges insights with service providers, enabling ISSI AMS to meet the needs of operators while offering them quality information on technologies and solutions. This paper is focused on service provider needs for home networks that are robust and that complement service provider products and content delivery.

Operators have crossed the threshold from providing access and related CPE (DSL modems, gateways, etc.) to being responsible for the home network. Quality of content delivery throughout a home's network is their customer's expectation; therefore, service providers find their responsibilities extend to ensuring quality content delivery to everywhere in the home.

Here are the home network requirements most widely sought by service providers to achieve high end-to-end quality:

- Whole home coverage at 100 to 500 Mbps for all major systems
- Support Wi-Fi services
- Minimized install costs and issues – customer self-install or very simple SP tech install, with no hidden issues such as the neighbors' networks
- Extremely reliable service immune to interference – consistent connectivity with no lost packets or connections (High throughput and coverage mean nothing if a high packet error rate interferes with content delivery)
- IP Connectivity – the network must support IP traffic, especially TCP at small and large packet sizes
- Customer acceptability – unobtrusive looks, low power, easy install, no disruptions to furniture/walls/ambiance
- Supports current leading services – UHD (4K) with ability to meet next generation (8K) services needs
- Low latency – for gaming and voice services
- Security – the technology must be secure from hacking and intrusion
- Strong home backbone network supporting IoT applications and devices
- Upgradeable, expandable network

Service providers have numerous options for home networking technologies. In the following sections the options are reviewed, showing there is a choice that stands above all others – ISSI AMS' G.hn Prime, the right choice for home networks.

Overview

Home networks have evolved over the last 20 years from wired Ethernet to hybrids of wired and wireless technologies. This has come about based on two driving forces: consumer demand for connectivity anywhere, and the need to keep pace with the bandwidth demands of consumer electronics systems and applications. On top of these requirements, consumers demand a high-quality experience through interference-free content delivery.

Service providers are in a never-ending battle for residential customers, with delivered bandwidth, quality of content delivery, and customer satisfaction topmost in determining the customer's decision to stay with or leave a provider. If a home network has problems, then delivered bandwidth means little, for the content quality will be poor along with the consumer satisfaction level. Ensuring the user experience is exceptional means the home network must be consistently issue-free.

Service providers continuously evaluate their choices of home network technologies, and seek to standardize on one or two as their offerings to customers. Selections must be cost effective, robust, and provide highest quality and whole home coverage. This paper presents the choices service providers have, showing that G.hn is the best option, with ISSI AMS' G.hn Prime the best in G.hn, in other words: the right choice.

Service Provider Choices

Service providers have choices for home networks, with several to evaluate. After being involved in all aspects of home networks for over twenty years, ISSI AMS' has in-depth knowledge of the issues, service provider needs, and the technologies, which are presented in the following sections.

In the home, residential customers want quality connectivity wherever they consume content. This "connectivity anywhere" demand is leading service providers to consider a sole focus on an 802.11 wireless LAN (Wi-Fi®) option as their choice for home networks. After summarizing the evaluation criteria service providers have stated are most important to them, the various wireless and wired options are evaluated in later sections.

Evaluation Criteria

Whatever choices service providers consider, these should be evaluated against several criteria, such as:

1. Coverage: the technology provides a consistent, high quality connection throughout the residence
2. Throughput: provides the data rate required for peak traffic throughout the home
3. Fast, Simple, and Trouble-free Install: by either user or technician
4. Interference: the technology must be robust enough to withstand interference, including from other instances of the same network in neighboring homes. High throughput and coverage mean nothing if there is a high packet error rate during an IPTV session
5. Security: the technology is secure from hacking and intrusion
6. Life-cycle: the technology meets service provider and customer needs over its projected service life
7. IP Connectivity: the technology supports IP traffic, both IPv4 and IPv6 as well as TCP and UDP with small and large packet sizes
8. Content Delivery: the technology supports IGMP and MLD for broadcast IPTV, with a consistent quality of service under heavy VoD traffic, including substantial TCP traffic with minimal latency
9. Other Network Agnostic: the technology provides a solid backbone network for other networks to work off of, such as IoT networks
10. Powerline Communications: PLC (if used): robust to interference, able to work through a power strip, consistent connectivity, avoids cross-network interference, and able to expand as needs evolve

While these evaluation criteria are sound, ISSI AMS understands that various influential associations, such as the Blu-ray Disk Association (BDA) and the Society of Motion Picture and Television Engineers (SMPTE) as well as Dolby and over the top (OTT) service providers have requirements that go beyond the criteria listed here. Service providers frequently incorporate such requirements into their evaluations to ensure best in class service is delivered. Services routed over ISSI AMS' G.hn Prime will meet these requirements.

The Importance of TCP[1]

The Transmission Control Protocol (TCP) enables a head-end server and a set-top box (STB) to establish a reliable connection for content delivery. Contrary to The User Datagram Protocol (UDP)[2], TCP guarantees packet delivery and processing in the same order as transmitted. This guaranteed delivery is extremely important for many service provider applications, especially video on demand (VoD) and OTT video video, where clean content delivery is vital to user satisfaction, as shown in the following table.

Protocol Usage	IPTV	DVR	VOD	OTT	Added Devices
UDP	X				
TCP		X	X	X	X

ISSI AMS has seen that all service provider home network RFPs have mandatory TCP requirements, underscoring its importance. Many important TCP requirements, such as window sizes, are discussed later, as these are critical to quality service delivery.

With ISSI AMS' in-depth knowledge of set top boxes, video platforms like Mediaroom®, and how service providers use TCP for quality streaming content delivery, ISSI AMS' has engineered outstanding TCP performance into its G.hn Prime chipsets. Globally, after testing home networks in labs and the field, service providers are reporting best in class quality and TCP performance by G.hn Prime versus all other options.

802.11 Wireless Option

802.11 (Wi-Fi) technology has evolved over the 18 years of its existence. It has a strong set of capabilities, including nomadic device support with the value proposition that a single access point (AP) at the gateway may cover a whole home at adequate data rates.

For service providers, wireless LANs offer a compelling value proposition... only a Wi-Fi AP is needed to provide and achieve whole home coverage with a strong, high-quality delivery mechanism.

However, Wi-Fi does not guarantee complete home coverage nor does it guarantee packet-error-free content delivery at acceptable data rates or an easy installation. One major North American service provider stated that over 80% of their customers' network installation complaints were related to Wi-Fi issues.

Lately, two other wireless network issues have begun to appear. The first is the simple fact that more devices are using Wi-Fi, so contention and congestion is more likely over the network. The second issue is the growing use of UHD/4K video by CE and mobile devices, such as the latest iPhones. This congests Wi-Fi networks considerably, meaning a higher probability of poor streaming services over the air. Relying on such a congested medium means service providers may encounter poor customer service metrics.

Based on ISSI AMS' discussions with service providers regarding Wi-Fi coverage most Gateways are located where the minimum point of penetration for the access line is in the house. In many cases, this location is not optimized for best

wireless coverage throughout the home. For example, when the Gateway is in the basement, Wi-Fi coverage is poor in areas of the first floor and all floors above it.

Expensive solutions are being touted as ways to solve this, with both very expensive Wi-Fi access points and devices or with remote access points (APs) placed where there are weak coverage areas.

Such use of remote APs adds complexity and increased networking demands, further eroding Wi-Fi's value proposition. There are two options when considering adding remote APs, either:

1. Rely on the Wi-Fi network to pass traffic between the APs, thus taking up double the time on air for the same data connection (passing data from main AP to remote AP, then the same data from remote AP to terminal device), which also increases the probability of content interference - or -
2. Rely on a wired link between APs to pass data from main to remote AP. Service providers going this second route are seeking the highest quality wireline option to ensure maximum quality of service and connectivity, with ISSI AMS' G.hn Prime the best choice for this application. This option is discussed later.

Other areas of Wi-Fi concern are configuration, security, congestion, and interference. As Wi-Fi radio waves emanate out of the residence, they pose a potential security as well as interference risk, causing congestion. This is especially problematic in multi-dwelling unit (MDU) buildings and highly dense population areas. The solution is to turn down the broadcast power of Wi-Fi networks, thus reducing the likelihood of signal interception and congestion, yet substantially decreasing throughput and increasing the likelihood of reduced coverage; unfortunately fixing one issue exacerbates another.

Bottom line – Wi-Fi has a compelling value proposition but there are issues to resolve. It needs a complementary backbone network to extend it or replace it in problematic areas. This is where G.hn provides the solution.

Wireline Choices

What wired choices are available and how do they compare to one another?

Twisted pair networks, such as standard Ethernet, are good for short distances (nearby connectivity) in the home, but they require in-wall cables to be run for longer connections.

Running new wires for networking is expensive and, given a home's construction, not always possible. Technologists sought ways to reduce or eliminate the need for new wiring.

In an effort to avoid new wires, phoneline wiring (twisted and untwisted pairs) was used for in-home Ethernet. It has lower throughput, higher interference levels, location challenges (existing phoneline wiring tends to be where phones are likely - not data connections), and there is a need to support analog voice and possibly DSL service over the phonelines, leading to throughput issues.

Meanwhile, coax was run initially for antenna feeds to TVs throughout a home, then used to pass cable service to TVs and or set top boxes (STBs). Thus, as coax use was for television connectivity, it is run where TVs are likely. Coax's locations hamper its utility for other applications, and become problematic when a TV is located at a new spot in the home.

Further, it is widely agreed that end users do not find coax, and coax networking, to be a plug and play option, with one common complaint being troublesome and labor intensive coax connectors causing network problems.

Powerline communications (PLC) was developed as a way to avoid new wires and achieve near ubiquitous connectivity, i.e., "the power socket becomes the network connection point." Powerlines have a built-in advantage over other wires in the home, as large consumer electronics (CE) devices need power sockets as well as connectivity, thus, PLC eliminates any need for network wiring.

The table below depicts the probability of a coax, phoneline, or power socket in rooms of a US household. As can be seen, a coax jack is more likely than a phone jack in a room, while powerline sockets are nearly universal to every room and wall in a home. On the other hand, as consumers frequently find, coax and phoneline jacks in a room are not where service is needed.

Room	Coax Jack	Phone Jack	Electric Sockets
Den/Game Room	28.5%	25.6%	100%
Kitchen	15.2%	60.5%	100%
Living/Family Room	81.2%	64.6%	100%
Dining Room	6.1%	13.4%	100%
Home Office	34.1%	40.2%	100%
Master Bedroom	69.0%	73.0%	100%
Bedroom 2	46.7%	48.9%	100%
Bedroom 3	24.6%	27.3%	100%
Other Room	5.9%	7.0%	100%

Probability of cable jacks/sockets in specific rooms of US households [3]

However, early PLC could not overcome powerlines' harsh interference and signal deterioration. Technologists from service providers and industry worked together to define a way to have PLC overcome these limitations and gain maximum use of all existing wires in a home. The result was the ITU-T set of G.hn standards. These define an "anywire" technology able to achieve best-in-class performance in throughput, quality of service, and coverage.

Important Considerations

Heterogeneous Networks

In today's world, home networks typically consist of wired and wireless broadband networks, all under a single Ethernet network. This means that the home broadband network is a heterogeneous network of networks.

The IEEE created the 1905.1 standard a couple of years back (ISSI AMS was a founding member and active participant) to codify how a heterogeneous network appears to the user as a single network in regards to password entry/ acceptance and management, and even parsing heavy traffic loads. All in an effort to reduce network management complexity while improving the probability for a quality user experience under heavy traffic and interference.

Different networking technology groups view 1905.1 from different perspectives. As G.hn is already the most robust wireline technology, the G.hn side sees 1905.1 as a means to simplify the end user's experience as well as enable G.hn to take traffic, whenever possible, from less robust networks (i.e., Wi-Fi, HomePlug AV/AV2).

ISSI AMS' sees 1905.1 as a simplifying technology for users that adds a layer of complexity to systems' designs and software. It therefore has its trade-offs. ISSI AMS products fully support 1905.1; however, ISSI AMS believes 1905.1 is not crucial to achieve the highest quality user experience due to the nature of G.hn. Therefore; service providers do not need to mandate 1905.1 to achieve high customer satisfaction when deploying G.hn Prime.

Coexisting with Deployed HomePlug AV/AV2

HomePlug AV was in the retail market before G.hn appeared. Consumers have used it as a "no new wires" network extender and/or as the basis for some Smart Home applications. Regardless of the success or not of HomePlug AV, it is a fact that HomePlug AV does exist in the home. Therefore, coexistence with HomePlug AV/AV2 is an important requirement for service providers considering PLC.

The ITU-T recognized this need and the G.hn family of standards includes a definition of how G.hn can coexist with HomePlug AV/AV2 implementations, if they are fully conformant to the IEEE Standard 1901-2010©. Unfortunately, except for the ISSI AMS' HomePlug AV solution (http://www.ISSIdesigns.com/media-connectivity/homeplug/), there are currently no HomePlug AV/AV2 IEEE 1901 implementations with the mandatory G.hn coexistence functionality, called ISP. Further, older HomePlug AV installations cannot be upgraded to support the coexistence defined in 1901. Therefore, adding G.hn into homes with HomePlug AV/AV2 may be problematic.

ISSI AMS recognized this problem and designed an industry-unique, automated function within our G.hn Prime chipsets that detects nearby HomePlug AV networks and automatically manages the different powerline networks in a traffic-dependent fashion. The trade-off is slightly reduced G.hn throughput; however, ISSI AMS' G.hn Prime performance still exceeds what others deliver. Please see the Netperian lab test results below.

To ensure a completely plug and play installation for G.hn Prime systems, ISSI AMS' advanced coexistence algorithm detects and determines the mode that G.hn Prime operates in:

- HP AV/AV2 Not Detected – in cases where there are no HP AV/AV2 networks detected nearby, the G.hn Prime service runs at full rate, 100% of the time
- HP AV/AV2 Network Detected – in cases where G.hn Prime detects a nearby HP AV/AV2 network (even a neighbor's network), the G.hn Prime systems manage the time-on-wire for all networks to maximize throughput for both network types. See G.hn Prime Coexistence Capabilities later for more information

Not all PLC technologies were created equal, and they still aren't

Among PLC offerings, two stand out: G.hn's PLC mode and HomePlug AV2. HomePlug AV technology is from 2005. It was a retail technology defined to provide low-data-rate, best-effort Internet connectivity to some power sockets within the home. Packet errors were probable and users had to accept this trade-off.

Since 2005, the HomePlug AV technology has been modified substantially; mostly in an effort to compete with G.hn, while maintaining backward compatibility. HomePlug AV's later iterations, including AV2, face issues due to this need for legacy technology backward compatibility. Thus, HomePlug AV2 is hampered in its security, throughput, quality of connectivity, and interference mitigation techniques versus G.hn, as are seen in recent lab tests (see later section on these tests).

Here are some issues that service providers report encountering with HomePlug AV/AV2 deployments:

- When HP AV2 and HP AV are in the same network, lower rates result
- Due to the use of "proprietary extensions" to the technology, there are varying degrees of reduced interoperability between HP AV/AV2 systems based on chips from different companies
- HomePlug AV and AV2 are based on a contention networking scheme, resulting in packet collisions under moderate to heavy traffic, causing lost packets and jitter
- HP AV/AV2 single network with more than a small number of systems suffers throughput and lost packet issues
- In high population density/MDU deployments, HP AV/AV2 suffer inter-network interference that deteriorates service below acceptable levels
- TCP encounters substantial issues over HomePlug AV/AV2, especially with the typical TCP window size of 64K

The following sections discuss how G.hn, and especially G.hn Prime, overcome these issues.

The Top Choice – G.hn

Overview

In 2006, leading service providers and technology companies banded together in the ITU-T (http://www.itu.int) to define a best in breed "anywire" home networking technology family of standards. The ITU-T designated this technology as G.hn (think gigabit home networks).

Most importantly, as the ITU-T is led by service providers and focused on meeting service provider needs and requirements, the G.hn standards were "defined by service providers to meet the needs of service providers." The ITU-T defined G.hn to be a solid service provider tool for high throughput, high quality of service home networks over any wire. G.hn provides a vast improvement in all categories over any competing technologies.

Highlights

Throughput

G.hn was defined to achieve upwards of a gigabit of throughput over any wire, regardless of wire type. With modes specific to the wire type operated over, G.hn is able to achieve best in class throughput over any wire.

One G.hn industry first is the enhancement to PLC known as MIMO: multi-input/multi-output. MIMO enables all three wires of a socket and powerline wiring to be used for PLC, versus the traditional two wires used. MIMO virtually doubles the throughput and improves the quality of connectivity for G.hn. Even when there is no third wire in the powerlines, G.hn MIMO is defined to improve performance in data rate, reach, and connection quality. See the G.hn HomeGrid Forum introduction to MIMO: **http://AMS.ISSI.com/sdi/wp-content/uploads/G.hnMIMOan4U.pdf.**
ISSI AMS' G.hn Prime includes G.hn MIMO as well as its own data path accelerators that further maximize throughput and quality of connectivity.

Quality of Connectivity

Throughput is only one area to consider when defining a technology for home networks. As users need a quality network connection for streaming content, the network must be robust to noise with consistent connectivity. As can be seen from the recent lab tests of G.hn versus HomePlug AV2 (see later section), G.hn achieves higher quality connections versus HomePlug AV2. G.hn PLC was defined to deliver coax-like quality of connectivity over powerlines, the medium most subject to interference and packet loss. Meanwhile, G.hn Prime was engineered to provide the best TCP performance, regardless of window size-as can be seen in the following figure, which depicts a standardized lab test result of G.hn Prime versus a competing G.hn source, which outperforms HomePlug AV2.
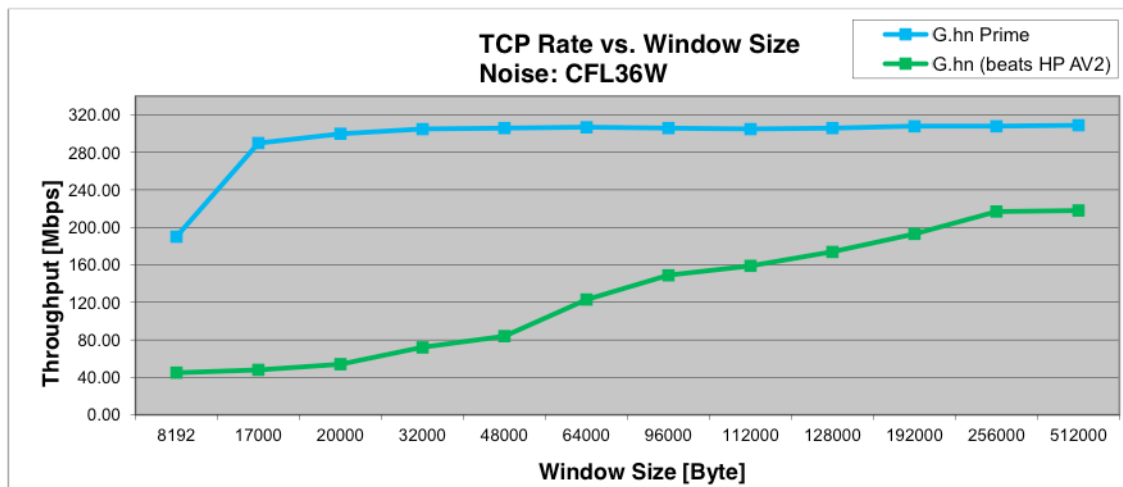
Expected Results: TCP Testing - One to One - vs. Window Size with Noise

Interference Mitigation

Quality connectivity is due to the interference mitigation techniques incorporated in G.hn technology, and tested for compliance by HomeGrid Forum. ISSI AMS' complies with all G.hn specifications in this area while our enhanced algorithms ensure maximum throughput and quality are achieved for streaming content.

Fully Managed Networks

The G.hn technology defines a fully managed network that maximizes wire use efficiency, avoids packet collisions, and ensures essential traffic, such as IPTV and VoD, is given priority.

Security

As PLC signals may extend beyond a residence, there is a need to ensure these signals are protected against:

- Unauthorized access to private data from outside or unauthorized parties
- Unauthorized use of service
- Unauthorized control; for example, someone deleting files on their neighbor's computer
- Spoofing while either receiving or sending messages
- Loss of confidentiality and integrity of communications

The ITU-T built specific security safeguards into the G.hn standards to protect the integrity of and provide confidentiality for the data flowing over the wires and stored on devices attached to the G.hn network.

Neighboring Networks

As stated above, PLC signals may exit the residence and cause cross-network interference as well as a security risk, thus the term "neighboring networks interference." G.hn is defined to ensure that multiple G.hn networks can be in close proximity, such as in an MDU building, and not interfere with one another. This is unique to G.hn versus HomePlug AV/AV2, which suffer degradation when multiple HomePlug AV/AV2 networks are in close proximity. See the G.hn HomeGrid Forum introduction to Neighboring Networks: **http://www.issi.com/WW/pdf/whitepapers/NeighboringNetwork4oMq.pdf.**

Interoperability

The G.hn standards are explicit and do not allow proprietary extensions that may cause interoperability issues. The HomeGrid Forum has taken this approach further with their certification testing to ensure 100% interoperability and performance between systems based on G.hn chips from different sources, see **http://www.homegridforum.org/content/pagesphp?pg=integrators_list.** ISSI AMS' G.hn Prime is HomeGrid Forum certified.

Not All G.hn Chips are Equal

ISSI AMS' brings a unique set of know how and technology engineering capabilities to G.hn chip designs.

- ISSI AMS' ongoing HomePNA experience and success gives ISSI AMS a full understanding of the needs of service
  providers and home networks
- ISSI AMS' pioneering leadership in media processing and Mediaroom deployments gained ISSI AMS an in-depth understanding and appreciation for the issues encountered with content delivery over home networks – the

home network is just as critical to content delivery as the broadband link to the home

- Because ISSI AMS also offers HomePlug AV chips, we have a complete understanding of their capabilities and limitations, and PLC in general. ISSI AMS has used this knowledge to develop unique capabilities in our G.hn Prime chipsets that enable service providers with existing HomePlug AV deployments to convert to G.hn without experiencing inter-network interference – a unique ISSI AMS' advancement

ISSI AMS' R&D engineering staff was able to combine all of these factors with our ability to optimize for service delivery, creating an enhanced G.hn product line. "The best in class of the best in class wireline home networking technology – G.hn Prime."

Commitment To Partners and Service Providers

ISSI AMS' stands out with our focus on partner and service provider success with our products. ISSI AMS supplies a complete set of design and development tools, reference designs, and software for service provider suppliers to ensure their G.hn Prime products are best in class themselves. Meanwhile, ISSI AMS also supports service providers directly to ensure their deployments are trouble-free.

- Production line tools that enable ODMs to test devices before shipment
- ISSI AMS qualifies every ODM design to make sure it meets ISSI AMS' high performance standard
- ISSI AMS provides intimate support to service providers in integrating the solution to their service and tuning it to get maximum performance for the specific services
- ISSI AMS can remotely monitor devices globally, to collect data on their performance; enabling ISSI AMS to continuously improve designs and product performance

PLC Lab & Field Testing

Marketing claims are one thing, test results another. ISSI AMS' G.hn Prime products have participated in lab as well as field testing with an excellent record in both areas.

ISSI AMS' is committed to providing service providers the tools they need to succeed, including testing. Testing guides for powerline communications are one area ISSI AMS has made a strong effort in.

In August 2015, the Broadband Forum (BBF) published a Technical Report (TR-208): "Performance Test Plan For In-premises Powerline Communication Systems ." This test regimen can produce unbiased and repeatable results for PLC in general for performance and QoS metrics. ISSI AMS' was among the leaders of the TR development effort. See the HomeGrid Forum Press Release about this TR (**http://www.homegridforum.org/content/pages.php?pg=news_press_releases_item&id=329**).

In addition, ISSI AMS' has developed its own test plan for G.hn: "G.hn Device Lab Testing Plan" that provides for TCP traffic testing under real world noise sources, as this traffic is crucial to service provider customer satisfaction.

While lab tests are an important component of a technical evaluation, field-testing is also important.

ISSI AMS' G.hn Prime Testing in the Field

As ISSI AMS' G.hn Prime lab and field test results with various service providers are under NDA, their results cannot be shared here; however, this section covers the latest test events in the field that can be shared.

Tests have been held with competing G.hn products versus HomePlug AV2 and for G.hn Prime versus other G.hn products and HomePlug AV/AV2. For all results, G.hn outperforms all types of HomePlug AV and AV2 with G.hn Prime the ultimate performer across all metrics.

The following sections discuss field tests that included G.hn Prime.

The Online Reporter

A ISSI AMS G.hn competitor contracted a lab to test their products versus the leading HomePlug AV2 products. The tests were both in the lab and in the field. The results were reported in "The Online Reporter" ending with this statement: "... [G.hn] won in all scenarios and in the worst case environments in both the Lab Testing and Home Field Testing. " ISSI AMS' contracted with labs to test G.hn Prime against this G.hn product and HomePlug AV2.

The Online Reporter is an independent and objective publication that strives to report accurately about activities and developments in the home networking and IPTV market. As stated on their publications: "The Very Best Coverage of Internet TV - No one else tracks OTT services, broadband, home networking and the proliferation of bandwidth-hungry UHD TVs – and their coming industry-wide impact."

The Online Reporter, based on requests from industry and others, decided to do an impartial test of PLC adapters at two homes and report on the test results. The testing was focused on throughput with caveats on connectivity and consistency of connections.

The initial intent was to test two retail products; however, the early results were skewed for various reasons and did not reflect state of the art and ISSI AMS' G.hn Prime implementation. ISSI AMS submitted the same G.hn Prime evaluation systems supplied to service providers for their testing (lab and field). These systems are FCC-compliant and with PLC power levels within the limits set by regulators. The report included ISSI AMS' G.hn Prime results in an added section. Following are several relevant quotes from the report about ISSI AMS' G.hn Prime results.

"ISSI AMS' home network engineers have developed new firmware called G.hn Prime that substantially increases the speeds of the company's G.hn chips.

We confirmed that by testing the products in the same home where some months ago we had tested G.hn adapters from Comtrend and ISSI AMS as well as HomePlug adapters from D-Link.

ISSI AMS says the new G.hn Prime firmware "provides unmatched performance" on its existing G.hn CG5300 and CG5200 series chipsets.

The chips are intended for G.hn powerline products that pay TV services, primarily the telcos, will use to provide flicker-free videos, including bandwidth intensive 4K videos, on every TV in the home and without having to send an installer into the home."

"Both the ISSI AMS and the Comtrend adapters clearly outperformed D-Link's HomePlug adapters in this test." Among The Online Reporter's conclusions:

"All three tests showed that G.hn Prime, in this residence and on the three days we tested, is faster than HomePlug."

Netperian Lab Tests

ISSI AMS contracted a well-known and respected test lab, Netperian. Their focus is on service provider content delivery in the home.

The testing with Netperian was defined that they take off-the-shelf systems from ISSI AMS' and independently test them in the field versus off-the-shelf versions of a HomePlug AV2 system from D-Link and Comtrend's non-ISSI AMS G.hn product. These are the same products tested by The Online Reporter.

ISSI AMS makes the full report available under NDA, while highlights are provided in the following sections.

Test Arrangement/Overview

ISSI AMS' contracted with the lab under the terms that no one from ISSI AMS would engage lab personnel or be present during testing. Further, that the report includes all results. The following edited excerpts are from the full report. Three system types were tested:

1. ISSI AMS' CG5200 service provider evaluation system with G.hn Prime (PLC mode: MIMO 50 MHz)
2. Comtrend PG-9172 using Marvell's G.hn chips (PLC mode: SISO 80 MHz)
3. D-Link DHP-701 AV using Broadcom's HP AV2 chips (PLC mode: MIMO 86 MHz)

Two test homes were selected for testing. Each home consists of a basement, a first floor, and a second floor. Each home's gateway and server were located in the respective basement. The electrical wiring in home #1 was aluminum except for an addition to the home, while home #2 was all copper. Each home had a main breaker panel, with the addition to home #1 having a sub-panel off the main panel.

Various noise sources were active/inactive during the testing. Noise sources included a hair dryer, a vacuum cleaner, an iPhone charger, various lights throughout each home, and appliances.

As the ISSI AMS' G.hn technology was the only one with a coexistence mode, coexistence was not tested between G.hn and HomePlug AV2. However, since the ISSI AMS' coexistence mode for HomePlug AV can be forced to be active, some tests were run to show the performance of the ISSI AMS' G.hn systems as if they were coexisting with HomePlug AV/AV2.

The results vary between the homes, between the floors in each home, when noise was present, and when the PLC

adapters were plugged into a power strip. The use of the power strip was to replicate a "real life" user scenario and to see how a PLC technology performed when one of its modems is on a power strip. There were varied results with power strips.

Issues were encountered when attempting to run tests for the HomePlug AV2 systems between the furthest connection points (basement to second floor). Netperian reran the tests repeatedly and troubleshot the wiring in an effort to determine (and clear) any factor that caused failing HP AV2 test results; however, no factor with the wiring was found that caused such a stark failure. The ISSI AMS G.hn Prime systems were reported to perform very well over the same connections.

As can be determined from studying the following figure, the ISSI AMS G.hn Prime systems without HomePlug AV/AV2 coexistence vastly outperformed all others. While in coexistence mode, the ISSI AMS' G.hn Prime systems either outperformed or matched performance of the others. This is very important for those service providers planning on a mixed environment as they migrate from a HomePlug deployment to G.hn Prime.
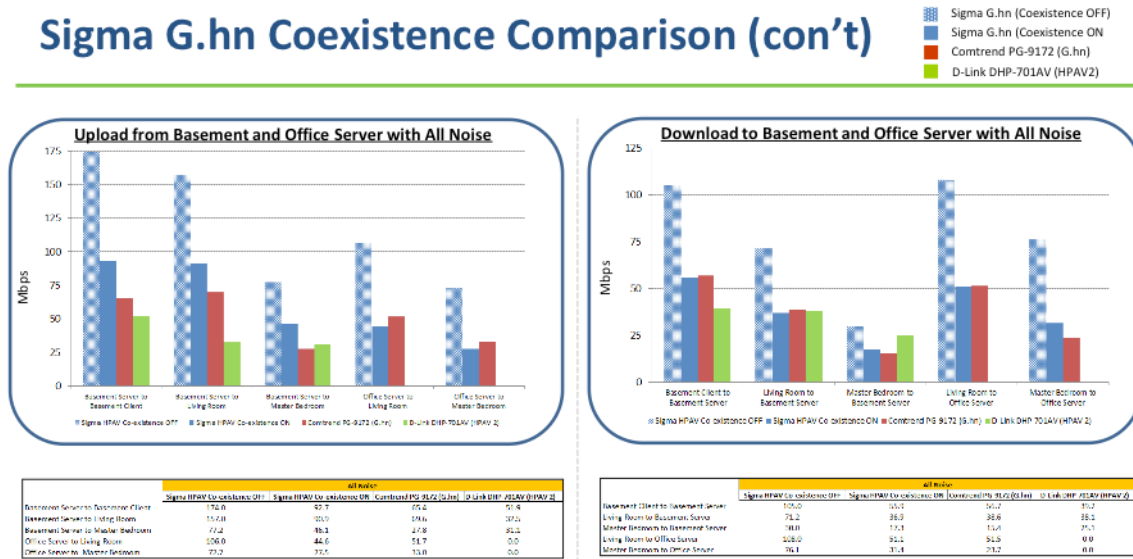

Figure 1: Tests Comparing ISSI AMS' G.hn Prime with and without Coexistence mode,
Netperian Test Report, page 11

Netperian tested point to multi-point networking to better simulate a consumer's home and reflect real world scenarios. In these tests, Netperian installed one PLC adapter at a server type system and two other adapters installed for clients (such as at PCs or IPTVs).

In test home #1 Netperian encountered two issues. The first was the unbalanced nature of traffic handling over the Comtrend non-ISSI AMS G.hn systems in a simultaneous point to multi-point test. The test lab was unable to determine a cause or resolution. The second was the failure of the D-Link HomePlug AV2 systems to establish a link (connection) when installed behind a power strip. This is a well-known PLC issue that G.hn was defined to eliminate (especially with

MIMO). Note that the ISSI AMS' G.hn Prime systems operated in coexistence mode for this test to stress their links as much as practical.
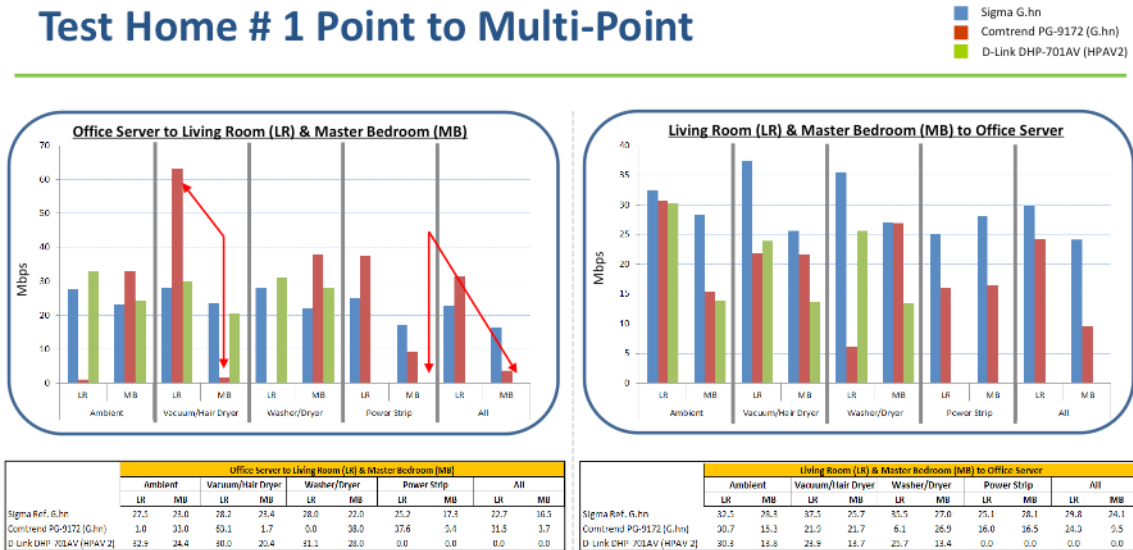

Figure 2: Point to Multi-Point Testing, Home #1, page 23, Netperian Test Report

In Summary

The Netperian testing provides a clear example of how ISSI AMS' G.hn Prime technology is the best choice for PLC in the home: where G.hn is better than HomePlug AV2 and G.hn Prime is the best G.hn.

ISSI AMS' G.hn Prime – the Right Choice

G.hn Prime uses state-of-the-art optimization algorithms and techniques to dramatically improve content delivery performance across real-world home networks, providing a significantly higher quality of experience (QoE) for the user versus any other networking option.

G.hn Prime Coexistence Capabilities

As stated above, ISSI AMS G.hn Prime includes a coexistence mode for when HomePlug AV/AV2 networks are present nearby. This is only one aspect of the coexistence built into G.hn Prime. It has the following compatibility options when installed in homes with other networking technologies. The goal: provide a well-engineered migration tool for service providers. ISSI AMS' G.hn Prime is unique in its coexistence capabilities as shown in the following table.

Technology	Powerlines	Coax	Phonelines
HomePNA	NA	G.hn Prime coexists over the same cables. See Note 2.	G.hn Prime coexists over the same cables
HomePlug AV network nearby (same home or close neighbor)	G.hn Prime shares the lines, taking turns on wire based on traffic demands. See Note 1.	NA	NA
HomePlug AV2 network nearby (same home or close neighbor)	G.hn Prime shares the lines, taking turns on wire based on traffic demands. See Note 1.	NA	NA

Table 1: Probability of cable jacks/sockets in specific rooms of US households

Notes:

1. The performance of a G.hn Prime network coexisting with a HomePlug AV network nets a total throughput over both networks that is much greater than the HomePlug AV network would achieve by adding the same number of HomePlug AV2 nodes. When HomePlug AV/AV2 networks are further away from a G.hn Prime network versus nearby, G.hn Prime ignores them and operates in maximum performance mode and the HomePlug networks ignore the G.hn Prime network. G.hn Prime automatically switches to the appropriate mode depending on its network's conditions, eliminating the need for technician or user involvement. This ensures any HomePlug network continues to operate while the G.hn Prime network provides maximum benefit.

2. G.hn Prime operating over coax can work in coexistence mode or automatically switch to HomePNA mode to interoperate with an existing HomePNA network. For service providers with existing HomePNA deployments this means:

- One SKU for both network types, by equipment type – for example, a STB that uses one coax connector for either G.hn or HomePNA
- Reduced storage, replacement parts, and tech training time
- The same collateral and other materials
- Reduced CAPEX and OPEX
- Eliminates the need for technician or user intervention
- Ease of transitioning to the latest home network technology to boost performance, yet not disrupt the existing base

Please see the HomeGrid Forum paper for service providers, **http://www.homegridforum.org/uploads/resources/ Ny7H/Zg2h.pdf** on G.hn Coax coexistence options with HomePNA.

CG5200 and CG5300 Chipsets

Key G.hn Prime Points

- Unmatched Performance: on-chip accelerators provide over twice the TCP performance of any other powerline solutions
- High noise resilience: advanced algorithms, developed after years of home network experience, ensure maximum performance and interference mitigation
- Reliable in Real Environments: whole home coverage, trouble-free connectivity, and noise-free service with unique coexistence mechanisms, tolerating surge protectors and other appliances, and operating in congested/MDU installations
- Works over power strips and behind surge suppressors when others struggle: this area is a frequent failure point for PLC. As can be seen from the Netperian lab tests, HomePlug AV2 continues to encounter substantial issues in this area, while G.hn Prime outperforms all others, delivering quality service regardless of the presence of a power strip or not
- HP AV/AV2 compatibility: automatic detection of nearby HomePlug AV/AV2 networks and switching to a ISSI AMS-

  unique "PLC coexistence mode." This enables both technologies to operate over the same powerlines, and the G.hn Prime network to continue achieving best in class performance. No changes are made to the existing HomePlug AV/AV2 network.
- Self Installable/Expandable: plug-n-play operation enables self-installation with support for a large number of devices
- Low power and footprint: new single chip implementation (CG5300) offers low power and minimal RBOM for smaller footprint and lower cost implementation
- Fully HGF Certified - full interoperability with other certified G.hn devices
- Remote Management built in: monitoring tools (including full TR-69 support) enable service providers to monitor and manage the performance of each network (and even each device)

Value Proposition

G.hn Prime utilizes on-chip acceleration engines, advanced noise mitigation algorithms, and coexistence to deliver up to twice the performance of any other PLC solutions, G.hn or not, along with seamless expandability throughout the home.

Backbone for the IoT

ISSI AMS' knows the Internet of Things in the home. In fact, ISSI AMS' Z-Wave® technology is the service provider go-to choice for home IoT connectivity throughout North America, with use growing globally. ISSI AMS understands the needs, the issues, and the choices for service providers when it comes to Smart Homes and IoT. However, the Internet of Things is not an island of connectivity, separate from the home's broadband networks. IoT depends on a strong home backbone network to fulfill its promise of ubiquitous connectivity and ease of use. The home backbone network is therefore its communication foundation and G.hn Prime is that foundation. G.hn Prime: the network other networks rely on to interconnect.

ISSI AMS' Whole Home View Delivers Added Value

The G.hn advanced technology is only one part of the strengths and value ISSI AMS products provide to service providers and their OEMs. ISSI AMS' in-depth knowledge encompasses home networks over any wire types, the needs of service providers including the need for remotely managing and troubleshooting networks to save truck rolls, and achieving exceptional customer satisfaction. ISSI AMS' is leading the evolution of home networks into a hybrid of wired and wireless Broadband and IoT devices - synergistically co-existing and cooperating.

ISSI AMS' Corporate Overview

ISSI AMS' is a leading provider of system-on-chip (SoC) solutions that enable smart home applications and convergence through:

1. Advanced content delivery and interaction systems such as Set-Top Boxes and Smart TVs
2. Media Connectivity using G.hn Prime
3. IoT Devices using Z-Wave

ISSI AMS' supports our SoC design partners' success with board-level reference designs, sophisticated system level software, complete technical documentation, and world-class engineering support; enabling partners to provide complete solutions in a variety of set-top boxes, Smart TVs, media connectivity devices, and Internet of Things (IoT) devices.

ISSI AMS' products are sold worldwide through direct sales and distributors. Headquartered in Milpitas, California, ISSI AMS' has sales and engineering offices in Greater China (the Mainland, Hong Kong, and Taiwan), Denmark, Israel, Japan, and Singapore.

References:

1. Transmission Control Protocol, a core Internet Protocol (IP) process for guaranteed and ordered packet delivery. Best for streaming high quality media content

2. User Datagram Protocol, a core IP process for connectionless, unguaranteed, and unordered packet delivery. Best for best effort Internet access and streaming standard media content

3. "Understanding the in-home CE ecosystem and its relationship to Home Networking " – The Diffusion Group, 2007

4. ISP – Inter-System Protocol. Defined in IEEE Std 1901-2010. This is an excerpt from the standard stating the ISP is mandatory: "IEEE 1901 access and in-home stations shall implement the ISP coexistence mechanism described in this standard." The term "shall" means the functionality is required (normative), no claim that a HomePlug AV/AV2 implementation is 1901 conformant can be made without ISP. Per the 2014 IEEE-SA Standards Style Manual: "The word shall indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to)."

5. International Telecommunications Union – Telecommunications Standards. The ITU is the United Nations specialized agency for information and communication technologies

6. TR-208: Performance Test Plan For In-premises Powerline Communication Systems, Issue 1, Broadband Forum, 2015. The Broadband Forum is a non-profit corporation organized to create guidelines for broadband network system development and deployment. Service providers lead the Broadband Forum in defining guidelines to assist service providers. One such widely accepted Technical Report is TR-069 and all related work.

7. The Online Reporter, Issue 954, November 6-12, 2015, pages 1, 4

8. "Home Networking Industry 2015 Report," The Online Reporter, October 2015

9. Also G.hn-based

10. Netperian Inc., http://www.netperian.com