MaxLinear

Wave-2 Coax and Phone Line Networking Evaluation

Public User Guide

Revision History

Document No.	Release Date	Change Description
057-W2CPLHNUGPR01	October 18, 2018	**Updated:** ■ New template applied. ■ Minor edits so that the document applies to home networking or industrial applications.
057-W2CPLHNPUGR00	March 29, 2018	Initial release.

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Introduction

The scope of this document is to provide a guide for evaluating MaxLinear's G.hn Wave-2 Coaxial and Phone Line solutions for home networking or industrial applications. The features described and performance data within this document are for guidance only, and they cannot be construed as any form of specification, guarantee, or contract between MaxLinear and the evaluator.

This user guide helps engineers to evaluate coaxial and phone line networking solution feature set at technical level using hardware and software tools provided in evaluation package, and to learn about the technology at the same time as checking its real world performance.

Warning! The electrical safety of this Evaluation Kit (EVK) has not been fully evaluated against the requirements of the *EN 60950-1:2006 (IEC 60950-1:2005)* standard and this EVK does not fulfill with all the relevant electrical safety requirements stated in such standard.

Before continuing read carefully the

Wave-2 G.hn Networking Technology

MaxLinear's standard International Telecommunication Union (ITU) G.hn technology enables a complete wireline transceiver for use over all existing cables: powerlines, coaxial cables, and phone lines.

The MaxLinear G.hn offering introduces the new Wave-2 Digital Baseband (DBB) processor family 88LX5152/88LX5153/88LX5153A and new Analog Front End (AFE) 88LX2720/88LX2730/88LX2740/88LX2741 chipsets, Spirit 7.x firmware, SDK/API, associated reference designs, and auxiliary software tools.

MaxLinear's G.hn technology provides exceptional performance and industry-leading features, and it is intended for triple-play service provider, industrial, and consumer applications. The new MaxLinear Wave-2 G.hn chipset provides a very compact, flexible, and cost-effective solution, which includes several interfaces such as an RGMII and SGMII.

MaxLinear's new 88LX5152/88LX5153/88LX5153A and 88LX2720/88LX2730/88LX2740/88LX2741 G.hn families support:

- PHY bit rate of up to 2Gbps over phone line and coax line.

- SISO 200 MHz profile for coaxial and 2-wire telephone lines.

- Features such as:

  - Phone and powerline Multiple Input Multiple Output (MIMO) 100 MHz profiles.

  - On-chip remote management support (TR-069).

  - Powerline Neighboring Networks Interference Mitigation (NDIM).

  - Optimized power consumption with power saving mode.
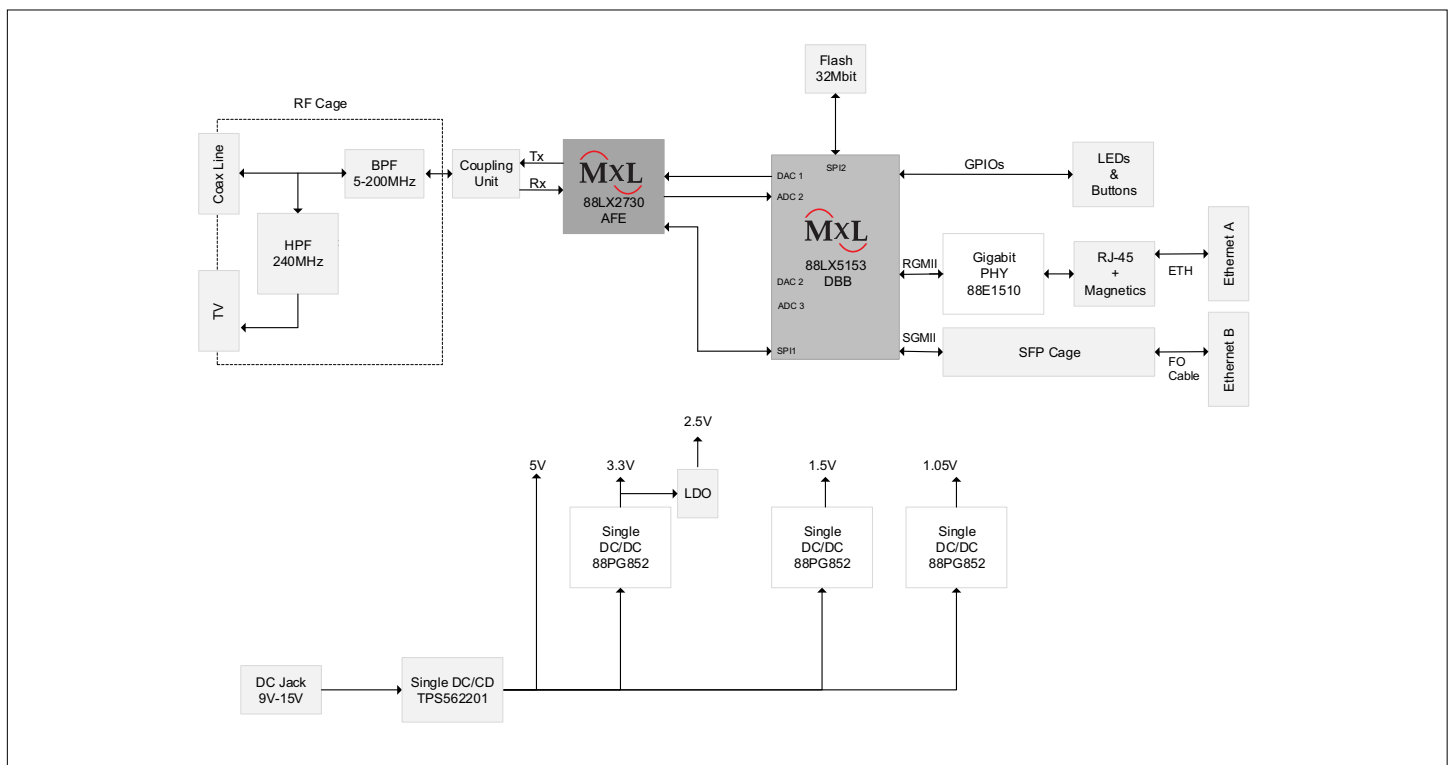
Figure 1: Wave-2 DCP962C Adapter Block Diagram
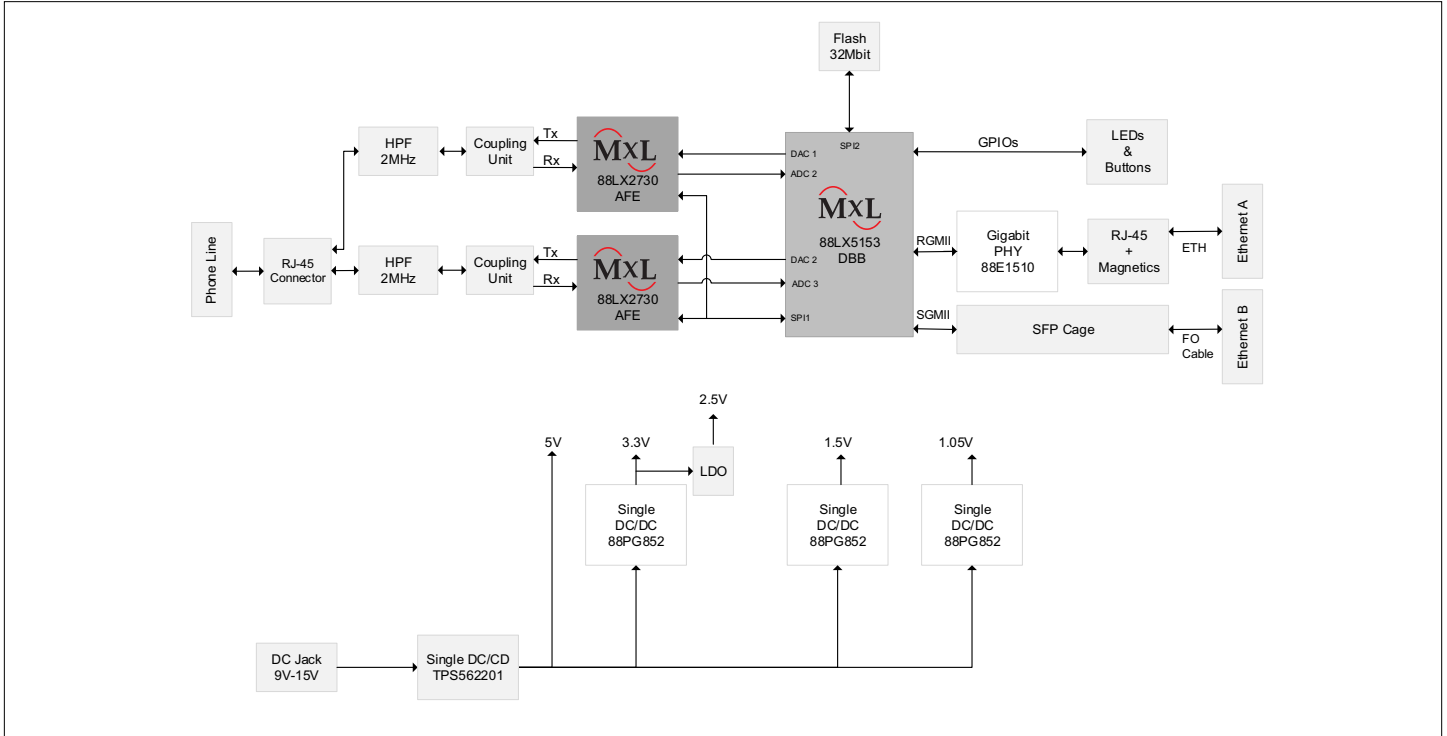
Figure 2: Wave-2 DCP962P Adapter Block Diagram

Ordering Information

To evaluate MaxLinear's G.hn Wave-2 phone line or coaxial networking technology, the following elements are required:

■ G.hn Wave-2 phone line or coaxial evaluation kit (DCP962P and DCP962Creference designs, using 88LX5153 and 88LX2730 chipset) with Spirit 7.x HN firmware loaded. Be aware that some multi-mode test cases require more than 1 kit.

■ This document: *Wave-2 Coaxial and Phone Line Networking Evaluation Public User Guide.*

■ Spirit Configuration Tool (SCT) to configure adapters during testing.

Evaluation Kits (EVKs) are available for both coaxial and phone line networking applications. The EVKs include either one or two adapters.

Table 1: Wave-2 Coaxial and Phone Line Networking Ordering Information

Part Number	Package Content
RD-HNCOAX2DCP962CKIT	Wave-2 Coax Networking Evaluation Kit with TWO (2) G.hn adapters (88LX5153 and 88LX2730 based) and accessories.
RD-HNPH2DCP962KIT-01	Wave-2 Phone Line Home Networking Evaluation Kit with TWO (2) G.hn adapters (88LX5153 & 88LX2730 based) and accessories.

Figure 3: RD-HNCOAX2DCP962CKIT

Figure 4: **RD-HNPH2DCP962KIT-01**

Figure 5: **Wave-2 DCP962C Coaxial Adapter**

Coaxial and Phone Line Adapter User Interface

The DCP962C and DCP962P reference designs provide the means for setting up a network based on either coax cabling or phone line. They incorporates one CONFIG button and four LEDs that allow the user to configure a secure G.hn network The main features provided by the DCP962C and DCP962P hardware user interface are listed below:

- Pairing (One Button Security setup, OBUS): Automatic generation of a random Domain Name and Encryption Password, used to guarantee network security, and exchanging of these parameters between adapters using a single button push as defined by HomeGrid Forum for compliance and interoperability purposes.

- Link Quality indicator: With a three-color LED, three different levels of link quality are shown in the receiver adapter.

- Manual factory reset.

- Unpairing: Return to default security settings.
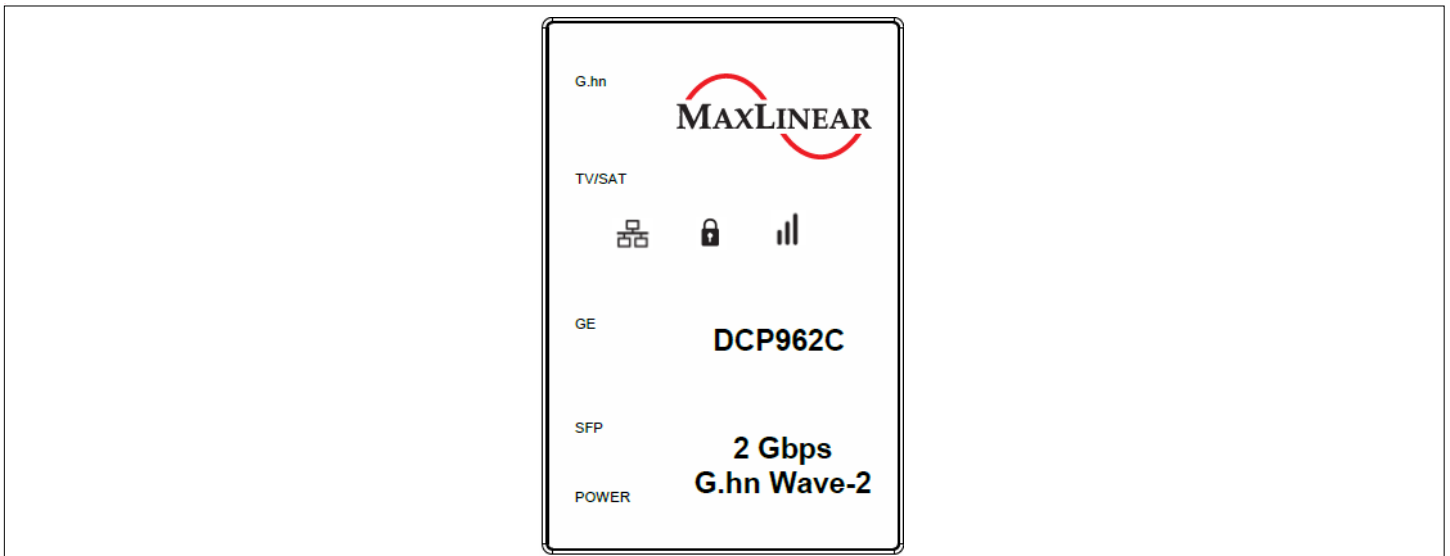
Figure 6: **Front Panel of the DCP962C Adapter**
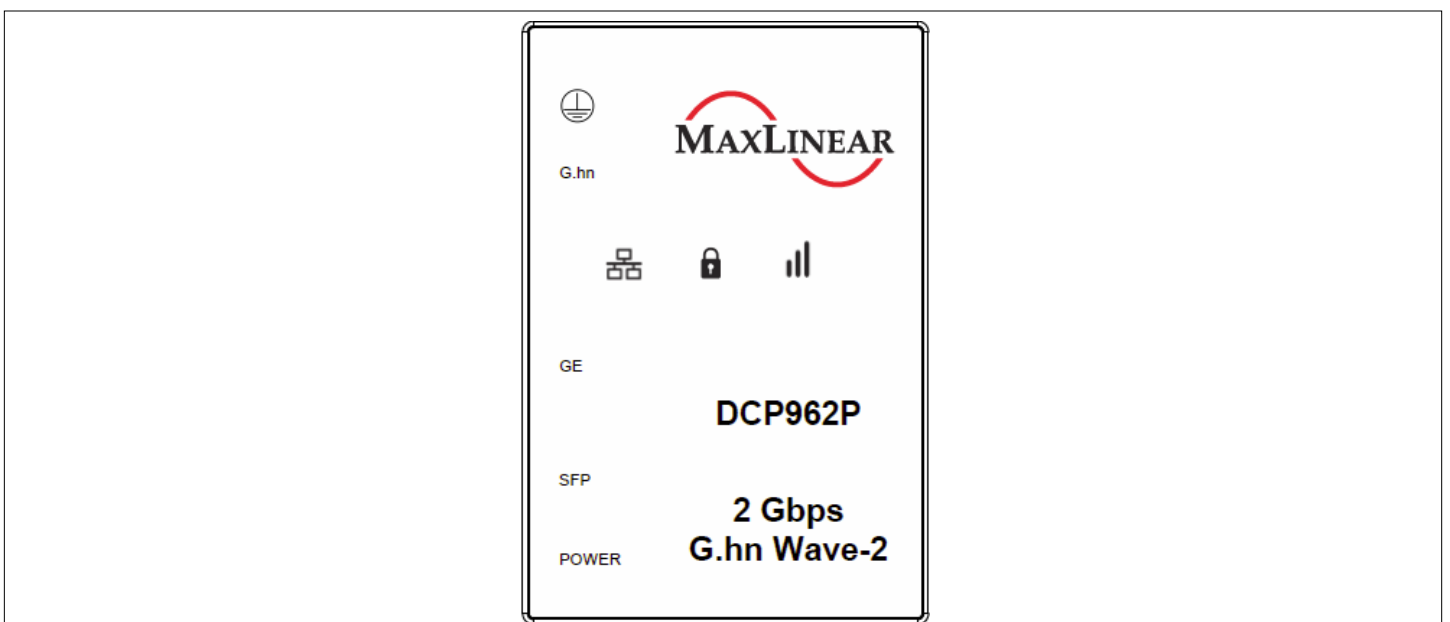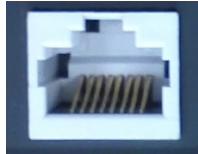
Figure 7: **Front Panel of the DCP962P Adapter**

The following table lists the features that the DCP962C and DCP962P reference designs provide on the side panel.

Table 2: **DCP962P and DCP962C Connectors and Button**

Definition	Icon	Function
CONFIG button		Used to implement the following tasks: ■ Pairing ■ Return to default security settings ■ Factory Reset
POWER		Power connector for power supply provided in the EVK
ETHERNET		RJ-45 connector for Ethernet C-5E UTP cable provided in the EVK (RGMII of 88LX5153).
SFP		SFP cage provided in the EVK (SGMII of 88LX5153).
COAX		Coax F-type connector for coax cable provided in the Coaxial EVK.
EARTH		Earth connection.
PHONE LINE		RJ-45 connector for supporting MIMO and SISO Phone with TIA-568A pins mapping.

The following table lists the function and behavior of the LEDs (available on the front panel) and the CONFIG button (available on the side panel).

Table 3: **DCP962C and DCP962P Connectors and Button**

Definition	Icon	Function
"CONFIG" button[1]		Used to implement the following tasks: ■ One Button Security Setup (Pairing). ■ Return to default security settings (Unpairing). ■ Factory Reset.
Link Quality[1]		Three-color LED indicating the application throughput level available in the G.hn link (*throughput indicator*) and the power saving mode.
Ethernet[1]		LED indicates the link and traffic through Ethernet port..
Secure[1]		LED indicating whether the device has received/generated the network key (it belongs to a single secure domain) or not.

1. See Figure 4 on page 5.

Table 4: **Link Quality Indicator Description**

Color	Adapter Status	Meaning
Off	ON	No G.hn link.
Red	ON	G.hn link is present and estimated application throughput < 20 Mbps (configurable value).
Orange	ON	G.hn link is present and 20 Mbps (configurable) < estimated application throughput < 40 Mbps (configurable).
Green	ON	G.hn link is present and estimated application throughput > 40 Mbps (configurable).
Blinking (red, orange, or green)	ON	Tx/Rx activity in the G.hn port.
Blinking in red every 5s	POWER SAVING	When the adapter enters in power saving, this LED blinks once every 5s.

Table 5: **Secure Indicator Description**

"Secure" LED State	Meaning
Off	Device is not secure, it has neither received nor generated network keys (domain name and encryption password).
On	Device is secure (it has either received or generated network keys).
Slow blinking	Device is in configuration mode (able to exchange network keys).
Quick blinking	Device is in *return to default security settings mode* (unpairing).
Three flashes	Device has received key from other secure device, and it has finished its configuration.

Table 6: **CONFIG Button**

Button	Meaning
CONFIG	■ Press more than 2s (*Secure* indicator starts slow blinking) and release: The pairing procedure is started and configuration period is open. ■ Press more than 5s (*Secure* indicator starts quick blinking) and release: Security settings are set to default values. ■ Press more than 10s (*Secure* indicator switches off) and release: A factory reset is performed.

Coaxial and Phone Line Network Setup

Pairing

All MaxLinear G.hn adapters have the same not unique domain name and AES encryption password by default. As a result, when they are plugged into the physical medium (PLC, coax, or phone line), a new network is created which operates smoothly, but without a secure unique configuration.

Any nearby G.hn adapter (wanted or unwanted) with same common domain name and AES encryption password connected to the same electrical grid becomes part of this G.hn network. MaxLinear recommends to configure a private G.hn network (with a unique domain name and AES encryption password) to guarantee the security of every user's network.

Configuring a Secure Coaxial and Phone Line Network

Main steps of the pairing mechanism are listed below.

- STEP 1

    - Press CONFIG button for 2s (until *Secure* LED starts slow blinking) to open a configuration period for 120s.

    - If a device does not detect any other device within the configuration period, it generates a random network parameter key (domain name and encryption password) and *Secure* indicator remains ON.

- STEP 2

    - Press CONFIG button for 2s (until *Secure* LED starts slow blinking) in an already secure device and in another unsecured device to open both configuration periods.

- STEP 3

    - Secure device sends the keys to the new device (configuration process is successful when its *Secure* indicator flashes three times for 0.5s) and both belong to same secure and unique domain.

    - At this point both devices can communicate data, *Secure* LED remains ON in both adapters and their *Link Quality* indicators show link quality between them.

    Note: Any secure device (*Secure* indicator ON) can admit and exchange keys with an incoming unsecured device.

Return to Default Pairing Settings Procedure

The Return to Default Pairing Settings procedure forces a G.hn adapter to return to its default security settings. This procedure only resets the following parameters (domain name and AES encryption password) and does not affect other parameters such as (IP configuration, G.hn profile, notches, etc.).

Perform the following steps to do it:

1. Press "CONFIG" button for more than 5s (*Secure* indicator should start slow blinking and after 5s starts quick blinking). Release the button.

2. At this time, the adapter resets its running security configuration to the default settings (unpaired).

Factory Reset Procedure

The Factory Reset procedure forces a G.hn adapter to return to its factory security settings. This procedure resets all parameters stored in flash memory, including (IP configuration, G.hn profile, security settings, notches, log file, QoS, Ethernet powers saving, etc).

Perform the following steps to do it.

1. Press *CONFIG* button (*Secure* indicator should start slow blinking and after 5s quick blinking) and DO NOT release it until the *Secure* indicator switches OFF (it takes around 10s). Release the button.

2. After a few seconds the *Link Quality* indicator is also OFF.

3. At this time, the adapter resets its running configuration to factory default settings and auto-reboots

Laboratory Evaluation and Tests

The following evaluation tests apply for both coax and phone line G.hn profiles. The test descriptions and results use a coax G.hn profile as a reference.

Evaluation Software Tool

The SCT is a Java software tool to help evaluators during their testing of G.hn adapters.

SCT enables reading and writing main configuration settings of MaxLinear G.hn adapters belonging to same logical network and it is used for most of the evaluation tests introduced in this section.

For more information about installation and use of SCT refer to document *Spirit Configuration Tool (SCT) Public User Guide (052-SCTPUG).*

Network Performance Test

Test 1: Performance in Coax "Home in a Box"

This test focuses on network performance. The evaluator can measure the variation of Ethernet, UDP throughput, and TCP throughput of a pair of G.hn nodes, depending on the coax outlet of the "Home In a Box" they are connected to.

The "Home In a Box" is a test bench that emulates typical channel responses and attenuations of coax installations within a home, using splitters and coax cables of different lengths as shown in the following figure.
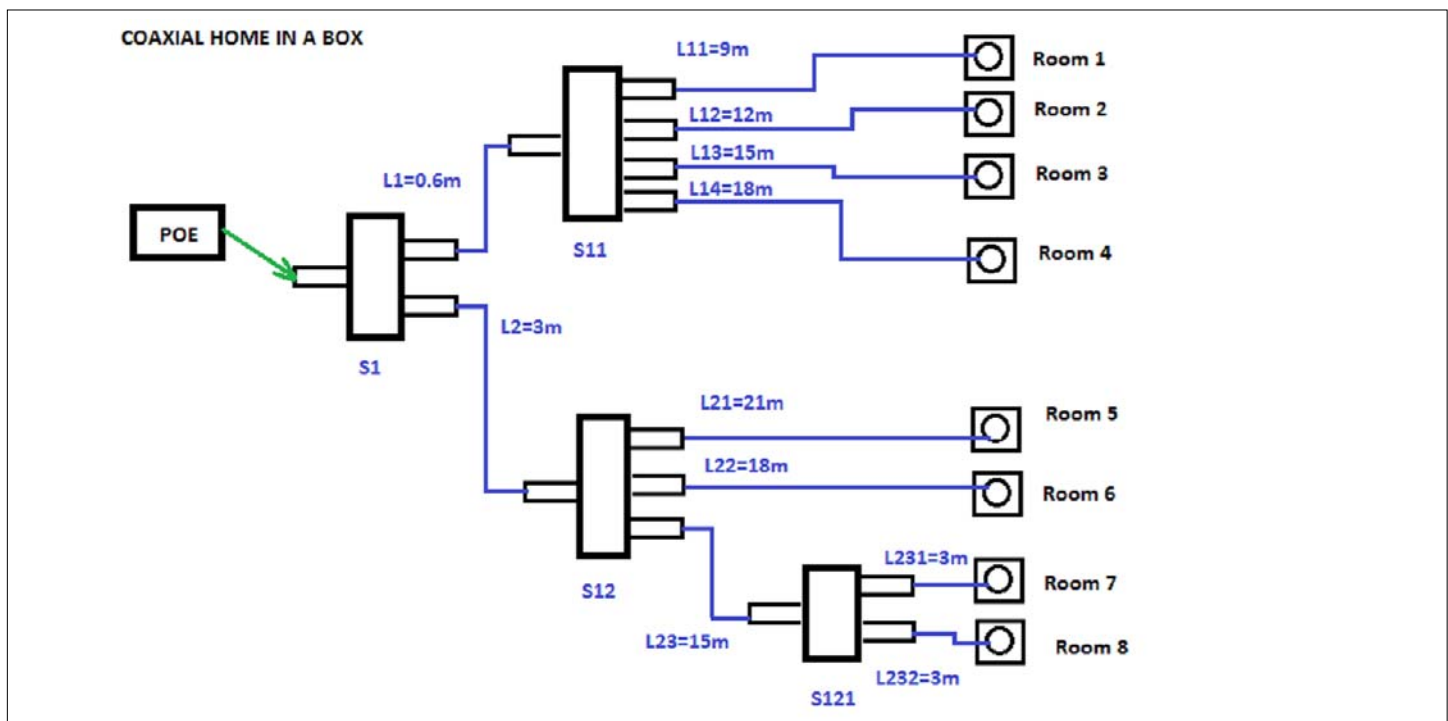
Figure 8: **Coax "Home In A Box" Test Bench**

It provides nine coax outlets:

■ One referred to as Point Of Entry (POE). It is the coax input into the house.

■ Eight coax outlets simulating each of the eight rooms.

Test Equipment

■ 2 × MaxLinear DCP962C adapters

■ A dedicated network performance analysis system such as Ixia

■ Alternatively, two PCs with either of the following software options can be used:

   ▪ Iperf 2.0.5 software (a public domain freeware application), but the specific hardware and OS could limit the results. For example, a Windows PC usually limits Iperf UDP performance as client, so Linux (or Mac OS) is recommended for UDP performance tests, if possible.

   ▪ The software is available from https://iperf.fr.

   ▪ PCATTCP software (a public domain freeware application), which can be used on Linux, Mac OS, and Windows PCs for both TCP and UDP measurements.

   ▪ The software is available from http://www.pcausa.com/Utilities/pcattcp.htm.

■ SCT

■ "Home In a Box" setup as shown in Figure on page 11

■ 1 × F-type 100m coax cable

■ 2 × F-type 25cm coax cables

Test Methodology

To perform this test:

1. Select the G.hn COAX-200 MHz profile to be tested in the G.hn adapters using the SCT.

2. Select a couple of coax outlets (it could be between rooms or from POE to a room).

3. Run the corresponding Ixia tests that measure TCP throughput, UDP throughput, latency, frame loss, and jitter.

4. Alternatively, run Iperf as follows:

   a. Perform a bidirectional TCP throughput test by typing the following in console window:

      ▪ Server side (PC 1): `iperf –s –w 32K`

      ▪ Client side (PC 2): `iperf –c [Server IP] –w 32K –i 1 –t 60 –P 32 –d`

   b. Perform a Bidirectional UDP throughput test by typing the following:

      ▪ Server side (PC 1): `iperf –s –i 1 –u –w 512K`

      ▪ Client side (PC 2): iperf -c [Server IP] -i 1 -u -w 512K -t 60 -b X -d

      where X is the injected bandwidth (in bps) for the application.
      The value for X should be selected such that the loss% is close to 0, for example, X = 850M.

5. Alternatively, run PCATTCP as follows:

   a. Perform a TCP throughput test by typing the following in a console window:

      ▪ Server side (PC 1): `PCATTCP.exe –r –c –f m –b 512000`

      ▪ Client side (PC 2): `PCATTCP.exe –t –f m –u –n 300000 <server IP>`

    b. Perform a UDP throughput test by typing:

- Server side (PC 1): `PCATTCP.exe -r -c -f m -u`
- Client side (PC 2): `PCATTCP.exe -t -f m -u -n 300000 <server IP>`

6. Optional: Write down the physical Tx and Rx throughput that you obtain using the SCT.

7. Repeat steps 3 to 6 choosing a different combination of coax outlets.

8. To evaluate an MDU coax scenario, add a 100m coax cable at POE, and connect one DCP962C device to the cable input and the second DCP962C to a room outlet (for example, R8).

9. Repeat steps 3 to 6.

10. Write down the results in a table similar to the following table.

Table 7: Test Results Iperf Bidirectional Coax 200 MHz in "Home In a Box"

Coax Outlets Pair	TCP (Mbps)	UDP (Mbps)
R4 – R8	1371	1552.844
R6 – R8	1354	1542.085
POE – R8	1438	1639.187
100m coax cable connected to POE – R8	1424	1585.232

Test 2: Dynamic Range Measurement in Flat Channel

This test concentrates on network performance. The evaluator can measure the variation of the following variables as a function of attenuation.

- Physical throughput
- TCP throughput
- UDP throughput

Test Equipment

- 2 × MaxLinear DCP962Cadapters(or 2 × MaxLinear DCP962P adapters)
- A dedicated network performance analysis system such as Ixia or Spirent's Smartbits
- Alternatively, use two PCs with one of the following software options:
  - Chariot SW from Ixia.
  - Iperf software (a public domain application that can be downloaded for free), but the specific hardware and operating system could place a limitation on the results. I.e., Windows PC usually limits iperf UDP performance as client, so Linux (or Mac OS)is recommended for UDP performance tests when possible.
    - PCATTCP software (a public domain application that can be downloaded for free) which can be used on Linux and Windows PCs for both TCP and UDP measurements. It is available at http://www.pcausa.com/Utilities/pcattcp.htm.
- SCT
- Combined 75Ω F-fixed attenuators (or phone attenuators)1 × F-type coax cable (or phone cable)

Test Methodology

To perform this test, follow the steps below.

1. Select the G.hn COAX-200 MHz and configure it by using SCT.
2. Set an attenuation of 0 dB between the adapters.
3. Run the corresponding Ixia tests that measure TCP throughput, UDP throughput, latency, frame lost, and jitter.
4. Alternatively, run Iperf as follows below.
   a. Perform a TCP throughput test typing the following in a console window:
      - Server side (PC1): `iperf –s –w 32K`
      - Client side (PC2):`iperf –c [Server IP] –w 32K –i 1 –t 60 –P 32-d`
   b. Perform a UDP throughput by typing:
      - Server side (PC1): `iperf -s –i 1 –u –w 512K`
      - Client side (PC2): `iperf -c [Server IP] -i 1 –u –w 512K -t 60 -b X-d`

      where X is the injected bandwidth (in bps) for the application. Select an X value around 850M.
5. Alternatively, run PCATTCP as follows:
   a. Perform a TCP throughput test typing the following commands in a console window:
      - Server side (PC1): `PCATTCP.exe –r –c -f m –b 512000`
      - Client side (PC2): `PCATTCP.exe -t -f m –u –n 300000 <server IP>`

    b. Perform a UDP throughput test by typing:

- Server side (PC1): `PCATTCP.exe -r -c -f m -u`

- Client side (PC2): `PCATTCP.exe -t -f m -u -n 300000 <server IP>`

6. Optional: Write down the transmission and reception physical throughput obtained using SCT.

7. Repeat steps 3 to 6 increasing the attenuation value by 5 dB until achieved throughput is near to 0.

8. Write down the results in a table similar to following table.

> **Note:** The following results were obtained using Spirit 7.6 HN GA version (SPIRIT.v7_6_r548+8) loaded.

Table 8: Iperf UDP Bidirectional Coax and Phone 200 MHz in Flat Channel

Attenuation	Mbps DCP962P (Phone)	Mbps DCP962C (Coax)
0 dB	1497	1643
5 dB	1496	1637
10 dB	1495	1619
15 dB	1498	1618
20 dB	1497	1631
25 dB	1496	1635
30 dB	1497	1623
35 dB	1492	1583
40 dB	1179	1500
45 dB	1147	1374
50 dB	957	1169
55 dB	728	928
60 dB	541	704
65 dB	541	507
70 dB	347	313
75 dB	152	129
80 dB	7	14

> **Note:** Channels with flat attenuation do not occur in the field. This test has been done only to get a dynamic range of solutions, but does not consider low pass effects with the frequency of real cables, which means higher attenuation in higher frequencies. Therefore, for benchmarking baseband versus RF coaxial technologies, either "Home In a Box", direct long coax cables, or real coax/phone installations should be used for true comparison.

Test 3: Performance with Direct Coax Cables

This test focuses on network performance. The evaluator can measure the variation of Ethernet, UDP throughput, and TCP throughput of a pair of G.hn nodes, depending on length and type of the coax (or phone) cable they are connected to.

Test Equipment

- 2 × MaxLinear DCP962C adapters

- A dedicated network performance analysis system such as Ixia

- Alternatively, two PCs with either of the following software options can be used:

  - Iperf 2.0. 5 software (a public domain freeware application), but the specific hardware and OS could limit the results. For example, a Windows PC usually limits Iperf UDP performance as client, so Linux (or Mac OS) is recommended for UDP performance tests, if possible.

  - The software is available from https://iperf.fr.

  - PCATTCP software (a public domain freeware application), which can be used on Linux, Mac OS and Windows PCs for both TCP and UDP measurements. The software is available from

  - http://www.pcausa.com/Utilities/pcattcp.htm.

- SCT

- Different coax (or phone) length cables (100m, 200m, 300m, etc.)

Test Methodology

To perform this test:

1. Select the G.hn COAX-200 MHz profile to be tested in the G.hn adapters using the SCT.

2. Connect each G.hn node to one input of a coax cable (for example, RG-59 100m or RG-6 300m)

3. Run the corresponding Ixia tests that measure TCP throughput, UDP throughput, latency, frame loss, and jitter.

4. Alternatively, run Iperf as follows:

    a. Perform a bidirectional TCP throughput test by typing the following in console window:

    - Server side (PC 1): `iperf -s -w 32K`

    - Client side (PC 2): `iperf -c [Server IP] -w 32K -i 1 -t 60 -P 32 -d`

    b. Perform a Bidirectional UDP throughput test by typing the following:

    - Server side (PC 1): `iperf -s -i 1 -u -w 512K`

    - Client side (PC 2): `iperf -c [Server IP] -i 1 -u -w 512K -t 60 -b X -d`

    where X is the injected bandwidth (in bps) for the application.
    The value for X should be selected such that the loss % is close to 0, for example, X = 850M.

5. Alternatively, run PCATTCP as follows:

    a. Perform a TCP throughput test by typing the following in a console window:

    - Server side (PC 1): `PCATTCP.exe -r -c -f m -b 512000`

    - Client side (PC 2): `PCATTCP.exe -t -f m -u -n 300000 <server IP>`

    b. Perform a UDP throughput test by typing:

    - Server side (PC 1): `PCATTCP.exe -r -c -f m -u`

    - Client side (PC 2): `PCATTCP.exe -t -f m -u -n 300000 <server IP>`

6. Optional: Write down the physical Tx and Rx throughput that you obtain using the SCT.

7. Repeat steps 3 to 6 choosing different cables (length and type).

8. Write down the results in a table similar to the following table.

Table 9: Test Results Iperf Bidirectional Coax 200 MHz with Different Type of Coax Cables

Coax Cable	PHY Rate (Mbps)	TCP (Mbps)	UDP (Mbps)
100m RG-59	1864	1469	1625
300m RG-6	1854	1440	1612

Test 4: RFC 2544 Throughput/Latency Test

The *RFC 2544* methodology, established by the Internet Engineering Task Force (IETF), is the de-facto methodology that outlines the tests required to measure and prove performance criteria for carrier Ethernet networks. The standard provides an out-of-service benchmarking methodology to evaluate the performance of network devices using throughput, frame loss, and latency tests.

The methodology defines the frame size, test duration, and number of test iterations. Once completed, these tests provide performance metrics of the Ethernet network under test.

To ensure that an Ethernet network is capable of supporting a variety of services (such as VoIP or video), the RFC 2544 test suite supports seven pre-defined frame sizes (64, 128, 256, 512, 1024, 1280, and 1518 bytes) to simulate various traffic conditions. Small frame sizes increase the number of frames transmitted, thereby stressing the network device as it must switch a large number of frames.

The test starts by sending frames at the specified rate (usually the maximum theoretical rate of the port), while the frame loss is monitored. Frames are sent from and received at all the ports on the device under test, and the Tx and Rx rates are recorded. A binary, step, or combo search algorithm is used to identify the maximum rate at which no frame loss is experienced.

The latency test determines the latency of the device under test. In the latency test, frames are transmitted for a fixed duration. Rx ports compute the latency values for every frame in the test by comparing the Tx timestamp with the Rx timestamp. The difference between the two timestamps is the latency. This quick test provides the statistical results: Average latency, minimum latency, and maximum latency.

Test Equipment

- 2 × MaxLinear DCP962C adapters (or 2 × MaxLinear DCP962P adapters)
- A dedicated network performance analysis system such as Ixia or Spirent's Smartbits
- SCT
- 20 dB F-type coax attenuators
- 1 × F-type coax cables

See below for test setup diagram.

Test Methodology

To perform this test:

1. Set a fixed attenuation of 20 dB between the G.hn modems.

2. Select the G.hn COAX-200 MHz profile to be tested in the G.hn adapters using the SCT.

3. Run the RFC 2544 throughput/latency unidirectional test in Ixia IxNetwork (it takes several hours to be completed).

4. Write down the final results in a table similar to the example shown in the following tables.

5. Repeat test with 2 DCP962P and 20 dB attenuation.

Table 10: **RFC 2544 PLR 0% Bidirectional Test Results for 20 dB Attenuation–Coax 200 MHz**

Frame Size (Bytes)	Passed Rate (Mbps) for PLR 0%	Min Latency (µs)	Max Latency (µs)
64	1275.986	110.24	12747.78
128	1599.833	111.80	8308.76
256	1669.322	116.56	12333.80
512	1684.073	120.10	10573.86
1024	1716.319	120.54	12421.14
1280	1722.873	132.90	12317.32
1500	1726.99	132.78	12602.18

Table 11: **RFC 2544 PLR 0% Bidirectional Test Results for 20 dB Attenuation–Phone 200 MHz**

Frame Size (Bytes)	Passed Rate (Mbps) for PLR 0%	Min Latency (µs)	Max Latency (µs)
64	1294.99	184.40	11605.78
128	1448.381	180.46	12511.46
256	1483.868	177.30	13661.90
512	1515.598	184.82	12369.54
1024	1544.607	201.08	13156.90
1280	1550.473	197.28	12080.20
1500	1529.663	215.90	12373.94

Power Mask and Notches Test

This test intends to check the frequency notching feature. With this test check the effects on the injected signal when the notches are added or removed and how to use **Power Mask** and **Notches** options in SCT.

Test Equipment

- 1 × MaxLinear DCP962C adapter (or DCP962P adapter)
- SCT

The following figure shows a test setup diagram using mentioned test equipment.

Test Methodology

To perform this test, follow the steps below.

1. Launch the SCT.
2. Discover the G.hn network.
3. Choose G.hn COAX-200 MHz or PHONE 200 MHz profile to be tested and configure it by using SCT.
4. Go to **Notches** tab of the G.hn adapter. Refresh measurement.
5. See default notches defined by G.hn enabled in selected profile band.
6. In the SCT, select **Notches Menu > Network > Configure Notches** tab to add or remove some USER notches. You can select up to 10 user notches starting from 1-10).
7. Refresh the **Notches** tab and notice new notches appearing in graph.

Leave only default notches profile removing extra notches before continuing with next tests.

Point-to-Multipoint Traffic Test in Coax "Home In A Box'

This test focuses on network performance in point-to-multipoint scenarios. The variation of the following variables is measured in a coax "Home In A Box" with four G.hn adapters in different rooms (see Figure on page 11):

- Physical throughput
- TCP throughput
- UDP throughput
- Latency
- Jitter
- Frame loss
- Test Equipment
- 4 × MaxLinear DCP962C adapters
- A dedicated network performance analysis system such as Ixia IxNetworks or Spirent's Smartbits.
- Alternatively, four PCs with Iperf 2.0.x can be used.
- 1 GbE switch (if using PCs)
- SCT
- Combined fixed attenuators
- 4 × F-type coax cable
- "Home in a Box"

Test Methodology

To perform this test:

1. Connect four DCP962C to coax outlets in different rooms.

2. Run the corresponding Ixia IxNetworks tests (RFC 2889) that measure UDP throughput, latency, frame loss, and jitter.

3. Alternatively, run Iperf as follows: G.hn D → G.hn A, G.hn C → G.hn A, and G.hn B → G.hn A, that is, PC 2 to PC 1, PC 3 to PC 1, and PC 4 to PC 1.

   a. Perform a TCP throughput test by typing the following in a console window:

   - Server side (PC 1):
     ```
     iperf -s -w 512K -p <port1>
     iperf -s -w 512K -p <port2>
     iperf -s -w 512K -p <port3>
     ```
   - Client side (PC 2, PC 3, PC 4):
     ```
     iperf -c [Server IP] -w 512K -i 1 -t 60 -P 5 -p <port1, 2, or 3>
     ```

   b. To test UDP throughput and jitter, type the following:

- Server side (PC 1):
  ```
  iperf –s -i 1 –u -w 512K –p <port1>
  iperf –s -i 1 –u -w 512K –p <port2>
  iperf –s -i 1 –u -w 512K –p <port3>
  ```

- Client side (PC 2, PC 3, PC 4):
  ```
  iperf -c [Server IP] –i 1 –u -w 512K -t 60 -b X –p <port1, 2, or 3>
  ```

  where X is the injected bandwidth (in bps) for the application.
  The value for X should be selected such that the loss % isclose to 0, for example, X = 600M.

4. Repeat steps 1 to 2 for the different room coax outlets.

Table 12: Results RFC 2889 Test PLR 0% Bidirectional for "Home In A Box" R1-R3-R5-R7 Outlets (POE Left Open)–Coax 200 MHz

Frame Length	UDP Throughput Aggregated (Mbps)	Average Delay Variation (µs)	Maximum Latency (µs)	Frame Loss
74	1268.366	10.228	21209	0
128	1340.406	15.949	20182	0
256	1437.511	29.727	22840	0
512	1491.504	57.238	30084	0
1024	1498.632	113.850	24641	0
1280	1418.327	151.020	18300	0
1518	1508.027	167.304	26681	0

Table 13: Results RFC 2889 Test PLR 0% Bidirectional for "Home In A Box" POE-R1-R5-R7 Outlets–Coax 200 MHz

Frame Length	UDP Throughput Aggregated (Mbps)	Average Delay Variation (µs)	Maximum Latency (µs)	Frame Loss
74	1031.644	12.993	28212	0
128	1083.499	20.227	27059	0
256	1161.908	37.628	27661	0
512	1205.832	72.383	36032	0
1024	1227.437	141.415	41181	0
1280	1233.586	175.637	34100	0
1518	1256.382	204.311	45331	0

Table 14: Results for Point to Three End Points Max UDP Bidirectional Throughput–Coax 200 MHz

Coax Outlets	UDP Throughput Aggregated (Mbps)
R1 – R3 – R5 – R7	1583
POE – R1 – R5 – R7	1405

Point-to-Multipoint Traffic Test in Flat Channels

This test concentrates on network performance in point to multipoint scenarios. As such, the variation of the following variables is measured as a function of attenuation for networks with three (or more) G.hn devices.

- Physical throughput
- TCP throughput
- UDP throughput
- Latency
- Jitter
- Frame Lost

Test Equipment

- ≥ 3 × MaxLinear DCP962C adapters
- A dedicated network performance analysis system such as Ixia or Spirent's Smartbits.
- Alternatively, use three PCs with Chariot or Iperf software.
- SCT
- Combined fixed attenuators
- 3 × F-type coax cables
- 1 × F-type T-junction or F-type splitter

Test Methodology

To perform this test:

1. Set all attenuators to 20 dB between the modems.

2. Write down the physical Tx and Rx throughput that you obtain using the SCT.

3. Run the corresponding Ixia IxNetworks tests (RFC 2889) that measure Bidirectional UDP throughput, latency, frame loss, and jitter for 1518 bytes packet length.

4. Alternatively, run Iperf as follows: G.hn C → G.hn A and G.hn B → G.hn A, that is, PC 2 to PC 1 and PC 3 to PC 1.

   a. Perform a TCP throughput test by typing the following in a console window:

      - Server side (PC 1):
        ```
        iperf –s -w 512K –p <port1> and iperf -s -w 512K –p <port2>
        ```
      - Client side (PC 2, PC 3):
        ```
        iperf –c [Server IP] -w 512K –i 1 –t 60 –d –p <port1 or 2>
        ```

   b. To test UDP throughput and jitter type the following:

      - Server side (PC 1):
        ```
        iperf –s –i 1 –u –w 512K –p <port1>
        iperf –s –i 1 –u –w 512K –p <port2>
        ```
      - Client side (PC 2, PC 3):

        ```
        iperf –c [Server IP] –i 1 –u –w 512K –t 60 –d –b X –p <port1 or 2>
        ```
        where X is the injected bandwidth (in bps) for the application.
        The value for X should be selected such that the loss% is close to 0, for example, X = 850M.

5. Repeat steps 1 to 3 for different attenuations in node generating traffic flows (for instance, set Att1=Att2=Att3=40 dB).

Table 15: Results for Point to Two End Points Bidirectional Test PLR 0% (RFC 2889)–Coax 200 MHz

Attenuation	UDP Throughput Aggregated (Mbps)	Average Delay Variation (µs)	Maximum Latency (µs)	Frame Loss
20 dB	1461.93	49.52	8900.82	0
40 dB	1253.75	61.92	12782.06	0
60 dB	483.44	178.47	15397.78	0

Table 16: Results for Point to Two End Points Bidirectional Iperf Throughput – Coax 200 MHz

Attenuation	Physical Throughput (Mbps)	TCP Throughput Aggregated (Mbps)
20 dB	1935	1473
40 dB	1639	1272
60 dB	460	372.7

Note: Channels with flat attenuation do not occur in the field. This test has been done only to get a dynamic range of solutions, but does not consider low pass effects with the frequency of real cables, which means higher attenuation in higher frequencies. Therefore, for benchmarking baseband versus RF coaxial technologies, either "Home In a Box", direct long coax cables, or real coax installations should be used for true comparison.

Field Evaluation and Tests

Field evaluation is the process of testing a G.hn technology in a real world environment. The main differences between evaluating G.hn in the field and in the laboratory are listed below.

- The field environment is more difficult to control than the lab environment.

- The results of a particular field test may be more difficult to reproduce than those of a lab test.

- The signal environment in a field test is dynamic and the characteristics of the communication channel change along the time.

- The field test environment can have a wide variety of interfering devices, which might affect the performance of equipment.

- The field environment has attenuation profiles depending on the frequency.

The results achieved in a field environment could be affected by a wide range of variables; the key elements are listed below.

- The size of the home where the tests are being performed.

- The way in which electricity is distributed: a single phase in all outlets or whether there are multiple phases going to different outlets in the home.

- Ground presence in the house.

- The electrical layout of the home in terms of the locations of electrical distribution.

- The age of the home and the type of electrical cabling used.

- The range of interfering devices connected to the electrical network.

Planning a Field Test Campaign

Despite the fact that the field environment is far more variable than the laboratory environment, it is possible to improve the quality of the test campaign by following an appropriate procedure.

The suggested steps to be performed when executing a field test campaign are listed below.

1. Determine the size of the testing campaign, resources and equipment required.

2. Determine the types of homes which is used in the campaign.

3. Select the tests to be performed.

4. Select G.hn profiles to be tested

5. Select the power points in each home to be tested (typical outlet where an IPTV service would be installed, for instance near the TV, in the home office, etc.).

6. Collect results.

7. Collate and present results.

Determining the Size of the Testing Campaign

Correct dimensioning of the test campaign beforehand is greatly help in ensuring the correct planning of the process. A field test in a single home usually takes a few hours performing typical throughput tests and depending on the number of chosen outlet combinations.

To get a more complete view of the capabilities of the technologies, the results of several homes can be compiled. Increasing the sample size can improve the statistical confidence in results.

The basic equipment required to undertake the campaign is listed below.

- Two G.hn adapters (DCP962C or DCP962P adapters)
- Laptop PCs, enough powerful to support throughputs close to 1Gbps in TCP and UDP, more than 1.5Gbps bidirectional.
- Testing software (iperf, Chariot or similar).

In case of ISP operators it is also recommended to use real IPTV service in the evaluation interconnecting home gateway and STBs through adapters as they are used in real deployments.

Determine the Types of Homes

Home types vary greatly according to geographical area, demographic groups and a wide range of other factors. The home-wide performance of powerline products is therefore a function of all of these variables. When selecting homes for a field trial campaign it is important that the homes selected are representative for the target market to use the technology. For example, the homes selected for a product targeted at IPTV for the Asian market is radically different from those chosen for a high-end home networking product for the US market.

To summarize, homes should be selected to provide a representative sample of the following variables for the chosen application, market, and geographical area.

- Floor area
- Construction type (single tenant unit or apartment building)
- Number of floors
- Age
- Electrical layout (three phases or single phase) and ground presence
- Selected outlets description
- Rooms in the house

Selecting the Tests to Be Performed

Depending on the target application, and the resources available, any of the tests mentioned in the previous sections can be done in the field environment in a similar way. Typically, TCP and/or UDP throughput, latency, jitter and frame lost measurements are some examples commonly chosen, as well as testing real services with which the technology are used (for instance, IPTV service, HD streaming from video server to video player,…).

Note: A very important point in case of performing benchmarking of different technologies is to do a test in one location for each technology almost at the same moment to avoid that the evolution of the communication channel along time affect the results. For example, execute test X for technology A in a outlet combination and after it finishes execute same test X for technology B in same outlet combination, same for C, and so on. After that, going to next outlet combination and repeat the process.

Selecting the Points to Be Tested

The time required to perform tests and collate results can be reduced, using the fact that results can be treated statistically. So even with a subset of results it is possible to interpolate the results for any home.

In the field, the electrical layout of the home in terms of wire length, type, and layout, is very seldom available. For this reason, field tests are generally aimed at assessing the statistical probability of achieving a particular performance between random outlet pairs, or between outlet pairs in random rooms. The number of measurements that can be made is therefore proportional to the square of the number of outlet pairs selected.

For example, if there are seven outlets selected for testing PHY speed, there are 21 connections between outlets, each of which produces a different result depending on whether the transmission or reception path is tested giving a total of 42 combinations. The recommended number of outlets for testing is three to five per home, for instance the typical ones in which final users usually plug the G.hn adapters.

For the correct collation of results in any statistical experiment, a proper random sample selection process is necessary, and for G.hn field tests there are two possibilities:

- Randomly select a number of outlets in the home: This technique provides the inter-outlet performance of the technology.
- Randomly select a outlet in each room of the home: This technique provides the inter-room performance of the technology.

Collecting the Results

Test results can be collected for each pair, performing the relevant throughput tests. Below some tables are presented that could be used as a model for evaluator's tests.

Table 17: *Example of General Field Test Information*

Test Parameters
Date test performed
Home tested
Modem "A" MAC Address, firmware loaded and reference design
Modem "B" MAC Address, firmware loaded and reference design
Home floor area (m2)
Electrical phase distribution
Ground presence
Building type
Country and city
Age (years)
Number of floors
Rooms in the house

Table 18: *Example of Outlet Description*

Outlet No
1
2
3
4
5

Table 19: *Example of Outlets Description*

Transmit	Receive											
Outlet Pair	Physical Throughput	TCP Throughput	UDP Throughput	Latency	Jitter	Frame Lost	Physical Throughput	TCP Throughput	UDP Throughput	Latency	Jitter	Frame Lost
1-2												
1-3												
1-4												
1-5												
2-3												
2-4												
2-5												
3-4												
3-5												
4-5												

Presenting the Results

Taking throughput or other performance field measurements (both for Rx and TX paths) and ordering the results, it is possible to present them graphically and interpret the results statistically, for example in a histogram graph. Drawing a line at any particular point, it is possible to see the percentage of outlet -pairs which achieve a particular minimum performance. For example, it can be seen in a graph that x% of outlet pairs achieves a UDP data rate of Y Mbps data rate.