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CTA Standard

Test Procedure for Powerline Carrier Technology

CTA-2002-A

(Formerly CEA-2002-A)

February 2009



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(Formulated under the cognizance of the CTA **R7 Home Networks Committee.**)

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CEA-2002 Test Procedure for Powerline Carrier Technology

1 Objectives and Test Procedure Overview

The objective of this Test Procedure is to establish a set of tests and analysis that will validate key aspects of Powerline Carrier Technology (PLT) for use in Home Networking products.

Specifically, tests and analysis will be conducted to evaluate the following:

- a) outlet coverage - using a minimum of 30 outlet pairs per test site, one pair at a time.
- b) application performance - using a minimum of 3 typical scenarios
- c) network coexistence performance - with networks operating simultaneously in neighboring residences
- d) performance over a range of network sizes - using node populations of 3, 5, 10, 14 in the field
- e) performance across a range of dwelling types and geographic areas - using a minimum of 30 homes, from a variety of geographic locations, building types, construction, and wiring methods.

There are three components to the tests:

- a) First, the initial pre-field lab verification tests of §8.1 to ensure that the technology can successfully complete the suite of field tests described below
- b) Second, the actual home testing (field tests) of §7
- c) Third, the post-field lab tests of §8.2 - §8.8 for those aspects of the technology that can be more easily exercised in a lab

Field testing in the actual homes also consists of initial preparatory activities in each home:

- a) home inventory (sketch home layout, select and number outlets, note special home characteristics, etc.)
- b) equipment set up and check out

Home profiling measurements (powerline characterization) may be taken either before or after the testing is complete in a given home, but home profiling is separate from these Test Procedures.

The Powerline Carrier Network (PLN) set will be pre-configured for 14 nodes using 14 dedicated personal computers (PC's). Once configured, the PC/PLN set will move from home to home.

2 Measurements of Interest

The following measurements will be observed and recorded during the tests:

- a) Effective data throughput delivered to the application
- b) Aggregate data throughput for all applications operating on the network
- c) Packet error rate. The packet error rate will include the number of dropped packets, the number of duplicate packets, and the number of out of sequence packets. Since most powerline technologies will employ some form of retransmission and/or packet verification it is expected that bit errors will manifest themselves as degraded throughput and dropped packets.
- d) Min, max, and average latency
- e) Jitter

3 Dwelling Types and Outlets

3.1 Dwelling Types

For the Field Tests in §7, select dwelling types from the following categories:

- a) Apartments, multiple dwelling unit and single dwelling unit
- b) < 2500 sq. ft
- c) 2500 to 5000 sq. ft
- d) 5000 to 10000 sq. ft

Homes are to be chosen that contain a typical complement of consumer appliances and electronics equipment, selected from a mix of one-, two-, and three-phase dwellings. Some of the homes are to also allow for testing of coexistence with neighboring homes.

3.2 Outlet Selection

A minimum of 30 outlet pairs per test site will be tested, one, two, three and five pairs at a time.

Outlet locations should be made according to the following criteria:

- 1) At least 4 of the outlets should be selected based on the following criteria:
 - Select 1 outlet as the (physically) closest to the breaker panel and label this outlet #1. Outlet #2 should be chosen in this room, if possible.
 - Select 1 outlet as the (physically) furthest from the breaker panel and label this outlet #20. Outlet #19 should be chosen in this room, if possible.
 - If not already chosen, select an outlet as the most common location for a PC connection and label this outlet #3. Outlet #4 should be chosen in this room, if possible.
 - If not already chosen, select an outlet as the most common location for an Internet Appliance connection and label this outlet #5. Outlet #6 should be chosen in this room, if possible.
 - If not already chosen, select an outlet as the most common location for a Residential Gateway connection and label this outlet #7. Outlet #8 should be chosen in this room, if possible.
 - If not already chosen, select an outlet as the most common location for a cable Set Top Box connection and label this outlet #9. Outlet #10 should be chosen in this room, if possible.
 - If not already chosen, select an outlet as the most common location for an Entertainment Device connection and label this outlet #11. Outlet #12 should be chosen in this room, if possible.
 - If not already chosen, select an outlet as the most common location for another consumer electronics device connection and label this outlet #13. Outlet #14 should be chosen in this room, if possible.
- 2) If there are rooms remaining in which no outlets have been selected, including a detached garage, office or mother-in-law apartment, select at least 1 outlet per room, up to a maximum of 20 total. Label these outlets using the unused numbers between 2 and 19, inclusive.

3) If less than 20 outlets have been selected, randomly select the remaining outlets until 20 unique outlets have been selected. Label these outlets using the unused numbers between 2 and 19, inclusive. If the selection process results in two outlets being selected in the same room, an effort should be made to label the selected outlets with consecutive numbers from the series 1-2, 3-4, 5-6, 7-8, 9-10, 11-12, 13-14, 15-16, 17-18 and 19-20.

4) If a neighboring house is provided for the coexistence test in 7.8, select 10 outlets as follows: Select outlets 11 through 18 as if they were 1 through 8 (but label them 11 through 18). Select 19 and 20 as usual. If a neighboring house is not provided, the outlets in the single home will be separated into two networks using the numbers initially assigned.

4 Geographic Areas

Test sites are to be chosen from at least five geographic areas to account for different building methods, lifestyles, weather patterns, and other environmental factors.

5 Scalability

Where possible, some provisions should be made to conduct a subset of these test procedures on next generation technology, provided it is designed to interoperate with the technology under test.

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6 Test Equipment

For consistency of test results, the same test equipment types should be used for all PLT's when testing competing technologies.

6.1 Test Software

6.1.1 Test Software Criteria

The test software will meet the following criteria:

1. Produce data at rates exceeding the maximum powerline data rate.
2. Collect results on a single computer automatically for aggregate throughput results.
3. Produce/simulate all forms of traffic required by test procedures: streamed, file transfers, internet (WWW and POP3), VoIP, audio, and video
4. Measure min, max, and average throughput
5. Measure min, max, and average latency
6. Measure jitter
7. Automate tests and data collection through scripts or programming interface.
8. Running the tests and collecting the data occurs independent of the powerline network, i.e., the control of the test equipment will occur on a separate wireless network.

6.1.2 Test Software

Software needed for the tests will include the following:

1. IxChariot software (version 4.2 or higher)
IXIA's Chariot test software provides most of the functionality required to meet the test software criteria. This is a commercial test package; however evaluation copies of the test software can be obtained from their web site
<http://www.ixiacom.com/products/ixchariot/>
2. Chariot test scripts (see Annex A)
3. PLT drivers for the PCs (where applicable)
If the PLT is connected directly to the PC and involves installing drivers, then the driver will communicate via the NDIS layer of Windows 2K or higher.
4. Iris network traffic protocol stack sniffer (recommended) or equivalent
Iris is available for download from
<http://www.eeye.com/html/products/iris/index.html>

6.2 Test Hardware

Each PLN node will be fitted with a dedicated PC. Most measurements will be recorded by Chariot on the PC's. Each PC will also communicate with a wireless network, so that control of Chariot and the other test equipment occurs on a separate wireless network. Various other measuring devices (network traffic, etc.), loads, and impairments will also be used.

The control network shown is wireless. The control network may be hardwired Ethernet on Category 5 cable instead, but wireless is recommended because it has less set up time and is less intrusive. If a hardwired control network is used, the PC's should have an Ethernet port.

6.2.1 PC/PLN Sets

The PC/PLN sets will include the following:

1. Personal Computers – portables or laptops
2. 802.11 wireless Ethernet network cards and access points:
 - WDT11 - PCI card
 - WPC11 - PCC card
 - WAP11 - Access Point

One card is used for each PLT node under test (14 per PLN set). Up to three (3) access points are to be available for each PLN set. The actual number used will depend on the size of the home.

6.2.2 Measurement Equipment

Most measurements will be recorded by Chariot on the PC's above. Other measurement equipment needed for the tests will include the following:

1. CISPR 16 spectrum analyzer
2. CISPR 16 LISN load
3. EMI scanning receiver and receiving antennas for 1 MHz to 300MHz.
4. bus analyzer

One set of these measurement devices will be needed.

6.2.3 Other Hardware

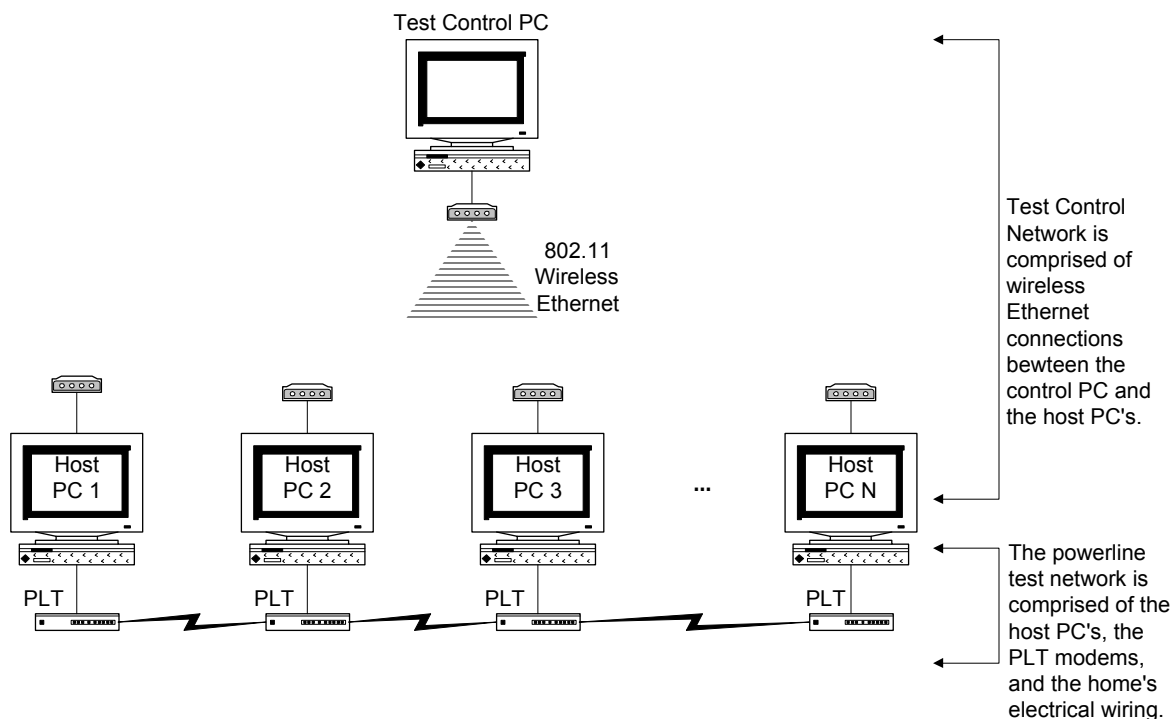
Other hardware needed for the tests will include the following:

1. Samples of X-10, CEBus (CEA-600), and LonWorks (CEA-709) nodes
2. UPS and filters (normal off-the-shelf)
3. household impairments (as available in homes)
When one or more dimmers are present the first one shall to be set at ~3/10 power, and subsequent ones set at higher and lower values (e.g. 4/10, 2/10, 7/10, full) to simulate normal operating variations. One 300 watt portable halogen lamp with dimmer should be brought in the event no dimmer is found at the test site.
4. misc items (e.g. power strips)
5. 40dB load
6. various attenuators in 8.3.2.2.2

Up to 5 sets of these devices may be needed, one for each PLN and a spare set, for simultaneous testing of all PLN's.

6.3 Field Test Setup

The following diagram shows how the test environment will be set up within each house.



7 Field Test Procedures

The following field tests, in conjunction with the accompanying lab tests and technology documentation, represents a comprehensive list that will adequately validate key aspects of the PLT for use in consumer home networking applications.

7.1 Control Network Test

7.1.1 Description

The Control Network connectivity tests will verify that the control network is not acting as a transmission medium for the PLTs and establish a baseline for the maximum throughput achievable in the tested configuration.

7.1.2 Test Procedure

7.1.2.1 Sanity Test

- 1) Connect node1 and node2 to two outlets in close proximity to each other. The purpose is to establish a good connection between the PLTs.
- 2) Verify with "pings" that they are communicating over both the Ethernet link and the PLC link
- 3) Send bi-directional data between node1 and node 2, using UDP datagrams.
- 4) Disconnect node 1 and node 2 PLTs from the outlets, and ensure at least 1 meter of separation.
- 5) Verify that no data is being received by either PC.

7.1.2.2 Baseline Test

The purpose of this test is to confirm that the transmission power levels actually being used for the testing are the same as those used for the RF field strength measurements. Steps 1 through 4 will be repeated, with each of the 14 PCs being tested as node 1.

- 1) Connect nodes 1 and 2 together in such a way as to obtain a perfect link, e.g., on an isolated power bar. Connect node 1 through a 40dB attenuator.
- 2) Send unidirectional data from node 1 to node 2, using UDP datagrams.
- 3) Record the transmit power levels as a Power Spectral Density measurement using the CISPR 16 LISN load and a spectrum analyzer. The CISPR 16 LISN will be connected to the power strip as near to node 2 as possible and the spectrum analyzer will be connected to the power strip as near to node 1 as possible. If the technology has been labeled "dynamic power", connect the spectrum analyzer to the node1 port of the attenuator.
- 4) Ensure that the measured transmission power levels do not exceed those of the technology's baseline measurement by 3% or more (linear measure) at any frequency used for data transmission, adjusting the power level of the PLT nodes as necessary.

7.2 Outlet Coverage Test

7.2.1 Description

The outlet coverage test will evaluate outlet coverage for both connectivity and throughput. This test will be performed using the test tool of section 6.2.

A minimum of 30 outlet pairs per test site will be tested one pair at a time. Outlet pair locations should be randomly selected primarily from room to room combinations including phase to phase and should encompass at least 20 different outlets.

The effect of physical configuration will also be tested by having two pairs operating simultaneously between two distinct pairs of outlets. At least 30 configurations of these two pairs of outlets will be tested.

The actual planned conduct of the single and dual pair node tests will result in having several silent nodes connected to the powerline during the conduct of the single pair tests. This might result in the use of relay nodes during the single pair tests. To insure that this is not happening, at the conclusion of the testing, all extra nodes will be removed from the powerline, leaving only the two most extreme nodes connected. The single pair tests conducted using these nodes will be repeated manually. If this check measurement results in a significant decrease in throughput, indicating the use of relay nodes during the regular test series, the entire test series will be repeated, including the manual check measurement. (If the measurements consistently indicate the use of relay nodes, a throughput of 0 will be entered for the entire test series.)

7.2.2 Test Procedure

This procedure balances optimal, random coverage and optimal use of allocated time. It is based on moving a group of nodes (10) times thus minimizing setup and tear-down times. All 4 nodes (PC1,2,3,4) are moved at the end of each iteration. Therefore, 4 sets of 10 random outlet groups must be pre-selected (Outlet1A,B,C,D; Outlet2A,B,C,D; Outlet3A,B,C,D; ... Outlet10A,B,C,D). It is allowable to use some of the same outlets within the various groups, since it may not be feasible to find or use 40 unique outlets.

- a) The "Repeater" capability is "DISABLED" in all 4 powerline modems to be used within this test.
- b) Plug the 4 PCs (PC1, PC2, PC3 and PC4), along with the 4 attached (non-Repeating) powerline modems, into (the next) 4 pre-allocated outlet group locations (The 1st group is: Outlet1A, Outlet1B, Outlet1C, Outlet1D).
- c) Optionally verify hardware has powered and initialized correctly (We don't want to penalize the results if the hardware was not initialized properly).
- d) Run the 2-Node (7.2.2.1) automated test tool that runs the appropriate Chariot Scripts.

The automated tool automatically runs the following 12 different outlet combinations

PC1 -> PC2
 PC1 <- PC2
 PC1 -> PC3
 PC1 <- PC3
 PC1 -> PC4
 PC1 <- PC4
 PC2 -> PC3
 PC2 <- PC3
 PC2 -> PC4
 PC2 <- PC4
 PC3 -> PC4
 PC3 <- PC4

Each of the above combinations sends two, 30-second UDP streams using 1500 and 64 byte packets. The elapsed test time for this combination is just over 12 minutes.

- e) Optionally "ENABLE" the "Repeater" capability in each of the 4 powerline modems, or simply skip to the next step.
- f) Run the 2-Pair (7.2.2.2) automated test tool that runs the appropriate Chariot Scripts

The automated tool automatically runs the following 6 different outlet combinations:

PC1 -> PC2 && PC3 -> PC4 (simultaneously 2 pairs)
 PC1 -> PC3 && PC2 -> PC4 (simultaneously 2 pairs)
 PC1 -> PC4 && PC2 -> PC3 (simultaneously 2 pairs)
 PC2 -> PC1 && PC4 -> PC3 (simultaneously 2 pairs)
 PC3 -> PC1 && PC4 -> PC2 (simultaneously 2 pairs)
 PC4 -> PC1 && PC3 -> PC2 (simultaneously 2 pairs)

Each of the above combinations sends three 30-seconds UDP streams using 1500, 64, and Variable byte packets. The elapsed test time for this combination is just over 4.5 minutes.

- g) Power down each of the 4 PC's and attached powerline modems, and move each to a new outlet location. Total move and reboot time is approximately 4 minutes for a single individual.
- h) Repeat steps (a) through (g) for the remaining 9 outlet groups.

Spot-Check Procedure:

- a) After running all 10 groups, 1 previously used 2-Node outlet combination should be re-configured (Replace the same 2 PC's and powerline modems to the original locations, WITHOUT the other 2 PC's). The other 2 PC's and powerline modems should REMAIN UNPOWERED AND UNPLUGGED. This pair should be selected based on it being a more difficult combination - more likely to require repeaters.

- b) Re-run a Chariot Script that only sends between the 2 powered nodes in each direction and compare with the original results to ensure repeaters were not being used. Outlet coverage should be approximately the same with no significant throughput differences.
- c) Repeat step (a) and (b) 3 times using 3 different combinations.

7.2.2.1 One Pair in the Same House

Note: This test is run concurrently with 7.2.2.2 in the Chariot Scripts.

7.2.2.2 Two Pairs in the Same House

This procedure balances optimal, random coverage and optimal use of allocated time. It is based on moving a group of nodes 5 times, thus minimizing setup and tear-down times. All 4 nodes (PCs) are moved at the end of each iteration. Therefore, 5 sets of 4 random outlet groups must be chosen as follows:

GroupABCDE
 PC 15112101
 PC 261781220
 PC 371415133
 PC 491816194

- 1) The "repeater" capability is to be disabled (where applicable) for all 4 powerline modems to be used within this test. Enable sources of disturbance that typically operate continuously for long periods (e.g., lights, dimmers, TVs, PCs, etc.). Note, these sources of disturbance will not be moved from their existing locations. The set of enabled sources of disturbance and their physical locations will be the same for all tests
- 2) Plug PC's 1 through 4, along with their associated powerline modems into the outlets selected for Group A.
- 3) Verify that the hardware has powered and initialized correctly.
- 4) Run the 2-Node automated test script (7.2.2.1) that runs the appropriate Chariot scripts. The test script automatically runs the following 12 different outlet combinations:

PC1 -> PC2
 PC1 <- PC2
 PC1 -> PC3
 PC1 <- PC3
 PC1 -> PC4
 PC1 <- PC4
 PC2 -> PC3
 PC2 <- PC3
 PC2 -> PC4
 PC2 <- PC4
 PC3 -> PC4
 PC3 <- PC4