Testing products with network connectivity

Bruce Nordman[1]
June 21, 2011

prepared for the Australian Government,
Department of Climate Change and Energy Efficiency

Summary

An increasing number of electricity-using products can be connected to a communications network to increase functionality. This can increase energy use several ways: operating the hardware directly associated with the network link, data processing necessary to maintain or interpret the network connection, the effect of the network on the overall behavior of the product. At one time, no energy test procedures took account of the possible existence of network connections, since they did not exist for ordinary products. Over time, some test procedures have added selected provisions related to networks, but this has usually been done in an *ad hoc* manner. There have been many developments in hardware and software associated with networks in recent years, so some new approaches are now required. Networks are becoming common in a wide range of products, so testing these elements and functions pervasively in energy test procedures is becoming necessary.

Energy efficiency policy would benefit from global harmonization of details around network connectivity that are specified in test procedures and specifications. This is both for a single product type across countries, as well as among product types.

What is needed is a "library" of standard elements for test procedures to draw on to drive harmonization. This document addresses some initial steps towards such a common library. After an initial version is developed, it will need to be maintained and expanded on over time, as more experience is gained with procedures, products, and advancing technologies. Such a library will also need to interface with general test procedures (such as IEC 62301 for standby power) as well as specific product test procedures, to facilitate these harmonized elements being uniformly adopted around the globe. The library will also need to take into account the needs of current and future energy policy requirements with respect to networks.

This report documents many existing requirements relevant to testing products with networks and sets out key issues to be considered. The main specifications in existence are in the Energy Star program and in the European Codes of Conduct for Broadband and Digital Television Services (Set Top Boxes). While there is significant common (or at least compatible) content in these documents, there are also some conflicts and a number of gaps. This report sets out where further work is required to develop a global approach to testing for products with network functionality. This will require close collaboration among interested parties.

[1] Bruce Nordman, bruce.nordman@gmail.com, +1 510 848-1428

Introduction

Networks enable arbitrary communication among many connected devices. A data link enables communication only between two directly connected devices. Most networks are built up as a series of data links, where packets of information are transmitted over each data links on the path from source to destination[2]. In any case, both network links and data links are covered by this discussion, so the distinction is not so important. Data links have many of the characteristics of network connections, so that a common approach is optimal. For the rest of this document "network" is used to cover all types of digital communication[3].

Energy test procedures can be used to provide information on energy consumption and power levels (e.g. to purchasers), for voluntary energy programs, or for mandatory efficiency regulations. Where a product has a network connection, defining the state of network connectivity becomes an important element of test conditions, test procedures, and program requirements.

Special attention is paid to testing of network equipment (i.e. products that are infrastructure for the network itself), as these products typically have a large number of network links that can be active. This is where the most detail is specified in current procedures, and is an indication of the types of details that could be adapted for other products in future.

A key conclusion of this document is that a traditional, single state, completely horizontal approach to product testing as is commonly specified in low-power mode policy is not possible for products with network connectivity. This is due to differences in products and how they incorporate networks, how products are used, variations in technology, and stages of policy development. However, as test procedure content is developed that recognizes these elements, they can be specified in the same way across many products and so a great deal of harmonization can be achieved. It makes good sense to apply some deference to existing approaches rather than invent something entirely new, so elements of existing procedures and requirements are reviewed for their applicability and usefulness.

General goals

A number of goals underlie the approach and content outlined here. These cannot always be accomplished, and are sometimes at odds.

Typical use

Testing products as they are most commonly used is helpful when a test result ends up being the basis of information communicated to ordinary users, either directly (as with an energy label that includes quantitative information), or indirectly (when a user looks up information on-line from the brand/model). This aids explanation of what the test result means, and helps people interpret the values. Also, there is obvious logic for policy to be based on measurements close to typical use.

---

[2] A few technologies enable communication intermediate between true network connections and data links (e.g. HDMI), but they can generally be best treated as single data links for testing purposes.

[3] Thus, analog communication is not covered, though test conditions and procedures will commonly want to address these as well. One test method which does address analogue is the Energy Star AV specification, for which the test method says "Audio Sources: A 1 kHz sine wave input signal shall be used as the audio source for all amplifier tests in Section 9. For stereo testing, sine wave signals shall be in-phase, with identical frequency." The communications interface between a PC and its monitor traditionally has been analogue video signaling.

Typical use covers many aspects of the product, from test conditions, to configuration, setup (what network connections are used), to the content of data flowing across the connection(s). This topic lends itself to innumerable possible combinations of hardware, software, and usage variations, so determining a single (or small set of) representative combinations can be challenging.

Similarity to non-network products

In many product types, there are models available with network connections, and others without them. Testing these without any use of the network technology can eliminate or minimize the effect that the connectivity ability has on the energy result. Also, this is practical when the effect of networking on products or the typical use of it is unclear. So the base case for a product with network capability is to test it without any network connection. Different levels of network functionality can then be added to this base case as applicable.

Consistency across products

Whether the issue is configuration, the state of connectivity to the network, or the type of connection, there is benefit to having products tested like each other to make the results most comparable, for ease of interpretation and regulation. This can apply within a product type, or between product types, and in either case between different types of requirements (e.g. voluntary vs. mandatory).

Simplicity of test

Having a test procedure with as few complications as possible makes it easier for the tester to accomplish, and easier to explain to anyone wanting to understand it. In some cases, a simpler test can require less test time and less expensive test equipment.

Public policy needs to balance the value of each of these goals against each other in determining how to test each product. The conclusions will naturally evolve over time, as we gain experience, and as technologies, products, and their use all change.

Cross-product structure

Much recent policy discussion has used the terms 'horizontal' and 'vertical' to denote overall approaches to policy across many product types. They can be described as:

- **Universally horizontal —** application to all products, or to all products with defined exceptions. This is an important way to construct policy, and the basis for much policy on low-power modes. This is appropriate for aspects of product energy use that are common across all (or almost all) products.
- **Vertical —** application unique to a single product type across all relevant modes for that product. This is the traditional approach to efficiency regulation, since active mode consumption has been the most important consideration for most product types and is so different among product types.
- **Sectorally horizontal —** this new term references content that is common across many or all product types within a defined broad group (of broadly similar functionality and features with respect to testing).

Both horizontal approaches are useful for network connectivity. The 'sectoral' term is new. Some logical groupings are: audio/video products, computer-oriented products, network equipment, appliances, and miscellaneous devices. These are groups of devices that could be treated in the same way with respect to testing network functionality due to similarity of technology and application. While these concepts are not developed further in this paper, they should form a useful basis for the disaggregation of requirements and approaches for test procedures.

Past work

Several past reports have considered the topic of testing devices with network connections. *Nordman et al, 2009* considered how network connectivity affects low power mode energy use, and included discussion on testing and regulation. *Harrington and Nordman, 2010*, covered network standby and regulation and recommended that a global suite of testing requirements be developed to cover products with network functionality as a complement to IEC 62301.

Many existing policies have requirements related to networks, in test procedures or elsewhere. The most extensive content is specified in the Energy Star program, although also several European Union Codes of Conducts are also important references. These existing requirements are covered in detail in this report, as is an outline of a test procedure from the EcoDesign Network Standby ("Lot 26") process.

Finally, some research reports on product energy use have shown how network connectivity affects consumption in ways that inform how we think about testing.

Technologies

Network technologies in common use today can be divided into wired and wireless. "Wired" includes traditional electrical connections, as well as light-based (fiber optic) ones. "Wireless" includes the common radio based technologies, as well as infrared. A key distinction for testing is that when a wired technology is used, a mechanical connection is made with a cable, so that there is the possibility of using that action to disengage electronic components when no cable is present. In addition, the electrical signaling in the network standard may also enable easy detection of the presence of the cable, and/or presence of a powered interface at the other end of the cable.

Wireless technologies provide the device in question no indication of the presence or absence of the possibility of connectivity other than listening for the data signal[4]. In some cases, searching for a signal can be more energy-intensive than maintaining an established connection.

A special type of wired network technology is the "power line carrier", where the electrical power cables within a building carry network traffic among devices. While this is a "wired" technology in terms of the physical transmission of signals, it may be more like a wireless one in terms of testing approaches (as the device cannot know whether there is another device present unless it actively looks for one). Specific requirements for these technologies will be needed.

[4] There are wireless technologies which have a radio-based "wakeup" signal separate from the transmission channel to enable devices to be in very low-power sleep states for extended periods of time, only waking when called for to receive data. These do not particularly leverage much total energy use and so are not considered here.

Reporting

Network connectivity can be manifested in diverse ways in products, there are many details which could affect energy use, and technology is rapidly evolving. For these reasons, it is necessary to provide more thorough documentation of these details than is common with other aspects of product testing. Sometimes it is unclear if reporting a particular data item is needed or not at the time of testing; this only becomes clear later.

Thus, it is best to err on the side of reporting more for information about network connections during testing.

Configuration

To the extent that a test procedure is a "sequence of operations", there are a number of conditions that must exist or be set up prior to initiating any formal test procedure. These could be called "test conditions" or "product setup", etc.

It is typical for testing to assume that the product is in its "out of the box" condition. This assures that no changes in configuration have been made since the product was shipped by the manufacturer. Some products come with components that are connected with data or network connections. A common example is a keyboard and mouse shipped with a desktop computer. These are generally considered part of the product and so not constituting a network connection for purposes of testing, or for "adders" for power consumption (unless the specification specifically says otherwise). Energy Star usually begins with the test-as-shipped assumption (making specific exceptions or additions as needed for individual product types). As an example, the SNE (Energy Star Small Network Equipment Specification) draft test procedure says:

> As-shipped Condition: Products must be tested in their "as-shipped" configuration. For products that offer a choice of user-configurable options, all options shall be set to their default condition.".

An example of something that should not be done is to "turn off" ports not used in the test so that they would not become active if a cable were connected. This is explicitly precluded in the EU Broadband Code of Conduct (CoC).

Test products in their "out of the box" ("as-shipped") state.

Naturally there will be exceptions. Attaining consistency in how products are tested will sometimes take precedence over the as-shipped goal. Additional configurations can also be tested in addition to the "out of the box" configuration. For consistency, several approaches can be applied as follows.

No communication

For product types in which network connectivity is rare, and where its use, even when present in a product is uncertain, it may be best to not use communication on those products that have the capability. Appliances (e.g. laundry and refrigeration) are a current example of this. This can be implemented by simply not connecting any wired connections or having any relevant wireless technologies in the vicinity of the test (more below on wireless issues). Or, it can be allowed to actively disable (e.g. via a software setting) the network ability. The goal is to not burden the device being tested with the power required for the network interface. The distinction in the two approaches is in whether the device can automatically turn off the network circuits when none is present; this is more obvious on how to implement for a wired interface with its physical connection. For wireless, power will typically continue to be consumed unless the interface is turned off.

The Energy Star TV test method directs that network capabilities be “deactivated”, as does the Top Runner TV specification. While this is a valid base case for these product types, testing with the network feature active is also necessary, especially as the prevalence of building networks increases in the future. If there is never testing of the power level with network functions active, there is no incentive for manufacturers to design these using low energy approaches.

Standard communication, single

For product types in which communication is common, it is desirable to test all products with the same type of connection. For example, the Energy Star PC specification requires testing with Ethernet connection established and Wi-Fi disabled (if Ethernet is not present, then Wi-Fi is to be used). In the PC case, the test uses only a single network connection, even if the product has more present.

The EU Digital TV CoC specifies measuring devices with the minimum required network connections, disabling all other connections that can be. The device is connected to a primary video feed.

Standard communication, multiple

Some product types might normally or commonly be used with multiple connections and so to make the testing most representative of typical use, this should be done.

One example is network equipment such as switches, routers and modems. However, while it is possible to use every port on a switch or router, more commonly only some are used. The Energy Star draft test procedure for Small Network Equipment specifies testing the product with half of the available LAN (Local Area Network) ports in use (rounding up when an odd number). The EU Broadband CoC specifies a single LAN connection for Home Network Interface Devices (which are those not associated with a service provider).

Set-top boxes are another product type that is commonly used with multiple interfaces, with one for acquiring content, and one or more for distributing it to displays.

The Energy Star specification for imaging equipment (printers, multi-function devices, etc.) currently allows between 1 and 3 ports to be connected during the test, at the discretion of the manufacturer. To make the test more deterministic and consistent, Energy Star is likely to change it to a specified number of ports and a specific method for determining which ports to use.

Maximum communication

For purposes of understanding how much power capacity might ever be needed for a device, it is desirable to connect every possible interface. This is rarely needed for energy efficiency purposes, but should not be ruled out.

General principles for testing

Interface speed

Many interfaces can operate at different speeds depending on configuration, implementation, or physical characteristics of the link. It is common to specify that the highest possible rate be selected (e.g. the TopRunner Small Router requirements) as this may require more power than lower speeds. In addition it is common for technologies to use the highest speed common to both ends of the link. However, any standard power-saving technologies should be recognized in the test procedure.

Interface selection

The Energy Star Audio/Visual (AV) test method picks the interface for content input as (note: UUT is "Unit Under Test"):

> AV Signal Interconnections: If the UUT offers several audio and video interconnection options, select and configure the system with one of the following interconnections, in order of preference: HDMI, component, S-video, and composite.
> Networking / Control Protocols: If the UUT offers several networking / control protocol options, each must be active and tested through all phases of the test procedure.

The Energy Star Display specification states that analog interfaces always take precedence over digital ones. This is likely as at present that is still the most common way that computers send data to monitors (the standard VESA traditional connector, the VGA (Video Graphics Array) connector, is analog).

The Energy Star SNE procedure specifies choosing Ethernet LAN ports in order starting at one (usually they are numbered).

Powering via a network connection

An increasing number of network technologies provide for distributing power in addition to exchanging information; USB and Power-over-Ethernet (PoE) are the most common of these. Thus, products with network connectivity have the possibility of receiving or transmitting power, and each of these must be addressed.

It is becoming more common to include products powered only by a network connection to be within the scope of energy policy instruments, but these often clarify that a device being tested must get either *all*, or *none*, of its power this way. As an example, the EU Broadband CoC specifies that powered devices "shall be disconnected for the power consumption measurement, except when this is in contradiction with the operation of the product." See the above mention of USB keyboards for an example of when such connection is appropriate (for PCs in that case)

Both the Energy Star SNE and Broadband CoC procedures allow products to be powered by a network (or data) connection, specifically noting USB and PoE as examples. This is not strictly a network issue, since even products with no network connection at all can be powered this way, though there is an obvious similarity in policy and testing. The SNE procedure measures the AC power consumption of a commercially available power supply for this purpose (e.g. a PoE Injector or powered USB hub with the product being tested powered by it). It chooses in order, a suitable supply 1) shipped with the product being tested, 2) from the manufacturer of the unit being tested, or 3) any other.

Provide for testing of DC-powered devices.

Verification

A question which arises for energy specifications is what features to accept based on the manufacturer stating that it is present, or which require verification that they properly work. Features for which there is a well-accepted technology standard in existence are less likely to require verification.

Specific interfaces

There are many details of an interface that could be specified, from physical characteristics like cable length or gauge, to electrical ones, to details of the amount and nature of the data transmitted and/or received. Many interface technologies have optional features for power delivery or auxiliary communication. These details can be determined by the cable used, the device at the other end of the link, or the device being tested (per its total capabilities, its configuration, or usage).

Ethernet (IEEE 802.3)

As one of the oldest interfaces still in use, and with impressively widespread use, Ethernet has developed the largest set of requirements. Ethernet covers a large family of physical layer interfaces, some historic (e.g. a common wire that systems would all tap into), and many for specialized applications (e.g. optical links for long and/or high speed communication, in equipment backplanes, and within data centers). A key feature of Ethernet is the ability of many types of interfaces to implement multiple data transmission rates. This enables backward compatibility so that new products can work faster while maintaining the ability to communicate (at the slower speed) with older ones. A common requirement is for the test to be done with a device that supports the highest speed that the device under test does. As power increases with speed[5], this ensures that the power measured is at the top range of what the product will use in actual use. Many products for general residential and commercial use offer 10/100/1000 Mb/s Ethernet (some just 10/100); data center products more commonly 1/10 Gb/s. This requirement can be expressed as:

Any network connection capable of multiple speeds shall be connected to a device capable of the highest speed.

Some products claim to reduce power consumption when an Ethernet cable length is less than the maximum of 100 metres. Aside from the fact that a 100 m cable is inconvenient, it is helpful to standardize on a single shorter length. The Energy Star SNE draft procedure specifies:

> "Ethernet Cabling: All Ethernet cables used for testing shall meet ANSI/EIA/TIA-568 Category 5e (Cat5e) specifications and shall be no shorter than 2 meters in length."

This is an excellent choice for any test procedure, though it may be more detail than is needed for most devices. The Energy Star SNE procedure is more detailed in this respect since the network connectivity is the primary purpose of the product, not a secondary one. The EU Broadband CoC specifies a cable length of 5 m. There is likely no significant energy difference between these two lengths (assuming a user of the SNE procedure uses a 2 m cable).

Both procedures specify that Ethernet links should be connected at the highest link rate of which they are capable. Energy Star SNE says that WAN connections should also be operated at their "maximum possible speed".

The Energy Star SNE procedure has specific requirements for the nature of the traffic passed through the device, in terms of packet size and quantity of data. While those are appropriate, they specify more detail than is required for other products.

A recent addition to the Ethernet standards is IEEE 802.3az, also known as Energy Efficient Ethernet (EEE). This allows the link to quickly go to sleep when no traffic is being transmitted, and quickly wake when data appear. As most of the time,

[5] There are products that use a very slight amount more in 10 Mb/s than in 100 Mb/s Ethernet, but the difference is small and this sort of occurrence rare.

most links have low traffic levels, any energy test procedure should require (again from the Energy Star SNE procedure):

> If the UUT supports IEEE 802.3az protocol, all connected devices must support IEEE 802.3az … If the UUT supports Link Layer Discovery Protocol (LLDP) for 802.3az, all connected devices must support LLDP for 802.3az.

A different version of the same requirement is in the EU Broadband CoC:

> Broadband equipment with Ethernet interfaces are encouraged to implement IEEE 802.3az ("Energy Efficient Ethernet") and enable the technology by default. For copper based Ethernet interfaces (WAN and LAN) supporting IEEE 802.3az (Energy Efficient Ethernet) the measurement equipment connected to such ports must as well support IEEE 802.3az and LLDP for IEEE 802.3az.

If both ends of the link support EEE, both will save power. If only one end supports EEE, then neither can save power.

LLDP is much less well known than EEE and is also used for purposes unrelated to EEE. LLDP for 802.3az is not required for EEE to operate on the link. What it does is to allow the end points to negotiate longer wake times than specified in the EEE standard. This may seem counterintuitive, since it increases latency (delay), but in some applications the latency increase may not matter, and this may enable more of the hardware in a device to power down when the link is asleep. For example, there may be buffer memory for storing received data, and the time to pull the memory out of a low power state may be longer than for the link to wake up, so without LLDP, the memory cannot go to the low-power state. LLDP would enable the devices to negotiate a wake time long enough for the memory to also wake. Thus, testing with a connected device capable of LLDP for 802.3az could result in lower power levels than could otherwise be achieved.

The power required for a standard (non-EEE) link varies with the speed of the link, particularly between 100 Mb/s and 1 Gb/s, and between 1 Gb/s and 10 Gb/s. The Energy Star PC specification requires:

> The speed of any active 1 Gb/s Ethernet network links shall be reduced when transitioning to Sleep Mode or Off Mode.

This allows the link to go to 10 Mb/s or 100 Mb/s. This does reduce power at the PC as well as at the other end of the link. However, once a device implements IEEE 802.3az, then this is unnecessary, and actually counterproductive. For Ethernet, such requirements should be removed (there may be other technologies for which such an approach is merited). Going forward, EEE should be required for any device that supports Ethernet (on types of Ethernet that support EEE which is all those used in ordinary products).

Other wired network links

USB has three primary speeds for versions 1., 2., and 3. of the specification: 12 Mb/s, 480 Mb/s and 5 Gb/s. IEEE 1394 (fire wire) is capable of 400 and 800 Mb/s. HDMI and DisplayPort are also capable of multiple speeds, but how they operate is more connected to the resolution required (the same also applies to older VESA analogy display connection standards). USB should be tested at the most recent version the interface is capable of. DisplayPort for a display device should be tested at the resolution of the display; for a sending device, it could be either the maximum the interface is capable of, or some standard resolution, e.g. the pixel dimensions of an HD television picture.

Wi-Fi (IEEE 802.11)

It is possible to construct a cage to isolate a device from outside radio signals, but that is a degree of rigor beyond what is usually warranted for energy efficiency testing. Many test environments, along with most urban places in general, will find several Wi-Fi networks visible. The Energy Star SNE test procedure takes two approaches to this. First it specifies removing the antennas from network equipment and attaching a coaxial cable that is connected to the test equipment. For devices without removable antennas, it does specify using a shielded enclosure. For end use devices, removable antennas are rare, but it seems unnecessary to use shielded enclosures unless data are produced that indicate that their use is needed.

The EU Broadband CoC specifies for the "idle" state, an access point being tested shall have "Beacon on, but no user traffic transmitted, no client associated".

The Energy Star SNE procedure specifies some details about various network and encryption settings, as well as frequency bands to use. Energy Star SNE specifies removing any removable antennas for Wi-Fi and connecting cables for testing. Removable antennas are common on network equipment (but not universal), but not on end-point Wi-Fi devices. For network equipment without removable antennas, the device is tested "inside a shielded enclosure". Integrated Access Devices are not tested with data on the WAN link, but only on LAN links (this is helpful as WAN test equipment is much less common and more expensive). Again, most of this detail only applies to network equipment (or similar devices such as some set-top boxes).

USNAP

USNAP (Utility Smart Network Access Port) is not a network technology itself, but rather an intermediate interface between a device and a network interface; a modular connection that enables a variety of network technologies to be used. This is designed for appliances and thermostats principally, and has a standard port that can accept modules that each support a different wired or wireless network technology. In this case the "no communication" method is easy to accomplish by not attaching any network module. Otherwise, a single network technology should be selected so that all products are tested the same (a wired technology would be simpler to test, though might be less common). Rules are needed for what to do if the device is shipped with one or more USNAP modules in the package, or if it is capable of supporting multiple modules at the same time (most likely to test with just one).

Network equipment specific requirements

Many requirements are specific to network equipment (in this case, set-top boxes can be considered similar to network equipment in that they often have technology-specific service provider interface types). Some of these, such as standard cable lengths, could be usefully transferred to other device types.

Telecom interfaces

Many interfaces were developed solely for voice communications attached to the telephone system (historically the traditional analogue phone system). These can be both upstream or downstream of a network device. The Energy Star SNE procedure tests none of these in active use (the only local wired interface type tested is Ethernet). By contrast, the EU Broadband CoC tests many, partly as it covers a wider range of devices. Table 1 below provides examples of how to configure various telecommunications interfaces in a standard way.

Table 1: EU Broadband Code of Conduct specific requirements for telecom interfaces (note: traffic rate requirements are listed elsewhere in this document)

ADSL2plus	Line is configured as per Broadband Forum Recommendation TR-100 [13], Table 7.3: Select a valid ADSL2plus specific test profile, configured in rate adaptive mode. Use a test loop of 1250m. The DSL line is active (in showtime) and passing user traffic: 3 Mbit/s downstream, 0,3 Mbit/s upstream
VDSL2 (8, 12a, 17a, but not 30a)	Line is configured as per Broadband Forum Recommendation TR-114 [14] Table 13 (Specific Line Settings): Select a valid VDSL2 profile line combination, for the governing profile bandwidth (namely 8, 12 or 17 MHz), configured in rate adaptive mode. Use a test loop of 300m for the 8 MHz profile and 150m for each of the 12 and 17 MHz profiles. The DSL line is active (in showtime) and passing user traffic: 10 Mbit/s downstream, 2 Mbit/s upstream
VDSL2 (30a)	Line is configured as per Broadband Forum Recommendation TR-114: Note: Since TR-114 does not specify any 30a profile for Region B (Europe), the line shall be configured as above with the following exceptions: VDSL2 Band Profile shall be: Profile 30a, using a valid Annex B PSD mask, configured in rate adaptive mode. Use a test loop of 100m. The DSL line is active (in showtime) and passing user traffic: 20 Mbit/s downstream, 5 Mbit/s upstream TR.114 Issue 2 (under development) will include profile 30a. Once finalized it will have to be used as line configuration reference
FXS	1 FXS port with phone connected (200 Ohm / 5m max cable length), phone on-hook, off hook detection active. Remaining FXS ports: no phone or other load connected, but able to detect a connection
ISDN S0	1 phone connected (5m max cable length), the phone is powered locally by its own power supply (i.e. it is not powered via the S0 interface), phone on-hook, off hook detection active. Remaining ISDN S0 ports: no phone or other load connected, but able to detect a connection.

As it is increasingly common to have a device that does Voice over IP over a broadband connection, test procedure content to test this functionality should be developed. Again, these details apply to network equipment.

Traffic Content and Levels

Once one has specified conditions for a data link and network parameters, there is the question of what the actual data being communicated should be and how much of it to present.

EU Broadband CoC defines a condition in which “the device is not processing or transmitting a significant amount of traffic, but is ready to detect activity”. Subsequently it then says that the CPU is “Not processing user traffic”. Some interface types do exchange data to maintain the data link; for example, Wi-Fi links have routine traffic that is not related to the “user”.

Both the Energy Star SNE and EU Broadband CoC procedures specify that all data transfer should be via UDP (not TCP). This avoids testing complexity introduced by using TCP. This is not expected to have any energy impact. UDP and TCP are methods to get data from one network host to another, independent of the physical layers below, and independent of the application sending the data.

The Energy Star SNE procedure specifies that data are to be “sent in a variety of datagram (or frame) sizes based on an Internet traffic mix (IMIX) sent at random intervals” and provides standard reference to IMIX (this describes a mixture of three packet sizes). The EU Broadband CoC procedure specifies that all packets should be 500 bytes in length. The TopRunner requirements for Small Routers specify packet lengths of 1,500 bytes. It is important to be specific in packet length descriptions, to clarify what headers are or are not included (e.g. UDP, IP, or Ethernet). The TopRunner Small Router requirements specify the layer 3 length. The SNE procedure includes the entire UPD packet (including header), but not the IP header or Ethernet header/footer. The CoC language is not clear which headers are or are not included, though the effect at 500 byte packets is not large. The SNE test procedure defines:

> "data rate" is the average number of bits per second passing over a link in one direction. Data rates are expressed as the average number of bits found in UDP data frames passing over a link in a one second period;

The Energy Star SNE test specifies that the actual data, and ports selected for the test, are to be random. Specifically:

> Port numbers for data traffic shall be randomly selected in advance of each test from the available pool of valid UDP ports. Once selected, port numbers shall not be changed for the duration of testing. If the selected port results in blocked traffic by a UUT firewall, select a different port at random before proceeding with the test.

By contrast, the TopRunner Small Router requirements specify that the data are all to be zero. This is not expected to affect energy use, but since the topic is new, it is best to err on the side of over-specifying conditions rather than miss something which actually does matter.

Energy Star SNE has a very low and very high speed test; EU Broadband CoC has a medium-high test. Both tests have an idle test with no data flowing at all (EU Broadband CoC says no "user" packets; this presumably to account for any data transferred as part of maintaining a link). The SNE very low rate is "1 kb/s (0.5 kb/s in each direction)" and is intended to be a 24-hour average of typical use. The EU Broadband CoC medium-high rates are shown in Table 2, and presumably are high usage rates that might occur in practice at some point on many links.

Energy Star SNE specifies standard high rates that are derived from the maximum rate of the link and Table 3. Because of headers, a 1 Gb/s link cannot deliver that amount of user data. These rates drive the link close to its capacity, but does so at standard rates, facilitating comparison among products (a separate test of actual maximum throughput is not part of an energy/power test).

Table 2: EU Broadband Code of Conduct traffic rate requirements

Downstream	Upstream	
		WAN
1 Mbit/s	200 kbit/s	WiMAX, 3G, LTE
3 Mbit/s	0.3 Mbit/s	ADSL2plus
10 Mbit/s	2 Mbit/s	VDSL2 (8, 12a, 17a, but not 30a), DOCSIS 2.0
20 Mbit/s	5 Mbit/s	VDSL2 (30a), 100 Mb/s Ethernet, Fibre Ptp 100 Mb/s, GPON, 1G-EPON, DOCSIS 3.0
50 Mbit/s	5 Mbit/s	10/1G-EPON, 1 Gb/s Ethernet
50 Mbit/s	10 Mbit/s	Fibre Ptp 1 Gb/s WAN, 10/10G-EPON, XG-PON1
		LAN
10 Mbit/s	10 Mbit/s	100 Mb/s Ethernet, Alternative LAN technologies (HPNA, MoCA, Powerline, POF...)
20 Mbit/s	20 Mbit/s	1 Gb/s Ethernet
5 Mbit/s	5 Mbit/s	Wi-Fi 802.11g or 11a
10 Mbit/s	10 Mbit/s	Wi-Fi 802.11n

The EU Broadband CoC "idle" test for Wi-Fi devices has no clients connected. The Energy Star SNE Wi-Fi tests all use a single client.

The EU Broadband CoC specification defines multiple states for WAN connections and wireless links. The Energy Star SNE document anticipates a single power state for network equipment.

While many technologies have fixed maximum rates, for some it is variable depending on the implementation and application, so that a direct mapping between Tables 2 and 3 is not always possible.

Table 3: Energy Star Small Network Equipment traffic rate requirements

Downlink	Uplink	
1.0 Mb/s	0.5 Mb/s	
2.0 Mb/s	1.0 Mb/s	
5.0 Mb/s	2.0 Mb/s	
10 Mb/s	5 Mb/s	
20 Mb/s	10 Mb/s	
50 Mb/s	20 Mb/s	

Note: higher or lower rates are created by simple extrapolation of this pattern.

The Energy Star SNE procedure specifies that "data shall be evenly split between both directions (transmission and reception) for a given link unless otherwise specified in this test procedure"

Energy Star SNE uses only one WAN port if more than one is available and specifies an order of interface type by which to choose it. The CoC specifies using two if two WAN ports are present and they are designed for simultaneous operation.

Energy Star SNE specifies some network configuration characteristics for the device, which addresses how the *content* of the data packets is treated.

Equipment Needed

The Energy Star SNE specification states that "A network traffic generator shall be used to simulate traffic and monitor link reliability. The generator shall be configured for the correct traffic topology and traffic profile, …". For devices other than network equipment, a computer could normally be used to provide the necessary data communications.

Set-top boxes

Set-top boxes are comparable to network equipment in many aspects, particularly for service provider network equipment like a DSL or cable modem.

The EU CoC for Digital TV Services specifies that DOCSIS/EuroDOCSIS interfaces be tested at the maximum data rate they support. It also specifies minimum data rates for video streams used to test the devices, one for standard definition, and one for high definition.

The Energy Star Set-top box specification test method defines "Head-end System Interaction" requirements for six different types of video provision systems. Some of these are continuous; others (e.g. terrestrial) are only operative when active.

Other topics

The following additional topics are relevant to network connectivity.

Terms

Harmonization and clear communication require clear and consistent terms. A common term here is for low power modes with network connectivity. More generally, IEC 62301 (2nd edition) defines "Network Mode(s)" as:

> any **product modes** where the energy using product is connected to a mains power source and at least one network **function** is activated (such as reactivation via network command or network integrity communication) but where the primary **function** is not active
>
> NOTE Where a network **function** is provided but is not active and/or not connected to a network, then this **mode** is not applicable. A network **function** could become active intermittently according to a fixed schedule or in response to a network requirement. A "network" in this context includes communication between two or more separate independently powered devices or products. A network does not include one or more controls which are dedicated to a single product. **Network mode** may include one or more standby **functions**.

The key point is that whenever network connectivity is active, the device is in a fundamentally different sort of state than when it is not.

Both the Energy Star SNE spec and EU Broadband CoC use "Alternative LAN Technologies" as a catch-all for wired interface types not otherwise specified.

The Energy Star PC spec defines "Network Interface":

> The components (hardware and software) whose primary function is to make the computer capable of communicating over one or more network technologies. Examples of Network Interfaces are IEEE 802.3 (Ethernet) and IEEE 802.11 (Wi-Fi).

Similarly, it defines "Full Network Connectivity" to speak to higher-level connectivity than just maintaining a link.

> The ability of the computer to maintain network presence while in Sleep Mode or another low power mode of equal or lower power consumption ("LPM") and intelligently wake when further processing is required (including occasional processing required to maintain network presence). Presence of the computer, its network services and applications, is maintained even though the computer is in a LPM. From the vantage point of the network, a computer with full network connectivity that is in LPM is functionally equivalent to an idle computer with respect to common applications and usage models. Full network connectivity in LPM is not limited to a specific set of protocols but can cover applications installed after initial installation. Also referred to as "network proxy" functionality

Finally, the Energy Star Imaging Equipment specification defines "Data Connection":

> A connection that permits the exchange of information between the imaging product and one external powered device or storage medium."

The 2005 Top Runner television spec defines "Digital network terminal" and refers to "i) iLink, ii) USB, iii) LAN, and iv) HDMI." though the 2009 version omits any reference to networking.

Product Definition

Sometimes network capability is integral to defining a product type. For example, in the Energy Star TV specification, a "Hospitality Television" must have specific communications features, specifically "a control port for bi-directional communication (DB-9, RJ11, RJ12, RJ45, coaxial cable, or HDMI-CEC)" and has software to utilize this ability.

Transition times

For network functionality, user experience, and energy savings, the amount of time it takes to transition from one mode to another can be important. The EU Broadband CoC specifies:

> When activity is detected on a component the appropriate components transition to the on- state. The transition time should be less than 1 second wherever possible in order to not adversely impact the customer experience. The detection of the Ethernet link may take more than 1 second, but must stay below 3 seconds. This longer transition time can be tolerated in this case because it requires some user interaction to bring up the link (e.g. connect a device or boot a PC).

The EU Digital TV Service CoC allows for 30 minutes of "housekeeping activities" after a device goes into a low-power mode before it is expected to be in its long-term stable state.

As another example, the Energy Star Computer specification defines a sleep state as taking no longer than five seconds of wake time, in recognition of the fact that when much longer than that, it is not useable for most people as a frequently used mode.

As a reference, auto-negotiation of an Ethernet link takes about two seconds. Some systems may drop the Ethernet link on going to sleep and so reestablish it on waking. Some PCs drop the link *rate* on going to sleep to save power and so need to renegotiate it at the higher rate on waking.

Cyclical activity and routine communication

Some devices need to wake periodically to do network maintenance functions so that test procedures need to account for these and measure an integral number of cycles covering both the low-power and active times. The EU Digital TV Service CoC specifies this. The Energy Star Set-top box specification limits such wake times to two hours per day. To some extent, activities like downloading an Electronic Programming Guide (EPG) depends on the number of channels present, so this may need to be defined to get consistent results during a test procedure.

IEC 62301 has text about cyclical functions in section B.2.3, and specifies that measurements that include them should be sure to cover an integral number of cycles so that the average is correct for the long-term average.

Network connected imaging equipment exposes information about its status to interested devices (e.g. PCs) primarily via the SNMP protocol (Simple Network Management Protocol). They also need to engage in ordinary network protocols such as ARP. If an imaging device wakes for these and stays awake for an extended time, it will lose much or all of its energy savings from sleep. The issue has been raised in development of the Energy Star specification and the next version may explicitly address it in the test procedure or requirements.

Power allowances

Since network interfaces introduce variations in product capability between products that affects power levels and energy use, it is common to provide additional allowances ("adders") for such functions. Usually the function must be active during the test, but some provide adders for inactive functions. The Energy Star PC and AV specs have sleep power adders for wake capabilities, mostly for the power needed to maintain the network link while asleep. Network equipment are tested in active, so the power is needed both for maintaining the link and processing the data on it. The Energy Star PC spec includes a large allowance for network "proxying".

If an allowance is to be granted for a function, then it should be exercised during the test.

Standards development

The EU Broadband CoC states that "signatories will endeavour to assist in the improvement of the existing low-power DSL standards, and the development of new ones as appropriate. " This is a unique requirement in that it is not on the product, but on the company making the product. It recognizes the key role that technology standards play in networks and their ability to enable energy savings. Similarly, the TopRunner requirements for Small Routers specifies:

(2) Actions of manufacturers

1) Efforts shall be made to promote development of energy-saving technologies for L2 switches and to develop those with excellent energy consumption efficiency.

This does not specify standards directly, but most of what can be done in this area does require standards development.

Standards development will sometimes be a subject of test procedures and regulations, and possibly testing, so that interested companies and others can affect the content of future versions of these through participation in standards development processes.

Analog interfaces

So far the discussion has not considered analogue interfaces. These are most common for communication, audio and video signals. Whether these ever do or should affect power use is not yet known. Test procedures typically do not require connecting analogue interfaces and reasons to do so will drop as digital ones take over. However, there may be exceptions, so this should be considered as methods are developed.

Loss of signal

The Energy Star AV spec defines "Loss of Signal (LOS)" as an indicator that a content stream has ceased, and when this continues for long enough power management can then engage. The spec states:

1) For audio signals, LOS is defined as:
   a) Analog inputs: Less than 1 dB above the measured noise floor for 60 seconds.
   b) HDMI: Receive <Inactive Source> or <Standby> signal over the CEC channel, or [Power Status] of an upstream device goes to "Standby" or "In Transition to Standby" over the CEC channel.
   c) Other Digital Inputs (e.g., Ethernet): No audio information in the data stream.
   d) Detectable cable disconnects.
2) For video signals, LOS is defined as:
   a) Analog Inputs: Loss of either the horizontal or vertical sync signal.
   b) HDMI: Receive <Inactive Source> or <Standby> signal over the Consumer Electronics Control (CEC) channel, or [Power Status] of an upstream device goes to "Standby" or "In Transition to Standby" over the CEC channel; or detection of a disabled TMDS link, a TMDS clock line signal below 22.5 MHz for more than one second, or a TMDS link operating outside of the valid frequency range.
   c) DVI: Detection of a disabled TMDS link, a TMDS clock line signal below 22.5 MHz for more than one second, or a TMDS link operating outside of the valid frequency range.
   d) Other Digital Inputs (e.g., Ethernet): No video information in the data stream.
   e) Detectable cable disconnects.

Some of these interfaces are also present on other device types so this table is well worth using elsewhere. This is important from a test procedure perspective to assess whether the product enters an automatic power management mode when there is no signal (as may be specified in some program requirements). A policy issue is whether it is necessary to test to verify these behaviors, or simply to accept assertions of them by the manufacturer.

Off modes

As devices that are off are not usually expected to perform network functions, there is no special test requirement for off. However, all configuration (physical and software), should remain the same as for other tests. Some PCs can retain some form of network connectivity in Off, though this feature is usually not enabled by default, so would not be evident in ordinary tests. However, products in low power modes where the network interface is active should be measured in this mode.

The EU Broadband CoC states that “Customer premises equipment is designed on the assumption that the equipment may be physically disconnected from the mains or switched off manually by the customer, from time to time, at his or her discretion.” This is to retain the option for people to engage in manual activity to reduce energy use below what automatic actions can accomplish. Whether people actually use this feature to save significant energy remains to be seen.

It may be necessary for a product that is in a “delay start” mode to receive information from a network. The power consumption with the network function active in these cases should measured.

Power management

Many policies recognize that saving energy in low-power modes has two components: reducing power levels, and changing operating patterns. This second aspect is generally covered through implementation of power management policies that move products automatically and effectively to lower power modes when possible. There are several elements to this. One is the basic ability of a device to recognize when power management might be possible, e.g. regarding user activity, data/network activity, and time. The second is the presence of an (internal) algorithm for automatic powering down that is both suitable for saving energy and compatible with people’s expectations and needs. Many specifications define this such as the EU Broadband CoC:

> Operational and control systems are specified on the presumption that hardware has power management built in, where applicable, i.e. depending on the functionality required of the unit, the hardware will automatically switch to the state with the lowest possible power consumption. … power management must not unduly impact the user experience, disturb the network, or contravene the applicable standards

The EU Digital Television CoC references user activity, as many do:

> auto power down feature that ensures that the Equipment automatically switches itself into the lowest standby mode which the service provider deems to be appropriate after a period of time in the on mode following the last user interaction.

Note that both of these are vague in not specifying details; most power management definitions have this character. Since many factors enter into power management algorithms, it is hard to be specific, and that risks unintentional problems. However, this also means that what manufacturers implement may or may not meet the goals of the policy. Another example definition is from the Energy Star display specification:

> Products shall offer at least one power management feature that is enabled by default, and that can be used to automatically transition from On Mode to Sleep Mode or Off Mode (e.g., support for VESA Display Power Management Signaling [DPMS], enabled by default).

This product class is amenable to a more specific description of when to power manage since it is confined to a single piece of information – the state of the sync signals on the data input line. However, not all displays follow this usage model so the spec further states:

> Products that generate content for display from one or more internal sources shall have a sensor or timer enabled by default to automatically engage Sleep or Off Mode.

Display power management is now on the verge of becoming more complicated.

More and more, sleep modes are associated with maintenance of network connectivity. This has always been the case for printers, so that the Energy Star imaging specification states:

> For products evaluated under the TEC test method, Sleep Mode permits operation of all product features (including maintenance of network connectivity),

Network connectivity is a primary determinant of the difference between sleep and off (though not the only or conclusive one in all cases).

Any test procedure needs to recognize that power management, whether internal and automatic, or coordinated through the network, will be present in a range of products. These types of features are likely to be more common, if not ubiquitous in the future. A test procedure does not define how a device is supposed to operate (or what requirements are to be met), but can only record how it does operate in carefully defined circumstances.

Policy context

Most of the material described above should be considered for inclusion in multiple standards for different products and countries. IEC 62301 is one of the first such standards to host such commonly useful information (non-product-specific) but there will be much more in future. The Lot 26 report identifies the need for a similar standard (or extension of 62301) to cover network issues, but that as that will take considerable time to develop, interim procedures will be needed (and the report provides an outline of one).

In the coming years, there are many more issues that will need to be addressed in a common way that are not done at all yet, or not done well enough. A list of these "gaps" should be developed.

Conclusions and Next Steps

Network connectivity introduces new complexities to energy test procedures and specifications. The challenge is to develop testing approaches that minimise the burden for manufacturers but do not undermine the validity of tests, as well as identify and verify any features that could save energy. The testing should also deliver what energy policy requires in terms of an assessment of all product types and verification of select program requirements.

This document has laid out many of the issues involved and has reviewed out some of the existing testing and policy approaches to the topic that may be useful on a global scale.

Many technical requirements in test procedures for networked products already exist. However, these are far from comprehensive and in some cases take divergent approaches. The two key international leaders are Energy Star (US EPA, but these are in effect global specifications) and the European Codes of Conduct, managed by the Joint Research Centre of the European Commission. Also relevant are IEC committees TC59 (appliances), and TC100 (audio, video and multimedia systems). To manage this profusion of content and documents, a "library" of discrete testing elements should be created so that the number of different approaches to the same problem is minimized, and to maximize clarity and harmonization.

To develop a global consensus on testing elements, initial discussions with these key stakeholders should be commenced with a view to preparing a global suite of test approaches for networked equipment. If there is good global agreement in the medium term, then consideration could be given to codifying this more formally.

Glossary

4E	IEA Implementing Agreement on Efficient Electrical End-use Equipment
AP	Wireless Access Point (AP or WAP)
ARP	Address Resolution Protocol for Internet Protocol Version 4 (IPv4)
AV	Audio visual equipment
CEC	Consumer Electronics Control protocol (under HDMI)
CoC	European Union Code of Conduct
DOCSIS	Data Over Cable Service Interface Specification
DPMS	Display Power Management Signaling
DSL	Digital Subscriber Line
EEE	IEEE 802.3az, Energy Efficient Ethernet
EPG	Electronic Program Guide
ES	Energy Star program (US EPA, DOE)
Ethernet	IEEE 802.3 wired network technology
EU	European Union
FireWire	IEEE 1394, also called i.Link
HDMI	High-Definition Multimedia Interface
IAD	Integrated Access Device
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IMIX	Internet Mix (of Internet traffic)
IP	Internet Protocol
ISO	International Standards Organisation
ITU	International Telecommunications Union
LAN	Local Area Network
LLDP	Link Layer Discovery Protocol
Lot 26	Study for EU Ecolabel on Network Standby
OSI	Open System Interconnection Model (ISO 7498)
PoE	Power over Ethernet
SNE	Energy Star Small Network Equipment process
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
USB	Universal Serial Bus
USNAP	Utility Smart Network Access Port
UUT	Unit Under Test
VESA	Video Electronics Standards Association
VGA	Video Graphics Array
VOIP	Voice Over Internet Protocol (see also IP)
WAN	Wide Area Network
WAP	Wireless Access Point – see AP
WLAN	Wireless Local Area Network
Wi-Fi	IEEE 802.11 – wireless network technology

References

Nordman, Bruce, Hans-Paul Siderius, Lloyd Harrington, Mark Ellis, and Alan Meier, *Network connectivity and low-power mode energy consumption*, Energy Efficient Domestic Appliances and Lighting, 2009. www.eedal.eu

Harrington, Lloyd, and Bruce Nordman, *Standby Power and Low Energy Networks – issues and directions*, Report for APP and IEA 4E Standby Annex, September 2010

Test Methods and Program Requirements

ENERGY STAR Test Method for Small Network Equipment, Draft 4 Rev. February 2011, energystar.gov/index.cfm?c=new_specs.small_network_equip

ENERGY STAR Program Requirements Product Specification for Set-top Boxes, Test Method Rev. Jan-2011, energystar.gov/index.cfm?c=revisions.settop_box_spec

ENERGY STAR Program Requirements Product Specification for Set-top Boxes, Eligibility Criteria Version 4.0, energystar.gov/index.cfm?c=revisions.settop_box_spec

ENERGY STAR Program Requirements Product Specification for Televisions, Test Method (Rev Aug-2010)

ENERGY STAR Program Requirements Product Specification for Audio/Video, Eligibility Criteria Version 2.1, energystar.gov/index.cfm?fuseaction=products_for_partners.showHomeAudio

ENERGY STAR Program Requirements Product Specification for Audio/Video, Test Method, energystar.gov/index.cfm?fuseaction=products_for_partners.showHomeAudio

ENERGY STAR Program Requirements Product Specification for Computers, Eligibility Criteria Version 5.2, energystar.gov/index.cfm?fuseaction=products_for_partners.showComputers

ENERGY STAR Program Requirements Product Specification for Computers, Test Method (Rev Aug-2010), energystar.gov/index.cfm?fuseaction=products_for_partners.showComputers

ENERGY STAR Program Requirements Product Specification for Displays, Eligibility Criteria Version 5.1, energystar.gov/index.cfm?fuseaction=products_for_partners.showMonitors

ENERGY STAR Program Requirements Product Specification for Displays, Test Method (Rev Aug-2010), energystar.gov/index.cfm?fuseaction=products_for_partners.showMonitors

ENERGY STAR Program Requirements Product Specification for Imaging Equipment, Eligibility Criteria Version 1.2, energystar.gov/index.cfm?fuseaction=products_for_partners.showPrintersScanners

ENERGY STAR Program Requirements Product Specification for Imaging Equipment, Test Method (Rev Dec-2010), energystar.gov/index.cfm?fuseaction=products_for_partners.showPrintersScanners

Code of Conduct on Energy Consumption of Broadband Equipment, Version 4, 10 February 2011, re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_broadband%20communication.htm

Code of Conduct on Energy Efficiency of Digital TV Services, Version 8, 15 July 2009, re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative_digital%20tv%20services.htm

Toprunner, Television Receiver Evaluation Standards Subcommittee Final Report, 2009, eccj.or.jp/top_runner/index.html

TREN/D3/91-2007/Lot 26 Preparatory Studies for Eco-design Requirements of EuP Study funded by the European Commission

Nissen, Nils F. , Lutz Stobbe, Karsten Schischke, Sascha Scheiber, Andreas Middendorf, Kurt Muehmel, Shailendra Mudgal, *EuP Preparatory Studies Lot 26: Networked Standby Losses: Final Report Task 8: Policy Options*, April 2011.