



Consumer Electronics in a Networked Digital World

An Overview of
Digital Living Network Alliance (DLNA®)
Interoperability



AN OVERVIEW OF DLNA®

Networked Consumer Electronics

Consumers have embraced digital technologies and given rise to the digital home. Over the past few years consumers have started to acquire, enjoy and manage an ever increasing amount of digital content. A large library of digital music, various photos from digital cameras or even from cell phones, home videos and more recently premium video content downloaded from the internet are just a few examples. The scale, options and size of digital content will only grow over the coming years. Along with the shift to digital content, consumers want an environment that allows all their devices in the home to easily work together regardless of vendor. This vision of the digital home integrates Personal Computers (PC), Consumer Electronics (CE) and Mobile Devices (MD) with a seamless interoperable network. It is also one that requires a common set of industry design guidelines to allow companies to build pervasive interoperability.

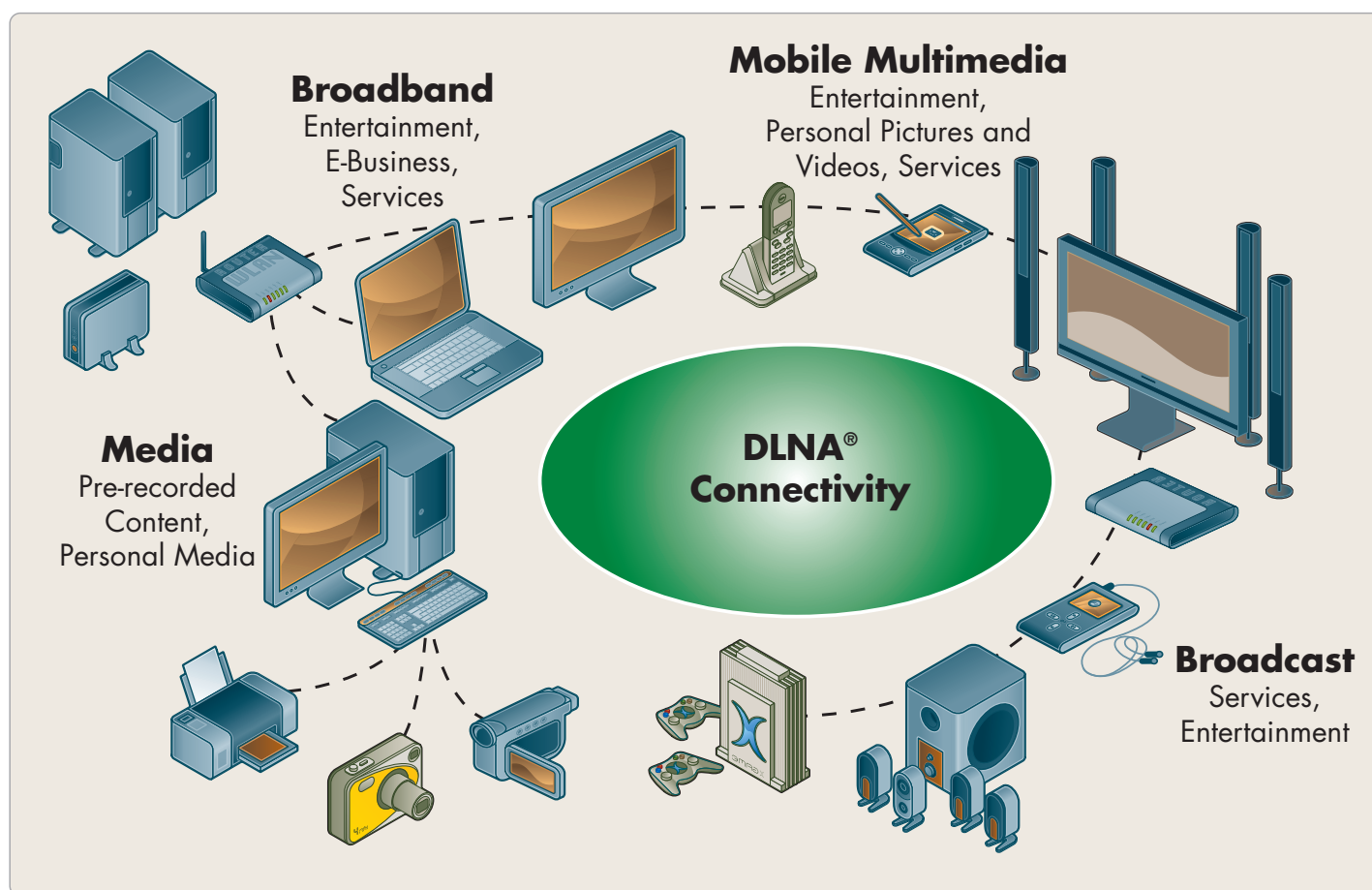


Figure 2.1 - Interoperable DLNA home network example

Evolution of DLNA

The Digital Living Network Alliance (DLNA) was formed to address the need for a common set of industry design guidelines. The DLNA Home Networked Device Interoperability Guidelines were created by a unique cross-industry effort that combined the efforts of over 250 Consumer Electronics, PC and Mobile Device companies from around the world who worked together with the aim of achieving the world's first substantial approach to true interoperability between personal computers, consumer electronics, and mobile devices. The Interoperability Guidelines provide product developers with a long-term architectural view, plus specific guidance for IP-networked platforms, devices and applications in the home.



The ability of DLNA to deliver workable interoperability guidelines in less than 12 months is largely due to the pioneering efforts of the Universal Plug and Play Forum (UPnP Forum - www.upnp.org). The mission of the Forum is simple: interoperability between devices using industry standards. To that end, the Forum selected TCP/IP as the basis for all network connectivity. Added to TCP/IP were Web standards such as HTTP, HTML, XML, and SOAP that provided the framework for device discovery, device and services description, control, and presentation.



With the core architecture defined, the Forum established a series of working groups to define device and service profiles for specific device categories. These categories include Audio/Video (AV), Internet Gateway Device (IGD), Printing, Scanning, Lighting Control, HVAC, and a number of others. The working groups – composed of member companies from relevant industries – delivered a series of XML schemas representing the baseline set of functions and services that each specific device type was required to support.

The most significant of the working groups efforts (at least in terms of digital media content) was the UPnP AV specification. In fact, it was so important that it became the basis for a new organization – DLNA. DLNA was formed in 2003 by 21 companies including Microsoft, Intel, HP, IBM, Sony, Philips, Toshiba, Pioneer, Motorola and Nokia, with the goal of accelerating the development and deployment of interoperable digital media devices for the home.

DLNA Device Model

The device model used by DLNA is derived from the UPnP Forum fundamental device model. This model consists of Devices, Services, and Control Points.

Devices are network entities that provide services and can contain other nested devices.

Services are the basic unit of control. They provide actions, and maintain status via state variables.

Control Points are network entities that are capable of discovering and controlling other devices on the network.

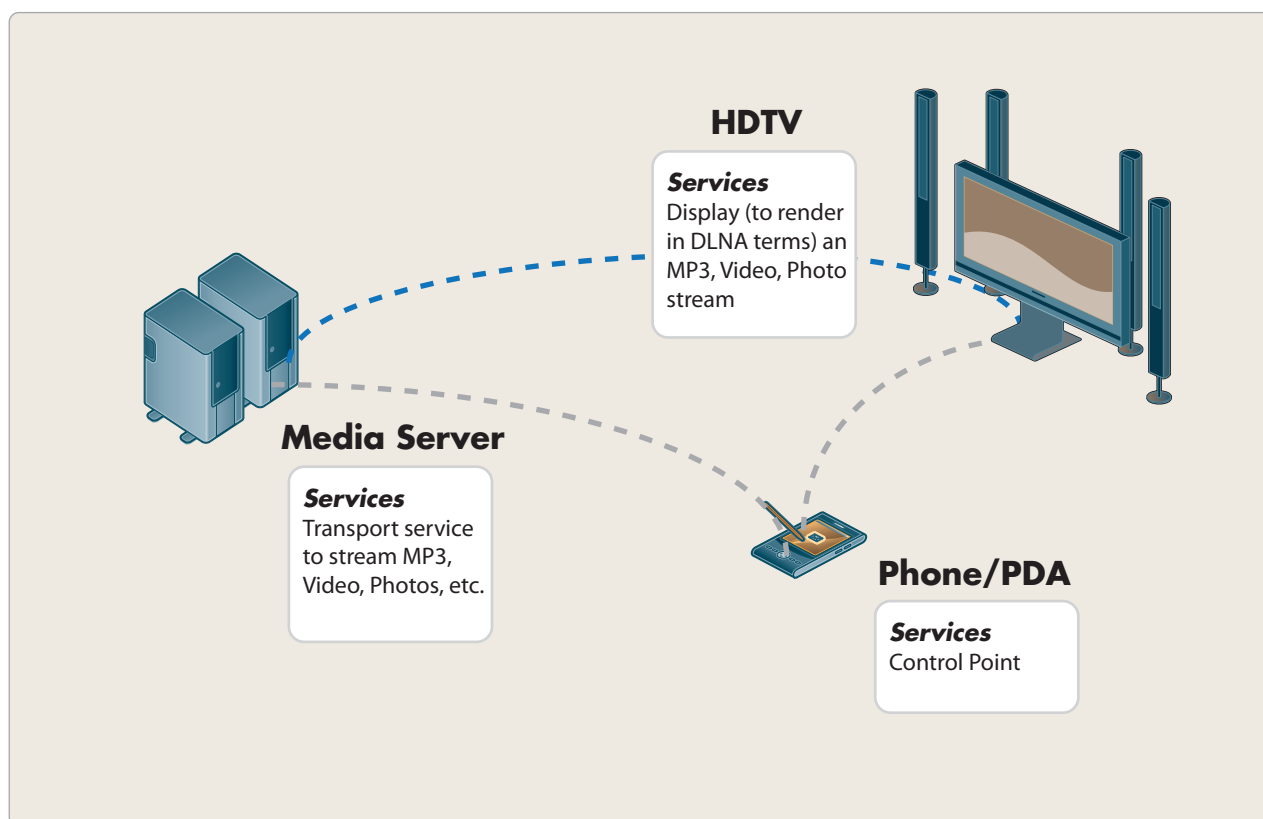


Figure 2.2 - DLNA devices interacting in a typical home environment.

In many cases it is very common for a DLNA *Device* to consist of multiple *Services* and potentially contain a *Control Point* as well. In Figure 2.2 above, the Media Server *Device* provides a transport service for streaming audio MP3 files, photos and movies stored on the internal RAID disks. The HDTV is a *Device* that provides a *Service* to display video content on the screen (in UPnP / DLNA terms it will render the content to the screen). The Phone / PDA is a *Control Point* used to tell the Media Server to stream stored content to the HDTV to display (or render) to the screen.

With the development of the UPnP AV (and thus DLNA) specifications for digital media content devices, the basic device model was extended. All control interaction (shown as dotted gray lines) only passes between a *Control Point* and *Device(s)*, but the *Devices* themselves interact (shown as dotted blue lines) with each other to pass digital content using a non-UPnP (“out-of-band”) communications protocol.

DLNA Device Categories and Classes

To better define the characteristics of devices and the services they offer, the DLNA Interoperability Guidelines define three *Device Categories*:

- Home Network Devices (HND)
- Mobile Network Devices (MND)
- Home Infrastructure Devices (HID)

Device Categories are based on a shared set of media formats and network connections with the focus on interoperability between devices within a category. *Devices* can and often do belong to more than one *Device Category*. The underlying requirement is that the *Device* must comply with the media formats and network connectivity of both categories.

Each *Device Category* is further broken into *Device Classes*. A *Device Class* specifies the functional capabilities of a device regardless of its physical attributes. In fact, a single physical device can, and frequently does incorporate multiple *Device Classes*. For interoperability, DLNA performs device certification at the *Device Class* level. All DLNA Certified™ devices must comply with all the requirements of the *Device Class(es)* that they belong.

The Home Network Device (HND) category is made up of five *Device Classes* that are in use in the home network, and rely on the same media formats and network connectivity requirements.

- Digital Media Server (DMS)
- Digital Media Renderer (DMR)
- Digital Media Controller (DMC)
- Digital Media Printer (DMP_r)
- Digital Media Player (DMP)

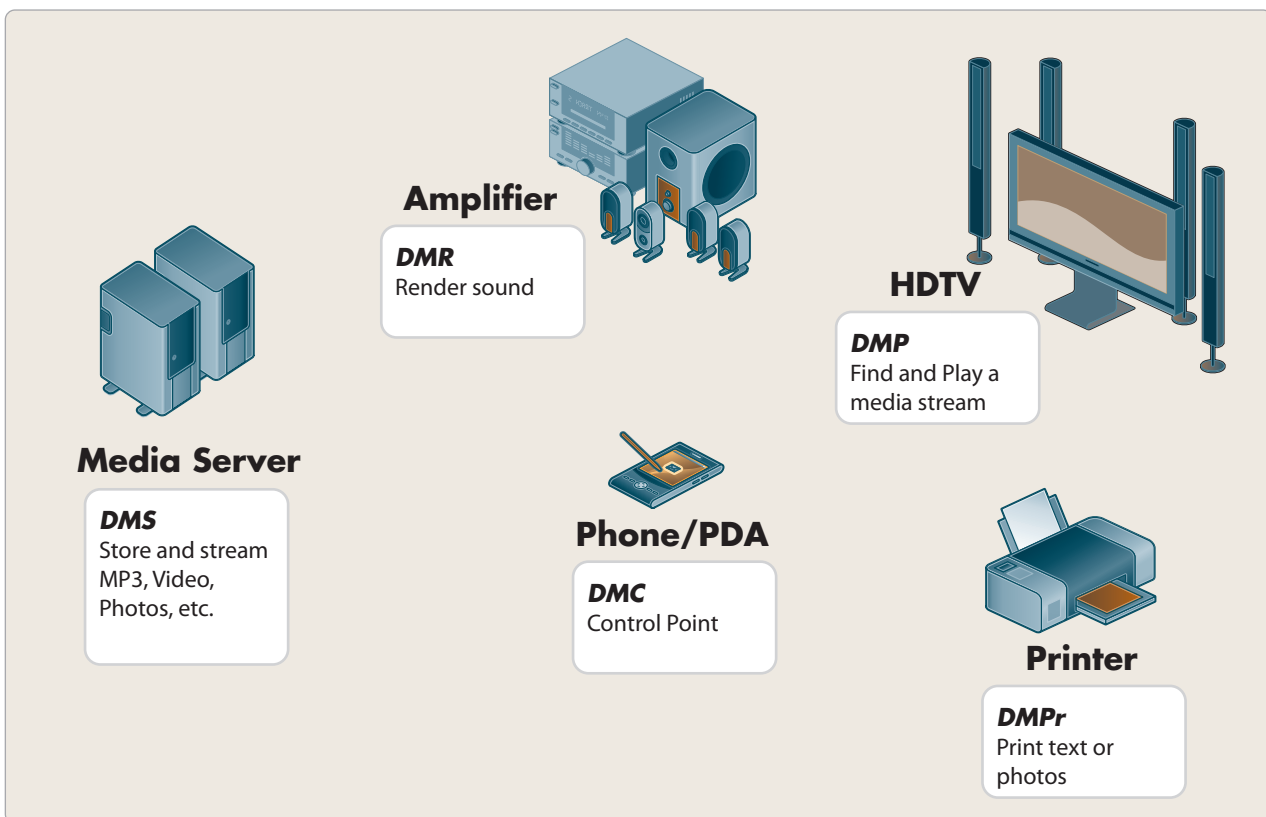


Figure 2.3 - DLNA Home Networking Device examples

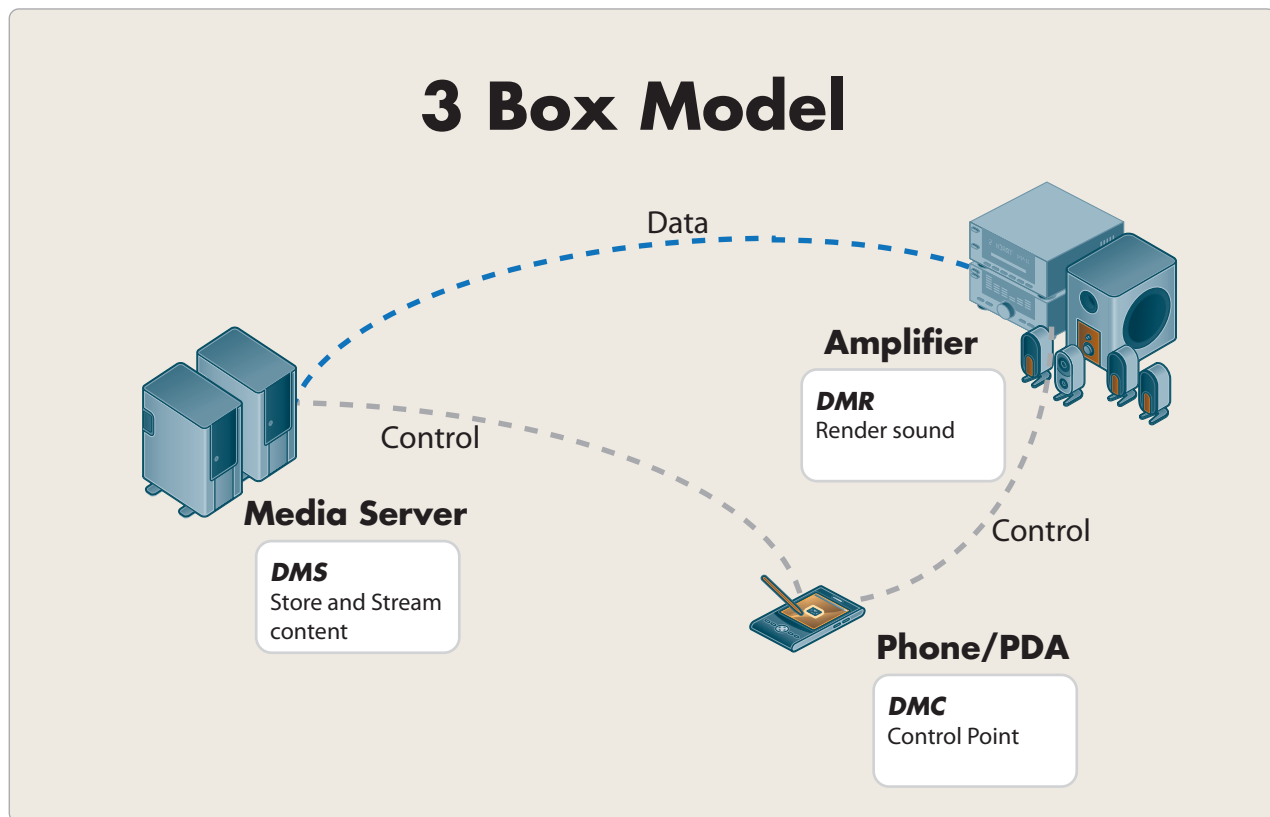


Figure 2.4 - DLNA 3 Box Model with a DMS, DMC and DMR

In the 3 Box Model (Figure 2.4) a consumer utilizes a DMC to discover DLNA devices on a home network. The DMC is used to browse and select content via a user interface (UI). The consumer continues by means of the DMC to select where the content will be rendered (or played). Then, with the standards based DLNA architecture, the devices automatically connect and the content is rendered (played) for the user. The five device classes within the HND category bring this about, however there are a few characteristics worth noting.

In an effort to initially simplify DLNA architecture, two specific models or scenarios were defined and utilized by manufactures of DLNA Certified products. The use of these scenarios bring to light various details about a DMP, DMR and DMC and how they interact in a DLNA home netowrking environment.

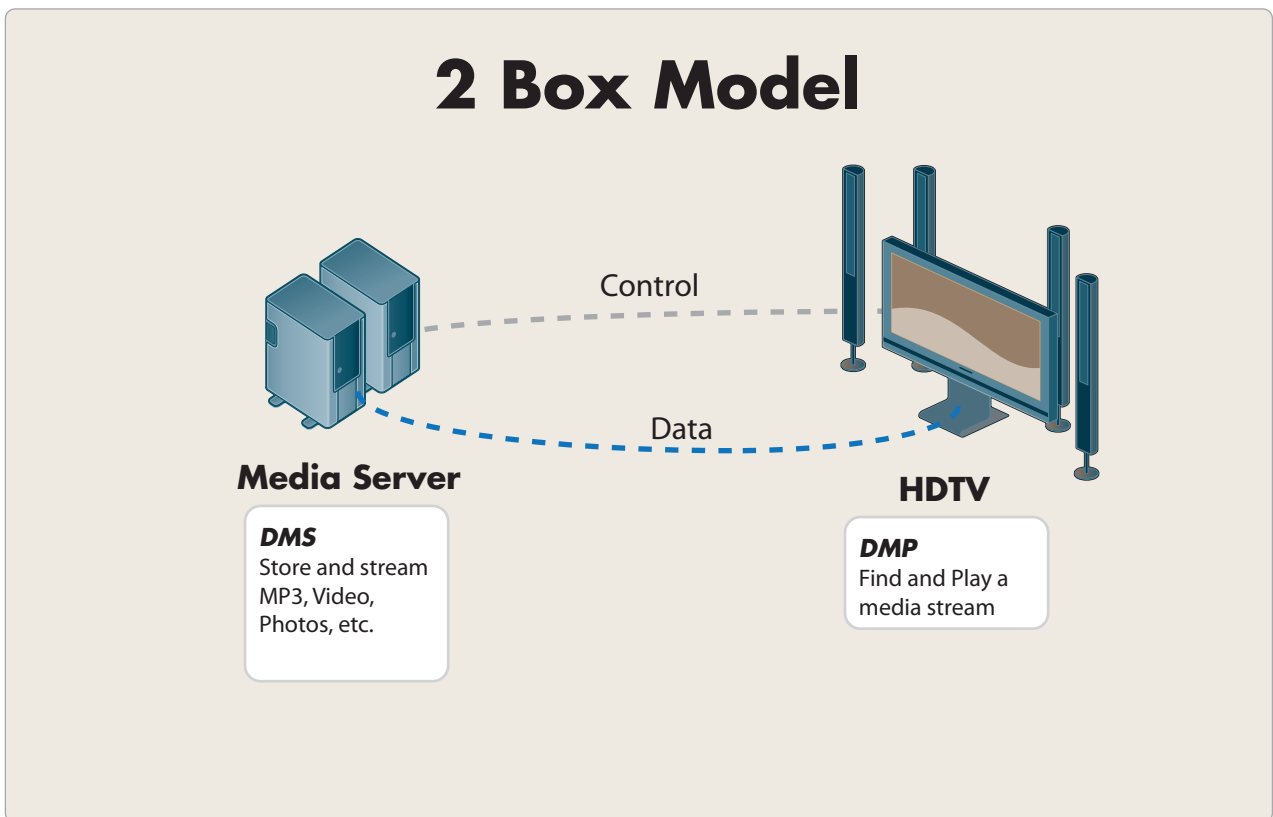


Figure 2.5 - DLNA 2 Box Model with a DMS and DMP

Figure 2.5 illustrates the DLNA 2 Box Model. The 2 Box model can be thought of as a special case of the 3 box implementation. In this use scenario, an HDTV acting as a DMP provides a consumer with an elegant user interface (UI) to find, browse, select and eventually view digital media. A DMP can be thought of as a combination of a DMC and DMR with a few additional characteristics. The DMC provides the control interface for finding, browsing and selecting content. The DMR provides the ability to render (or play) content to the wide screen TV. In the 3 Box model a DMC can discover and control (or cause) content to be rendered (or played) from any DMS to any DMR. In the case of a DMP and 2 Box Model, the DMC part of the DMP always selects the local DMR as the target renderer for all content. In addition the DMR in the 3 Box Model is always discoverable by other DLNA devices. The DMR within a DMP in the 2 Box Model is not discoverable (although some vendors also allow this DMR to be recognized outside of the DMP entity).

The Mobile Handheld Device (MHD) category is made up of five Device Classes that share the same usages models as the HND Device Category, but have different requirements for media format and network connectivity.

- Mobile Digital Media Server (M-DMS)
- Mobile Digital Media Controller (M-DMC)
- Mobile Digital Media Player (M-DMP)
- Mobile Digital Media Uploader (M-DMU)
- Mobile Digital Media Downloader (M-DMD)

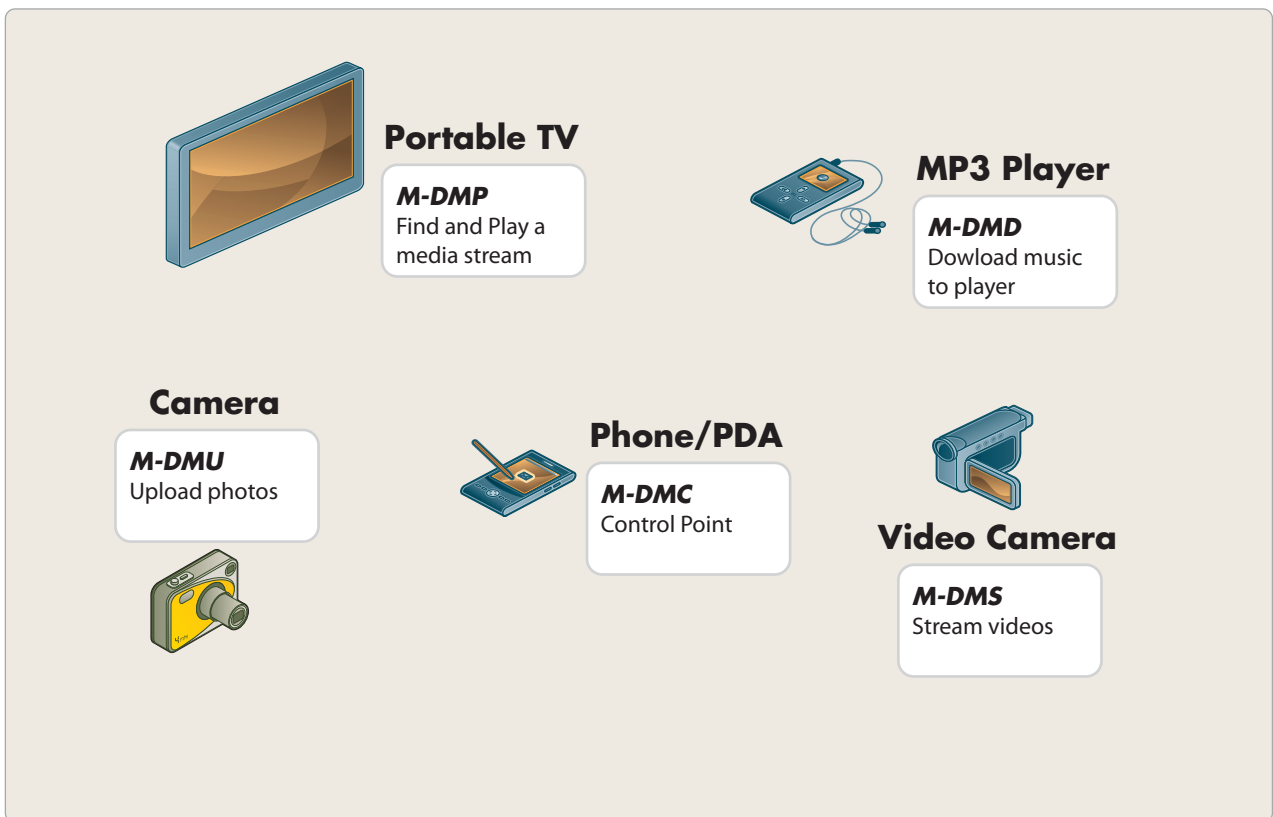


Figure 2.6 - DLNA Mobile Handheld Devices

Figure 2.6 illustrates the types of DLNA devices found within the Mobile Handheld Device category. It is important to note that just as the DMP could not be discovered in the HND the M-DMP Device Class is also undiscoverable by other DLNA devices.

The Home Infrastructure Device (HID) category is made up of two Device Classes. These devices are intended to allow HNDs and MHDs to interoperate.

- Mobile Network Connectivity Function (M-NCF)
- Media Interoperability Unit (MIU)

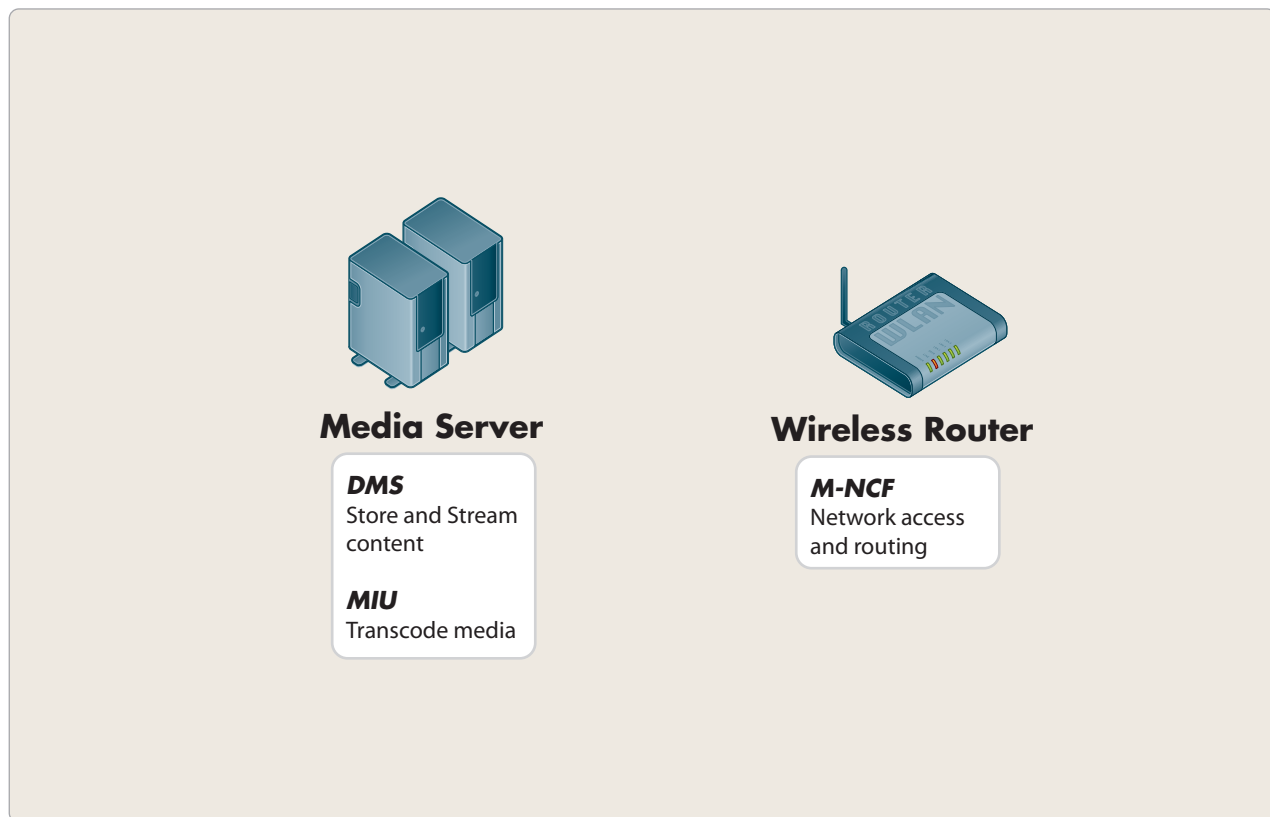


Figure 2.7- DLNA Home Infrastructure Device examples

Figure 2.7 illustrates examples of HID Devices in a home network. The Media Server is a member of the HND category as a DMS Device Class, this example shows the Media Server is also a member of the HID Device Category as a MIU Device Class. The MIU Device class provides a vital role in transcoding stored digital content into formats that mobile devices can consume. The M-NCF provides necessary access, routine and bridging functions to seamlessly connect mobile devices to a home network.

DLNA Architecture

Figure 2.8 illustrates the functional components of DLNA 1.5 as it relates to the Interoperability Guidelines network architecture. Each of the functional components are briefly discussed in the following sub-sections.

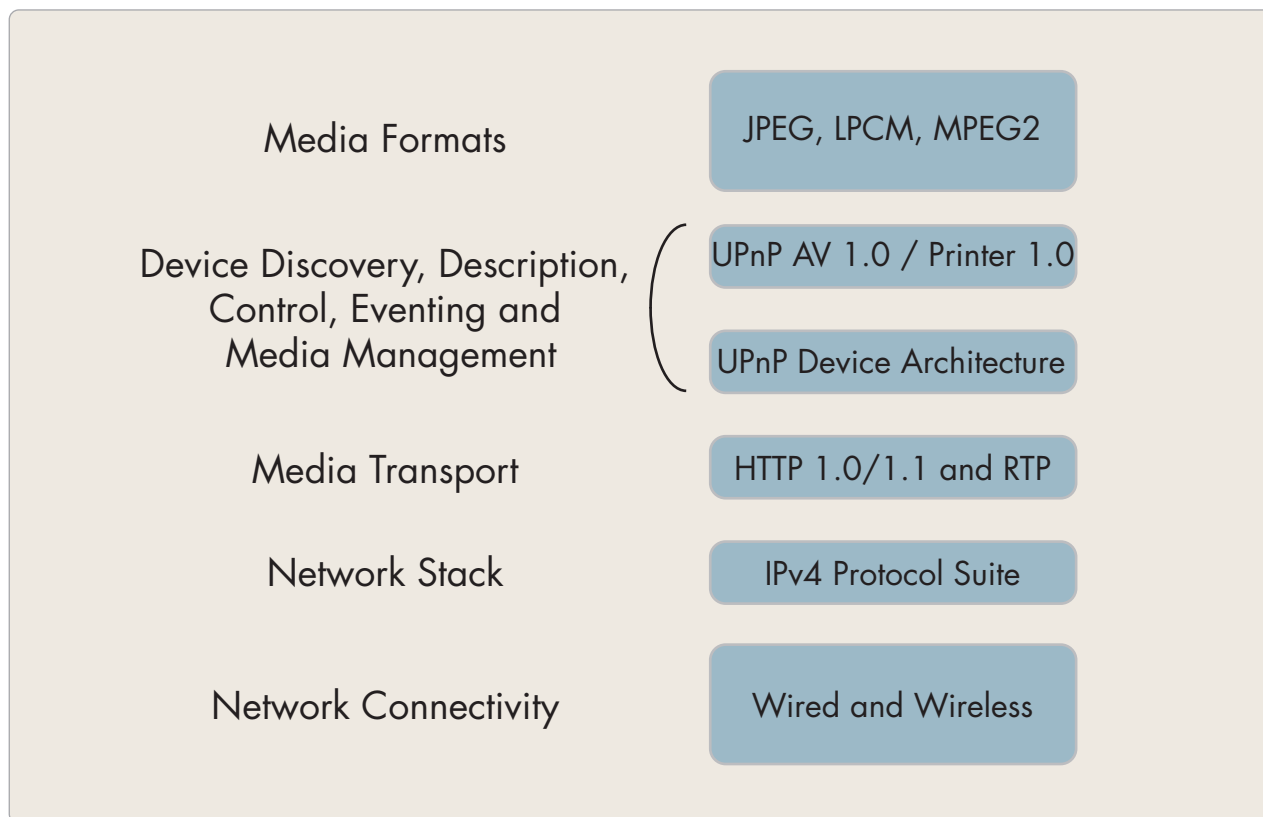


Figure 2.8 - DLNA Functional Component Architecture

DLNA Media Formats

Media Formats describe how digital content is encoded and formatted for each of the three *Media Classes*:

- Image
- Audio
- Audio Visual

Media format profiles are very explicit, with attributes, parameters, system, and compression level details defined in sufficient detail to ensure interoperability between DLNA Certified devices. The present set of *Media Formats* that must be supported by each specific device in a *Media Class* are listed in the Table 2.1. Optional media formats are also defined. The *Interoperability Guidelines* provide specific rules about using optional formats between compatible devices in addition to conversion between optional and mandatory formats.

Table 2.1 - Media Class mandatory and optional formats

Media Class	Mandatory Formats	Optional Formats
<i>Image</i>	JPEG	PNG, GIF, TIFF
<i>Audio</i>	LPCM	AC3, AAC, MP3, WMA9, ATRAC3plus
<i>Video</i>	MPEG2	MPEG1, MPEG4, VC1, MPV1

The focus on *Media Formats* is a key distinguishing factor between the UPnP Forum and DLNA. The UPnP Forum focused on achieving device interoperability, which was accomplished. But the lack of prescribed media profiles prevented the UPnP architecture from delivering media interoperability and led to the founding of DLNA.

DLNA Device Discovery, Description, Control, Eventing and Media Management

Device Discovery, *Description*, *Control* and *Eventing* enable a device on the home network to discover the presence and capabilities of other devices on the network and collaborate with these devices in a uniform and consistent manner. DLNA incorporates the UPNP Forum Device Architecture 1.0 as the basis for its device discovery and control.

Device Discovery

When a device is added to the network, the UPnP discovery protocol allows that device to advertise its services to control points on the network. Similarly, when a control point is added to the network, the UPnP discovery protocol allows the control point to search for devices of interest on the network. The message exchanged in both cases is a discovery message containing a few, essential specifics about the device, its services (such as the device type), an identifier, and an HTTP URL to access for more detailed information. The UPnP discovery protocol is based on the Simple Service Discovery Protocol (SSDP).

Description

After a control point has discovered a device, the control point needs to find out more about the device. For the control point to learn more about the device and its capabilities, or to interact with the device, the control point must retrieve the device's *Description* using the URL provided by the device in the discovery message. This URL points to a UPnP description document that is expressed in XML and includes vendor-specific information such as the model name and number, serial number, manufacturer name, URLs to vendor-specific web sites and URLs for control, eventing, and presentation.

The UPnP description document includes a list of *Device Services* provided by the device. For each *Device Service*, the *Description* includes a list of actions for the service, and arguments for each. The *Description* of a *Device Service* also includes a list of variables that reflect the state of the device. These variables are described in terms of their data type, range, and event characteristics.

Control

After a control point has retrieved the *Description* of the device, the control point can invoke actions that are supported by the device. To do this, a control point sends a suitable control message to the control URL for the service. Control messages are expressed in XML using the Simple Object Access Protocol (SOAP). Control actions are like function calls, and the device service will return action-specific values in response to the control message. The effects of the action may also be reflected by changes in the variables that describe the run-time state of the device.

Eventing

The UPnP description document for a service includes a list of variables that represent the state of the device. The device publishes updates whenever there is a change in the value of any evented variable. A control point may subscribe to receive this information by sending a GENA (General Event Notification Architecture) message. The device publishes updates by sending event messages. Event messages contain the names of one or more state variables and their current values. These messages are expressed in XML and sent using HTTP.

A special initial event message is sent when a control point first subscribes. This initial event message contains the names and values for all evented variables and allows the subscriber to initialize its model of the state of the service. To support scenarios with multiple control points, eventing is designed to keep all control points equally informed about the state of the device. This means that all subscribers are sent all event messages, and subscribers receive event messages for all evented variables that have changed.

Presentation

The presentation capabilities of a device enable HTML-based management of the device by the end user using a standard web browser. A control point can obtain the entry presentation URL from the device description document, retrieve the entry page from the URL, load the page into a browser, and start the user management of the device.

Media Management

Media Management enables devices and applications to identify, manage, and distribute digital media content across network devices. The *Interoperability Guidelines* incorporate the UPnP Forum AV technology as the basis for DLNA *Media Management*. There are four *Device Services* provided by this technology:

- Content Directory
- Connection Manager
- AV Transport
- Rendering Control

Content Directory

The *Content Directory* service provides a mechanism for each content server on the network to provide a uniform directory of all its available content to any interested devices on the network. Every content server must have an instance of this service.

This service might be used to display a list of songs stored on an MP3 player, still-images comprising various slide shows stored on a PC, movies stored in a DVD jukebox, TV shows currently being broadcast by a Set-top Box, songs stored in a media server, TV programs that had been downloaded to a PVR, photos stored in a digital camera, and many more. Nearly any type of content can be listed via the *Content Directory* service, even for devices that support multiple types of content. The information about the content (metadata) returned by the *Content Directory* service includes properties such as its name, artist, creation date, size, etc. In addition, the metadata also indicates the transfer protocols and data formats that are supported for each piece of content on the server. This information is used by the *Control Point* to determine if a given Media Renderer is capable of rendering the content in its current format or if some type of transcoding is required.

Connection Manager

The Connection Manager service determines how the digital media content can be transferred between two devices on the network. Each device that sends or receives content must implement the *Connection Manager* service. This service provides a mechanism for devices to:

- Match capabilities between server and render devices
- Set up and tear down connections between devices
- Discover information about current transfers in the network

AV Transport

The *AV Transport* service enables control over the “playback” of audio and video streams including the ability to Stop, Pause, Seek, etc. This service type defines a common model for *AV Transport* control suitable for a generic user interface. It can be used to control a wide variety of disc, tape, and solid-state media devices such as DVD/Bluray/CD players, VCRs, and MP3 players. Depending on the supported transfer protocols and data formats, this service may or may not be implemented.

Although most media will be sent across the network as data it may be more efficient to transfer the media data stream using other means. An example is when a personal video recorder is the DMS and a HDTV is the DMR. An Ethernet connection would not be as efficient as an HDMI or component video connection. Using a transfer medium that is not part of the TCP/IP network is called an “out of band” transfer. These transfers are not defined by the UPnP AV specification but are recommended and supported by the manufacturer of the media equipment.

Rendering Control

Most rendering devices contain a number of dynamically configurable attributes that affect how the current content is rendered. For example, video devices, such as HDTVs, allow user control of display characteristics such as brightness and contrast, while audio devices allow control of audio characteristics such as volume, balance, and equalizer settings. The *Rendering Control* service is intended to provide control points with the ability to query and/or adjust any rendering attribute that the device supports.

The *Rendering Control* service enables a control point to:

- Discover the attributes supported by the device.
- Retrieve the current setting of any supported attribute.
- Change the setting of any modifiable attribute.
- Restore the settings defined by a named preset.

DLNA Media Transport

Media Transport defines how content moves across the network. DLNA devices that send or receive any media content to/from the network must support HTTP 1.1 (including chunked transfer encoding, persistent connections, and pipelining) as the baseline transport mechanism. In addition, Real-time Transport Protocol (RTP) is available as an optional media transport protocol.

Network Stack

The basis for the DLNA *Network Stack* is TCP/IP v4. Every device must implement a DHCP client, and search for a DHCP server when first connected to the network. If a DHCP server is discovered, the device must use the IP address assigned by the server. If no DHCP server is discovered, the device must use Auto-IP to generate a link-local IP address.

Auto-IP uses an implementation dependent algorithm to generate an address in the 169.254/16 range. The first and last 256 addresses in this range are reserved and must not be used. After developing an address, the device must determine if the address is available by using an ARP probe. If the device receives a response, the address is assumed to be in use and the device must generate and test a new IP address.

An Auto-IP configured device must periodically check for the presence of a DHCP server. If a DHCP server is discovered, the device must switch to the IP address allocated to it by the DHCP server. In order to switch between IP addresses, the device must cancel any outstanding UPnP *Discovery* advertisements and re-issue them under the new address.

In addition to IP addressing, UPnP makes extensive use of both the UDP and TCP protocols. *Discovery* is implemented via an HTTP Multicast over UDP. This method is used by devices to advertise their presence to the network and by control points to discover what devices exist on the network. Definition, control, and eventing services are delivered via HTTP over TCP.

Network Connectivity

Three network connection technologies are incorporated in the DLNA 1.5 Interoperability Guidelines: 10Base-T and 100Base-T Ethernet (802.3i / 802.3u) for wired connections, WiFi (802.11a / 802.11b / 802.11g) for wireless connections, and Bluetooth for wireless connections for mobile handheld devices such as cell phones and PDAs. Additional network connections such as 1000Base-T Ethernet (802.3ab), WiFi (802.11n) and most Multimedia Over Coax Alliance (MoCA) will be added to the Guidelines in the future. It should also be noted that many other networking technologies such as LonWorks, CeBus, X-10, and Universal Powerline Bus (UPB) could be supported via UPnP Bridges.

Link Protection and Digital Rights Management (DRM)

When commercial content is made available for consumer electronics and mobile devices, it must be protected from unauthorized copying and use. Consumers now expect the capability to store, transfer and use their purchased content on any device at any location connected to wired or wireless digital networks. At this time UPnP and Digital Living Network Alliance (DLNA) are still working to provide a robust and versatile DRM solution capable of interacting with the breadth of proprietary solutions already installed. However, UPnP and DLNA along with many large industry players have approved DTCP-IP and Windows Media Digital Rights Management - Network Device (WMDRM-ND) technologies for the transport of protected content.

Certification

In order to ensure interoperability between DLNA devices, DLNA developed and manages a comprehensive certification program. Vendor products that successfully complete certification are awarded the DLNA Certified accreditation. This lets consumers know the product is fully DLNA compliant and interoperates with other DLNA Certified products. Look for the DLNA Certified logo on products and product packaging.



The initial step in obtaining certification calls for the manufacture of the product to subject the device to testing utilizing the DLNA's Conformance Test Tool (CTT). The CTT is a suite of tests that are run by the vendor against the product, and validate the devices' compliance with DLNA standards. The test harness for the CTT is a single Windows PC with the device under test connected via a DLNA defined network connection technology (Ethernet, WiFi, Bluetooth). When the device successfully passes the CTT as determined by the CTT's log file, it can begin the formal DLNA certification process.

The formal certification process entails submitting the CTT log and a product's UPnP certificate to DLNA. Next step is scheduling a test session with one of the Independent Certification Vendors (ICV) approved by DLNA. The ICV will test the submitted product per DLNA's Certification Test Plan (CTP) against 3 reference devices of the appropriate device class. For example, the ICV would test a DMP device against 3 DMS reference devices, while a DMC would be tested against 3 DMR and 3 DMS reference devices.

In addition to its formal certification program, DLNA conducts "plugfests" (interoperability workshops) on a regular basis. The plugfests are held each calendar quarter in various locations around the world in order to allow maximum participation from device vendors across the globe. These plugfests provide DLNA member companies the opportunity to test products under development against other member's products using DLNA test tools, and are an excellent dress rehearsal for DLNA certification testing.