Software Architecture for Networked Digital Media
Networked Digital Media Protocols

- Overview of protocols used by networked digital media devices such as music players, media servers, media adapters, etc.
- Description of UPnP™ and DLNA architecture and implementations
Traditional Consumer Electronics + Digital + Network

- CD players
- DVD players
- Stereos
- TV
- Cameras/Camcorders
- Etc.
Networked Digital Media Products

- New Networked Digital Media Devices
  - MP3 players
  - Music Jukeboxes
  - PCs
  - Electronic Picture Frames
  - Media Adapters
  - Whole House Media Servers (100Gb+)
  - Etc.
Networked Digital Media Protocols

- UPnP Forum - AV, Core, GENA, SSDP
- W3C - XML, SOAP
- IETF - HTTP, TCP, UDP, IP
- Media Formats - MP3, JPEG, MPEG, etc.
- Physical Media - Ethernet, 802.11a/b/g, etc.
- DLNA - Protocol Profiles to promote interoperability
Home Networking Protocols
Formerly Universal Plug and Play
> 700 Members
Core Protocols - SSDP, GENA, etc.
Working Groups
  Audio Visual - AV
  Internet Gateway - IGD
  Printing, Home Automation, etc.
Digital Living Network Alliance

Digital Home Working Group - DHWG

> 150 members

Protocol Profiles to promote interoperability

Profiles are side set to UPnP AV

Restrictions on use

Additional definitions for special services
# UPnP Architecture

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<th>Physical Media</th>
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**Internet Gateway Device, Media Server, Media Renderer, UPnP Printer**

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## Explanation
- **Physical Media**: Ethernet, WiFi, HomePlug, Bluetooth, Firewire, etc.
- **Network**: IP
- **Transport**: TCP
- **General Core**: SSDP, SOAP, GENA, HTML
- **UPnP Core**: Discovery, Description, Control, Events, Presentation, Streaming
- **UPnP Application**: Internet Gateway Device, Media Server, Media Renderer, UPnP Printer
## UPnP Architecture

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Home Network Physical Layer

- Ethernet - 10BT/100BT
- WiFi - 802.11a/b/g
- HomePlug
- Mixed - any that will run Internet Protocols
- Bluetooth
- Firewire
- Etc.
### UPnP Architecture

#### UPnP Application
- Internet Gateway Device, Media Server, Media Renderer, UPnP Printer

#### UPnP Core
- Discovery: SSDP
- Description: XML
- Control: SOAP
- Events: GENA
- Presentation: HTML

#### General Core

#### Transport
- Streaming: HTTP
- UDP
- TCP

#### Network
- IP
- Ethernet, WiFi, HomePlug, Bluetooth, Firewire, etc.

#### Physical Media
Home Network - Network & Transport

- TCP/UDP/IP Suite - Used WAN & LAN
- IP - Internet Protocol Packet Services
- TCP - Transmission Control Protocol
  - Session established between two nodes
  - Assured delivery
- UDP - User Datagram Protocol
  - Unicast and Multicast
  - Short, Single packet transmissions
## UPnP Architecture

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UPnP AV Architecture

- Media Controller
  - UPnP AV Actions and Events
    - Media Server
    - Media Renderer
      - Digital Media Stream
Media Server
- Discoverable UPnP Device
- Source of Digital Media Content
- Receives Content Directory Actions
- Receives Connection Manager Actions
- Receives AV Transport Actions
Media Renderer
- Discoverable UPnP Device
- Destination for Digital Media Content
- Receives Rendering Control Actions
- Receives Connection Manager Actions
- Receives AV Transport Actions
Media Controller
- Discovers UPnP Servers and Renderers
- Sends Content Directory Actions to Servers
- Sends Rendering Control to Renderers
- Sends Connection Manager Actions to Servers and Renderers
- Sends AV Transport Actions to Servers and Renderers
Media Server with Private Media Controller

- Discoverable UPnP Device
- Provides standard UPnP services to all controllers
- Built-in controller finds and controls only UPnP Renderers
Media Renderer with Private Media Controller

- Discoverable UPnP Device
- Provides standard UPnP services to all controllers
- Built-in controller finds and controls only UPnP Servers
Media Renderer with Media Server and Private Media Controller

- Discoverable UPnP Device
- Provides standard UPnP AV services to all Controllers
- Built-in controller finds and controls UPnP Servers for local Renderer
- Built-in controller finds and controls UPnP Renderers for local Server
UPnP AV Variations

- DLNA Digital Media Player
  - Non-Discoverable UPnP Device
  - Private Media Renderer (controlled locally)
  - Private Media Controller discovers and controls only Media Servers
- DLNA Digital Media Server
  - Standard UPnP AV Media Server
Media Server Service

DIDL - XML based representation of media library

Containers and object
  - Album - Song, Vacation - Photo, Action - Movie

Browsing - positional reading

Searching - metadata filters
Media Renderer Service
Volume, Brightness, Contrast, etc.
Control Point can
- Discover device attributes
- Retrieve current settings (!!!!)
- Change settings
- Restore default settings
Media Server and Renderer Service

Used by Control Point to determine

- Capabilities - Audio, Video, Still
- Media Formats - MP3, MPEG-2, JPEG, etc.
- Availability - Bandwidth, etc.
- Current Activity - What’s playing?
Media Server and Renderer Service

- Optional
- Play, Pause, Stop, Seek, FF, etc.
- Renderer Control - Pull Model
- Server Control - Push Model
- Can be used for Out-Of-Band control
  - S-Video for PVR->TV
  - Isochronous Wireless for Video Streams
DLNA Digital Media Formats

- DLNA Minimum Media Formats
  - Audio - LPCM
  - Image - JPEG
  - Video - MPEG-2

- DLNA Optional Media Formats
  - Audio - MP3, AAC
  - Image - PNG
  - Video - MPEG-4
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- Ethernet, WiFi, HomePlug, Bluetooth, Firewire, etc.
- UPnP Devices use HTTP servers for most services with HTTP client for events
- UPnP Control Points use HTTP clients for most services with HTTP server for events
- HTTP 1.1 required
  - Persistent connections
  - Chunked encoding of variable data
## UPnP Architecture

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- **Discovery**
  - SSDP
  - HTTP
- **Description**
  - XML
- **Control**
  - SOAP
- **Events**
  - GENA
- **Presentation**
  - HTML
- **Streaming**
Process independent data description

- Designed for document exchange
  - Human and machine readable
- Extensible (eXtensible Markup Language)
- Internal processing/format undefined
- Transport Independent
  - HTTP, Email, FTP, Serial Link, Diskette, etc.
- UPnP uses XML over HTTP
Embedded XML Characteristics

- Limited Resource Environment
- Defined Storage Format
- Low Syntax Volatility
  - Dedicated XML documents for a UPnP device
- Well-formed Documents are required
- Validated Documents are not required
  - Micro Parsers (non-validating) can be used
<?xml version="1.0"?>
<AddressParameters>
  <IpAddress>123.45.67.123</IpAddress>
  <SubnetMask>255.255.255.0</SubnetMask>
  <Gateway>123.45.67.200</Gateway>
</AddressParameters>

typedef struct {
  char    fIpAddress[4];
  char    fMask[4];
  char    fGateway[4];
} myAddress;
### UPnP Architecture

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#### Key Protocols
- **SSDP**: Used for device discovery
- **XML**: Markup language for describing devices
- **SOAP**: Simple Object Access Protocol for remote procedure calls
- **GENA**: General Network Access protocol
- **HTML**: HyperText Markup Language
- **HTTP**: Hypertext Transfer Protocol
- **UDP**: User Datagram Protocol
- **TCP**: Transmission Control Protocol
- **IP**: Internet Protocol
- XML objects over HTTP
- Envelope and Body objects
- Special HTTP header - Soap-Action
- Widely adopted in corporate Web Services
- UPnP and DLNA specify SOAP 1.1
<s:Envelope
    xmlns:s="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:xsi="http://www.w3.org/1999/XMLSchema-instance"
    xmlns:xsd="http://www.w3.org/1999/XMLSchema">
    <s:Body>
        <m:sayHello xmlns:m='urn:Example1'>
            <name xsi:type='xsd:string'>James</name>
        </m:sayHello>
    </s:Body>
</s:Envelope>

Namespaces indicate scope for particular elements/attributes.
“s”, “xsi” and “xsd” defined for entire document.
“m” defined for sayHello element.
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Simple Search/Discovery Protocol (SSDP)
UDP multicast based
Control Points
  Search (all, by type, by id)
  Listen
Devices
  Respond to Search requests
  Announce availability/shutdown
NOTIFY * HTTP/1.1
HOST: 239.255.255.250:1900
CACHE-CONTROL: 300
LOCATION: http://169.254.17.39/MyMediaRenderer.xml
NT: upnp:rootdevice
NTS: ssdp:alive
SERVER: Allegro RomPager 4.32 UPnP/1.0 Streamium/1.0
USN: 4F3G-014579-AEFEEA-234567-000017

CACHE-CONTROL - seconds until advertisement expires
LOCATION - URL of root device description
NT - Type of search
USN - UUID of this device
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UPnP protocols include:
- **SSDP**: Service Discovery Protocol
- **UDP**: User Datagram Protocol
- **TCP**: Transmission Control Protocol
- **HTTP**: Hypertext Transfer Protocol
- **XML**: Extensible Markup Language
- **SOAP**: Simple Object Access Protocol
- **GENA**: General Encapsulation for Network Access
- **HTML**: HyperText Markup Language
XML over HTTP

Description of
- Device types (IGD, MR, MS, etc.)
- Device services
- Manufacturers information
- Unique Device Identity
- HTTP URLs for Actions, Events, Presentation
<?xml version="1.0"?>
<root xmlns="urn:schemas-upnp-org:device-1-0">
  <specVersion>
    <major>1</major> <minor>0</minor>
  </specVersion>
  <device>
    <deviceType>urn:schemas-upnp-org:device:MediaRenderer:1</deviceType>
    <friendlyName>short user-friendly title</friendlyName>
    <manufacturer>manufacturer name</manufacturer>
    <manufacturerURL>URL to manufacturer site</manufacturerURL>
    <modelDescription>long user-friendly title</modelDescription>
    <modelName>model name</modelName>
    <modelNumber>model number</modelNumber>
    <modelURL>URL to model site</modelURL>
    <serialNumber>manufacturer's serial number</serialNumber>
    <UDN>uuid:UUID</UDN>
    <UPC>Universal Product Code</UPC>
  </device>
</root>
<serviceList>
  <service>
    <serviceType>urn:schemas-upnp-org::RenderingControl:1</serviceType>
    <serviceId>urn:upnp-org:serviceId:RenderingControl</serviceId>
    <SCPDURL>URL to service description</SCPDURL>
    <controlURL>URL for control</controlURL>
    <eventSubURL>URL for eventing</eventSubURL>
  </service>
  <service>
    <serviceType>urn:schemas-upnp-org::ConnectionManager:1</serviceType>
    <serviceId>urn:upnp-org:serviceId:ConnectionManager</serviceId>
    <SCPDURL>URL to service description</SCPDURL>
    <controlURL>URL for control</controlURL>
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</serviceList>
<presentationURL>URL for presentation</presentationURL>
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POST /ServerControl HTTP/1.1
HOST: 169.254.17.39:8181
CONTENT-TYPE: text/xml; charset="utf-8"
CONNECTION: close
SOAPACTION: "urn:schemas-upnp-org:service:ContentDirectory:1#Browse"

<s:Envelope
xmlns:s="http://schemas.xmlsoap.org/soap/envelope/"
s:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
<s:Body>
<u:Browse xmlns:u="urn:schemas-upnp-org:service:ContentDirectory:1">
<ObjectID>0</ObjectID>
<BrowseFlag>BrowseDirectChildren</BrowseFlag>
<Filter>*</Filter>
<StartingIndex>0</StartingIndex>
<RequestedCount>10</RequestedCount>
<SortCriteria></SortCriteria>
</u:Browse>
</s:Body>
</s:Envelope>
HTTP/1.1 200 OK
CONTENT-TYPE: text/xml; charset="utf-8"
Date: Mon, 09 Aug 2004 15:02:55 GMT
Content-Length: 1028
Server: Allegro-Software-RomPager/4.32

<s:Envelope
    xmlns:s="http://schemas.xmlsoap.org/soap/envelope/"
    s:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
    <s:Body>
        <u:BrowseResponse xmlns:u="urn:schemas-upnp-org:service:ContentDirectory:1">
                &lt;container id="947" parentID="0" restricted="1" childCount="5">
                    <dc:title>Playlists</dc:title>
                    <upnp:class>object.container</upnp:class>
                </container>
                &lt;container id="948" parentID="0" restricted="1" childCount="15">
                    <dc:title>AudioItems</dc:title>
                    <upnp:class>object.container</upnp:class>
                </container>
            </DIDL-Lite>
            <NumberReturned>2</NumberReturned>
            <TotalMatches>2</TotalMatches>
        </u:BrowseResponse>
    </s:Body>
</s:Envelope>
<u:BrowseResponse xmlns:u="urn:schemas-upnp-org:service:ContentDirectory:1">
  <Result>
    <DIDL-Lite xmlns="urn:schemas-upnp-org:metadata-1-0/DIDL-Lite/"
               xmlns:dc="http://purl.org/dc/elements/1.1/"
               xmlns:upnp="urn:schemas-upnp-org:metadata-1-0/upnp/"> 
      <container id="947" parentID="0" restricted="1" childCount="5">
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**UPnP Architecture**
- GENA - Generalized Event Notification Architecture
- HTTP like protocol
- Control Point(s) issue Subscribe and Unsubscribe commands
- Device sends Event Notifications to subscribers using HTTP Client to Control Point HTTP Server
SUBSCRIBE /RenderControlSubs HTTP/1.1
HOST: 169.254.17.39
CALLBACK: http://169.254.42.57/Notifications
NT: upnp:event
TIMEOUT: 3600

Host is device address
Callback is Control Point URL for notifications
Timeout value is subscription duration request seconds

HTTP/1.1 200 OK
SID: uuid:BBFEAA-10244096-000037
TIMEOUT: 900

Timeout value is actual subscription duration seconds
NOTIFY /NotificationSink HTTP/1.1
HOST: 169.254.42.57:4004
NT: upnp:event
NTS: upnp:propchange
SID: uuid:c0a80249-3f03c2c4
SEQ: 5
Content-Type: text/xml; charset="utf-8"

<e:propertyset xmlns:e="urn:schemas-upnp-org:event-1-0">
  <e:property>
    <LastChange>
      <Event xmlns="urn:schemas-upnp-org:metadata10/RCS/"
      InstanceID val="0">
        <Mute channel="Master" val="1"/>
      </InstanceID>
    </Event>
  </LastChange>
</e:property>
</e:propertyset>
## UPnP Architecture

### Physical Media
- Ethernet, WiFi, HomePlug, Bluetooth, Firewire, etc.

### Network
- IP

### Transport
- UDP
- TCP
- HTTP

### General Core
- SSDP
  - XML
  - SOAP
  - GENA
  - HTML

### UPnP Core
- Discovery
- Description
- Control
- Events

### UPnP Application
- Internet Gateway Device, Media Server, Media Renderer, UPnP Printer
- Streaming

## UPnP Applications

<table>
<thead>
<tr>
<th>UPnP Application</th>
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<tbody>
<tr>
<td>UPnP Core</td>
<td>Discovery, Description, Control, Events, Presentation, Streaming</td>
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HTML over HTTP (Web-based management)
Human accessible control of device
Windows XP Control Point will dispatch to Internet Explorer
Separate Web server may be used, distinguished by server port
# UPnP Architecture

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</table>

- SSDP: Internet Gateway Discovery Protocol
- UPnP Core: UPnP Application
- General Core: Discovery, Description, Control, Events, Presentation
- Transport: SSDP, UDP
- Network: Ethernet, WiFi, HomePlug, Bluetooth, Firewire, etc.
- Presentation: Streaming
UPnP Media Streaming is Out-Of-Band
- Any protocol and physical media
- Non-Internet Protocols and Media

DLNA Media Streaming
- HTTP Streaming required
- HTTP GET from Renderer to Server
- Intermediate buffer delivery
- Other protocols and physical media optional
UPnP Architecture

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Internet Gateway Device, Media Server, Media Renderer, UPnP Printer

Physical Media

Network

Transport

General Core

UPnP Core

UPnP Application
Allegro provides highly portable software toolkits that help embedded device manufacturers build Internet connectivity for machine-to-people and machine-to-machine applications.
## Allegro Product Family

### Web Servers
- RomPager Basic
- RomPager Advanced
- SoftPages
- Remote Host
- Graphlets
- RomPager Secure

### SMTP Clients
- RomMailer Basic
- RomMailer Standard
- RomMailer Advanced

### POP3 Clients
- RomPOP Basic
- RomPOP Standard
- RomPOP Advanced

### Command Line
- RomTelnet
- RomConsole
- RomCLI
- RomCLI Secure

### UPnP Toolkits
- RomPlug Basic
- RomPlug Advanced
- RomPlug Control

### XML Translator
- RomXML

### DNS Client
- RomDNS

### NTP Client
- RomTime

### RomPager Scheduler and Core Services

<table>
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<tr>
<th>OS Services</th>
<th>TCP</th>
<th>File System (optional)</th>
<th>UDP (optional)</th>
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RomPlug Toolkits

- Basic Device
  - Simple Discovery, Description, Presentation
  - No SOAP, or XML parsing required

- Advanced Device
  - Full UPnP Implementation
  - Optional IGD, MediaRenderer, MediaServer kits

- Control Point
  - Full UPnP Implementation
  - Optional MediaControl kit
RomPlug Application Toolkits

- Based on Forum Templates with extra APIs
  - Specific Solutions for a specific domain
- IGD - Internet Gateway Device
  - Selectable formats (POTS, PPP, DSL, etc.)
  - Sample SOAP actions
- MediaRender, MediaServe, MediaControl
  - DIDL support, HTTP Streaming support
  - DLNA support