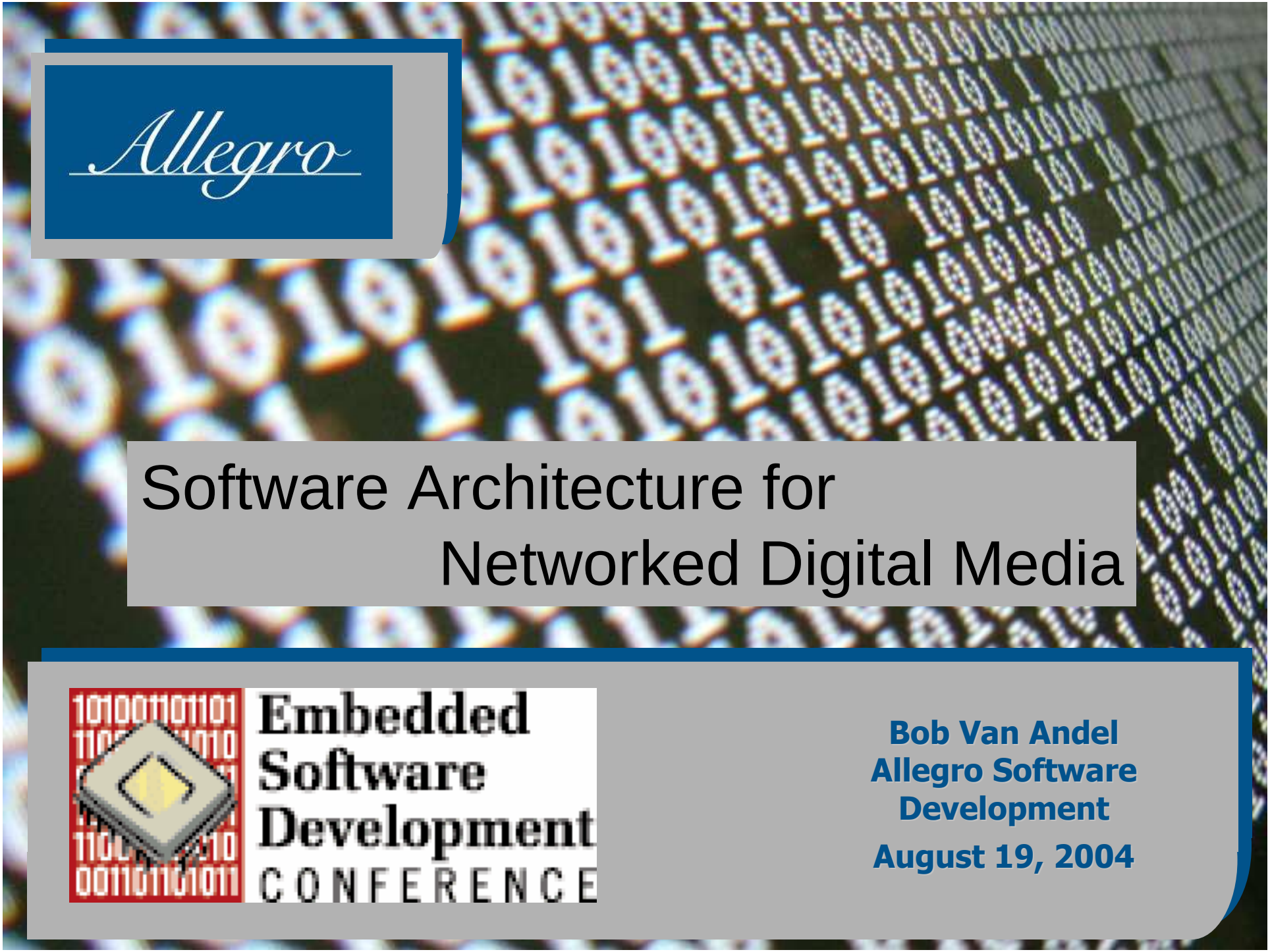


Software Architecture for Networked Digital Media

Embedded Software Development CONFERENCE

Bob Van Andel
Allegro Software Development

August 19, 2004

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

Networked Digital Media Products

- 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

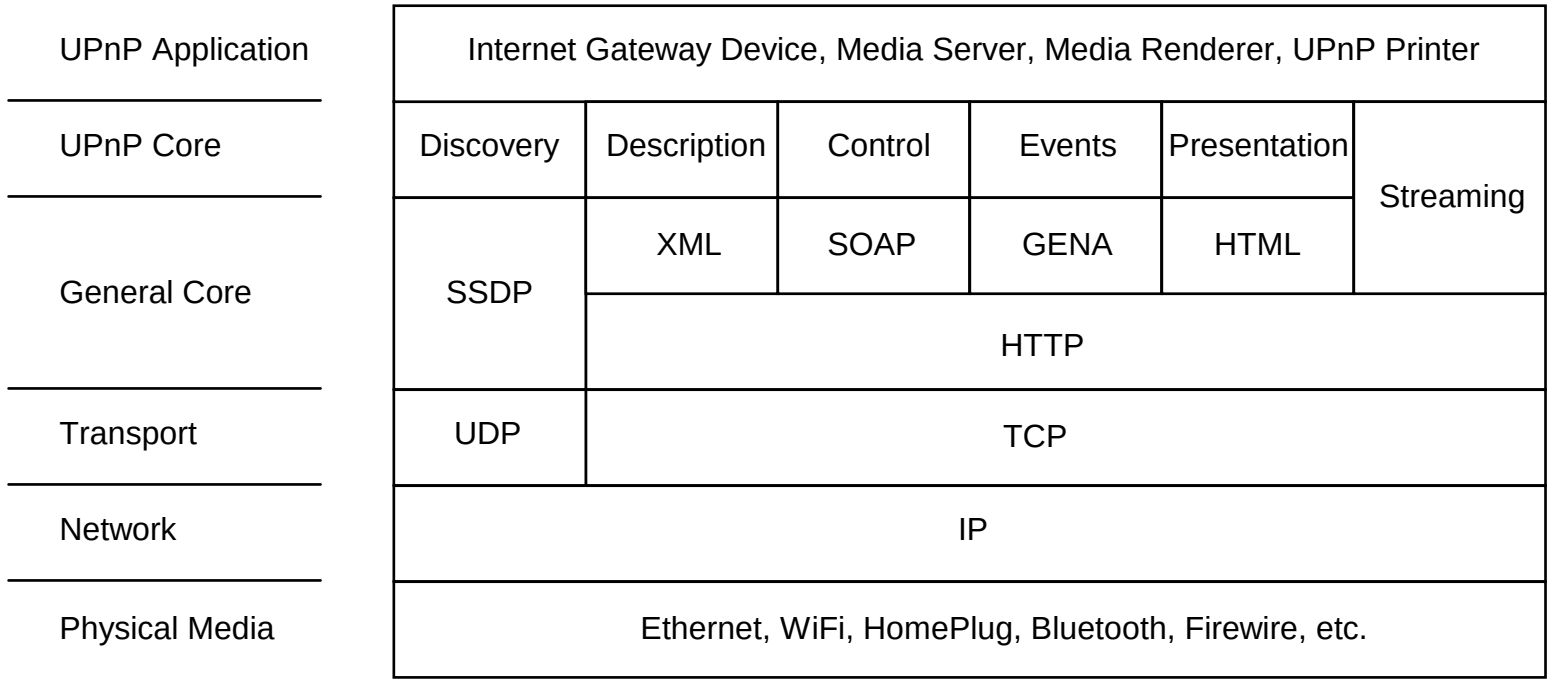
UPnP Forum - www.upnp.org

- 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.

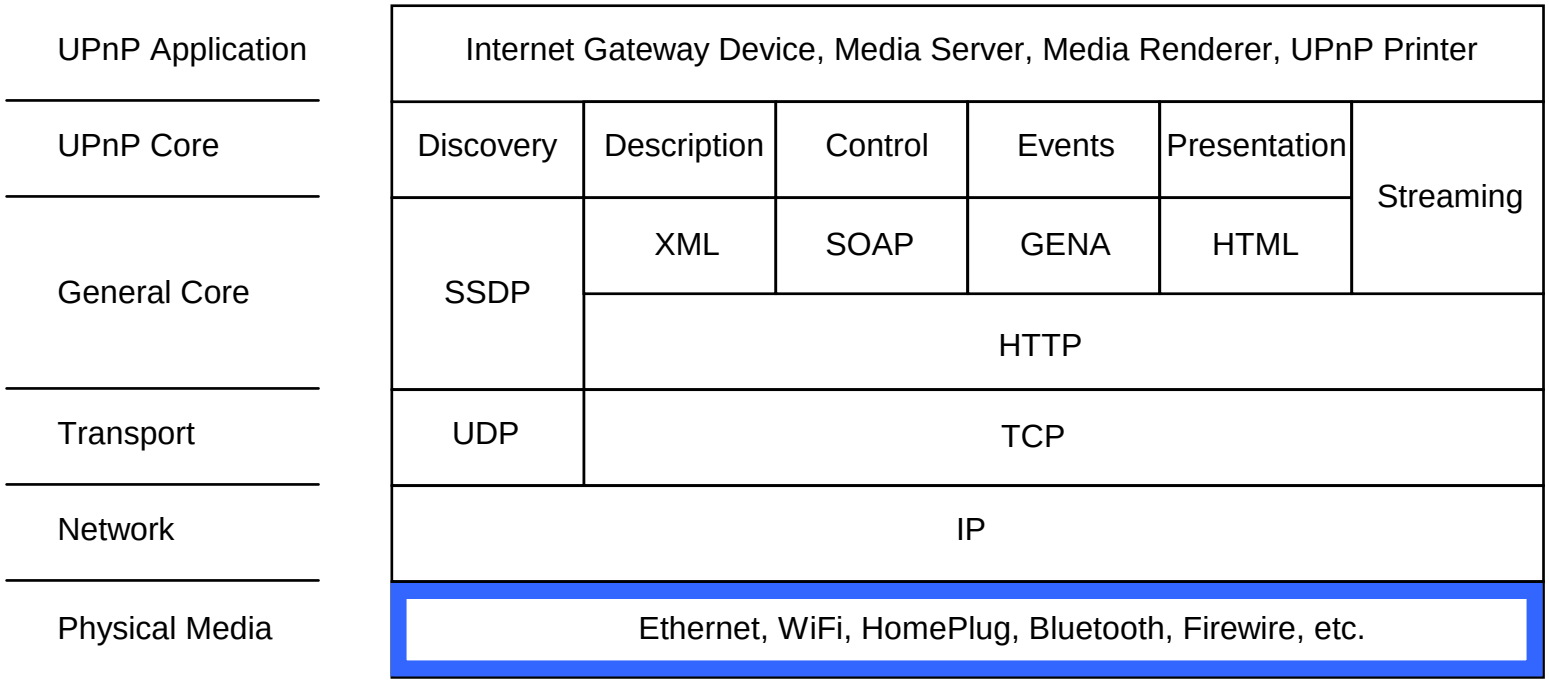
DLNA - www.dlna.org

- 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



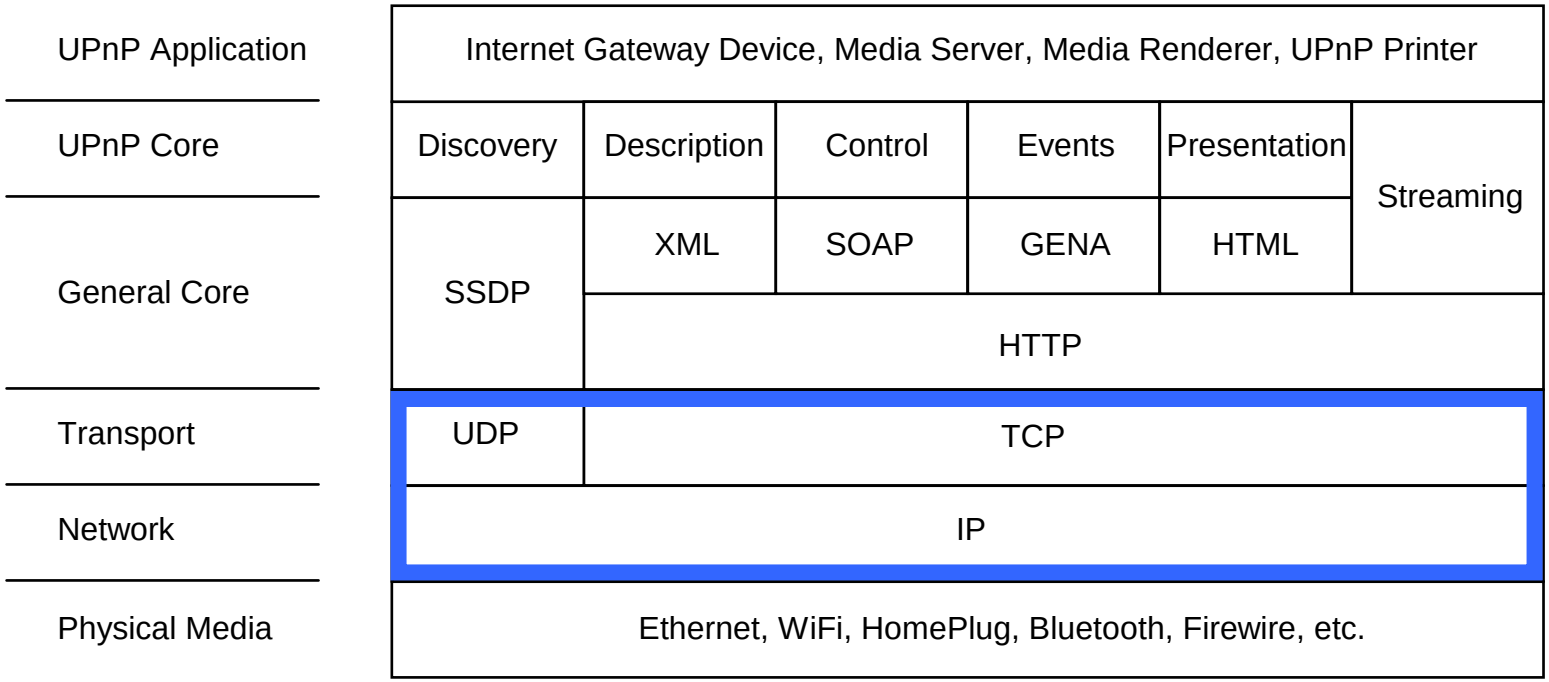
UPnP Architecture



Home Network Physical Layer

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

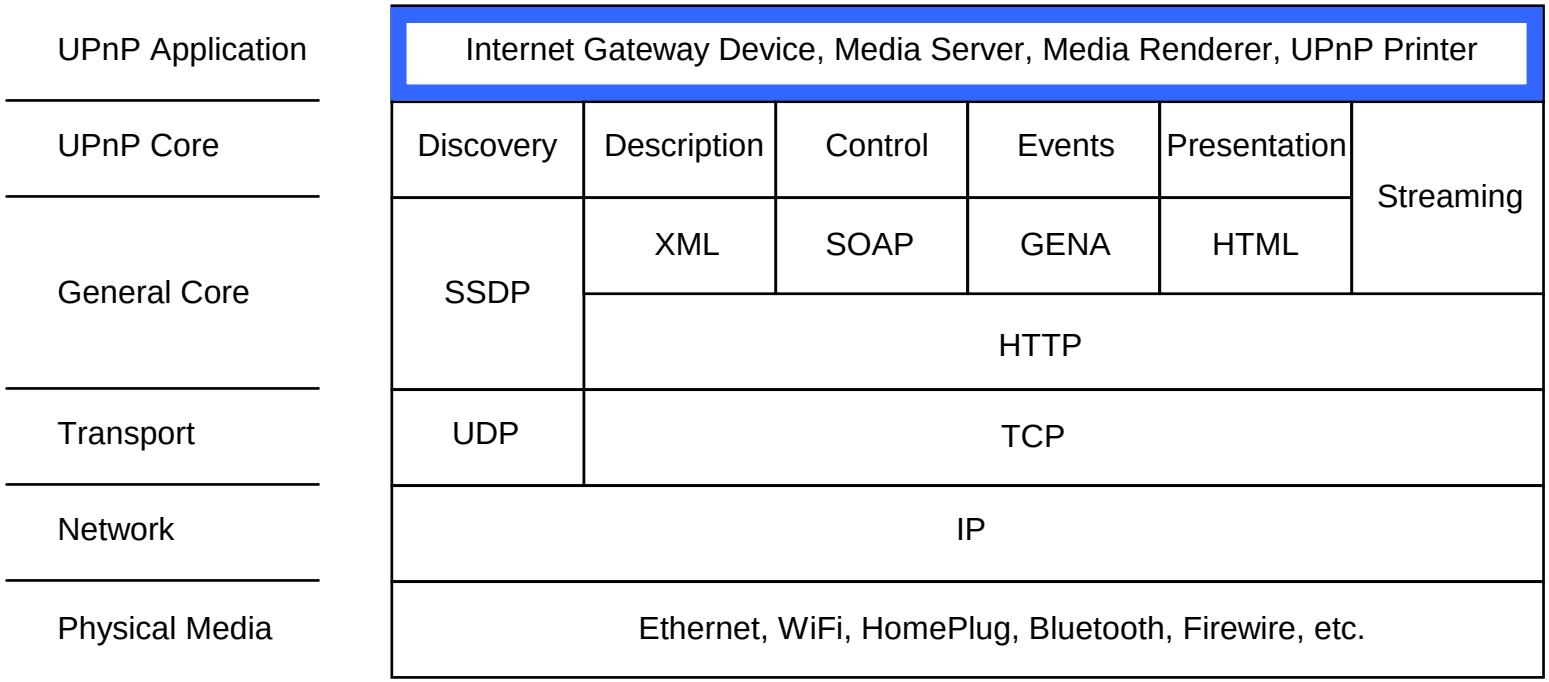
UPnP Architecture



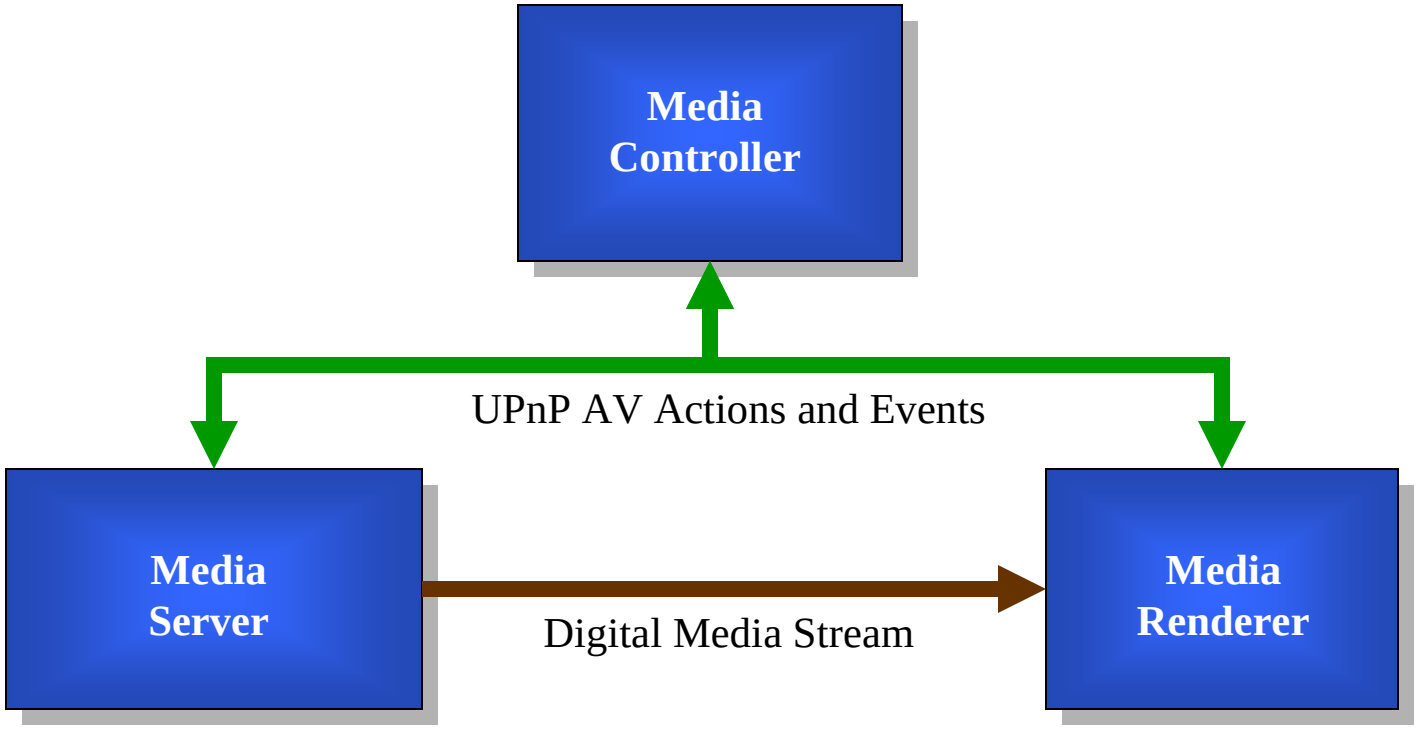
Home Network - Network & Transport

- 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



UPnP AV Architecture



UPnP AV Architecture

- Media Server
  - Discoverable UPnP Device
  - Source of Digital Media Content
  - Receives Content Directory Actions
  - Receives Connection Manager Actions
  - Receives AV Transport Actions

UPnP AV Architecture

- Media Renderer
  - Discoverable UPnP Device
  - Destination for Digital Media Content
  - Receives Rendering Control Actions
  - Receives Connection Manager Actions
  - Receives AV Transport Actions

UPnP AV Architecture

- 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

UPnP AV Variations

- 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

UPnP AV Variations

- 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

UPnP AV Variations

- 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

UPnP AV - Content Directory Service

- 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

UPnP AV - Rendering Control Service

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

UPnP AV - Connection Manager Service

- 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?

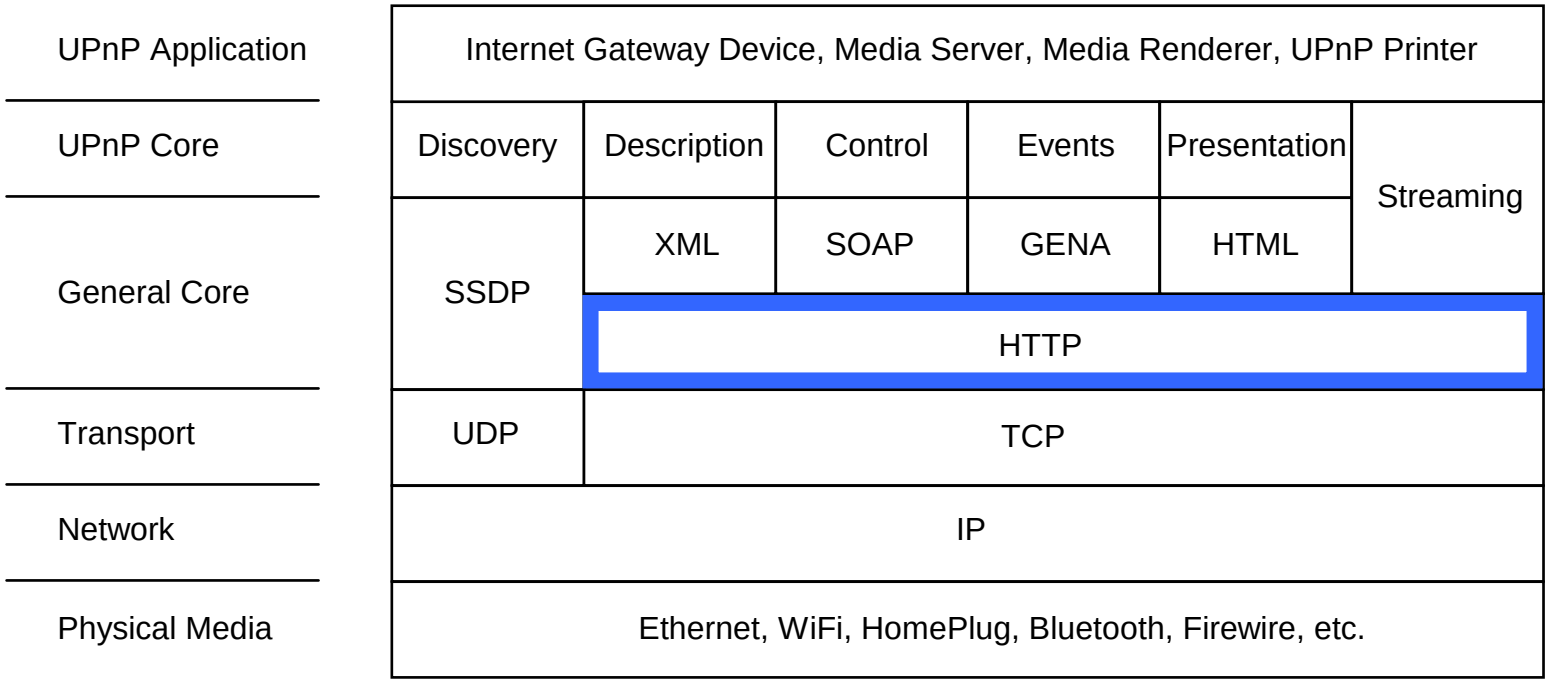
UPnP AV - AV Transport Service

- 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

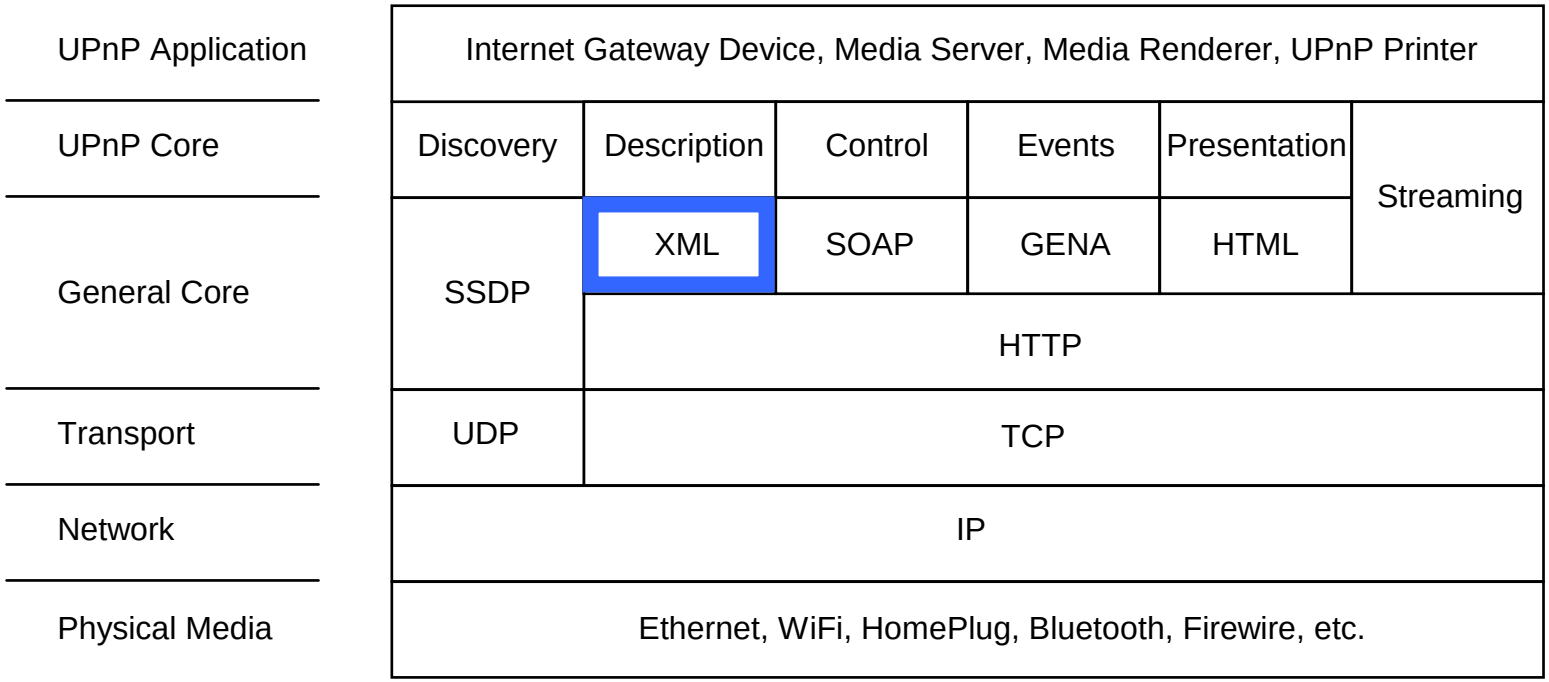
UPnP Architecture



HyperText Transport Protocol

- 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



XML Characteristics

- Processor 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

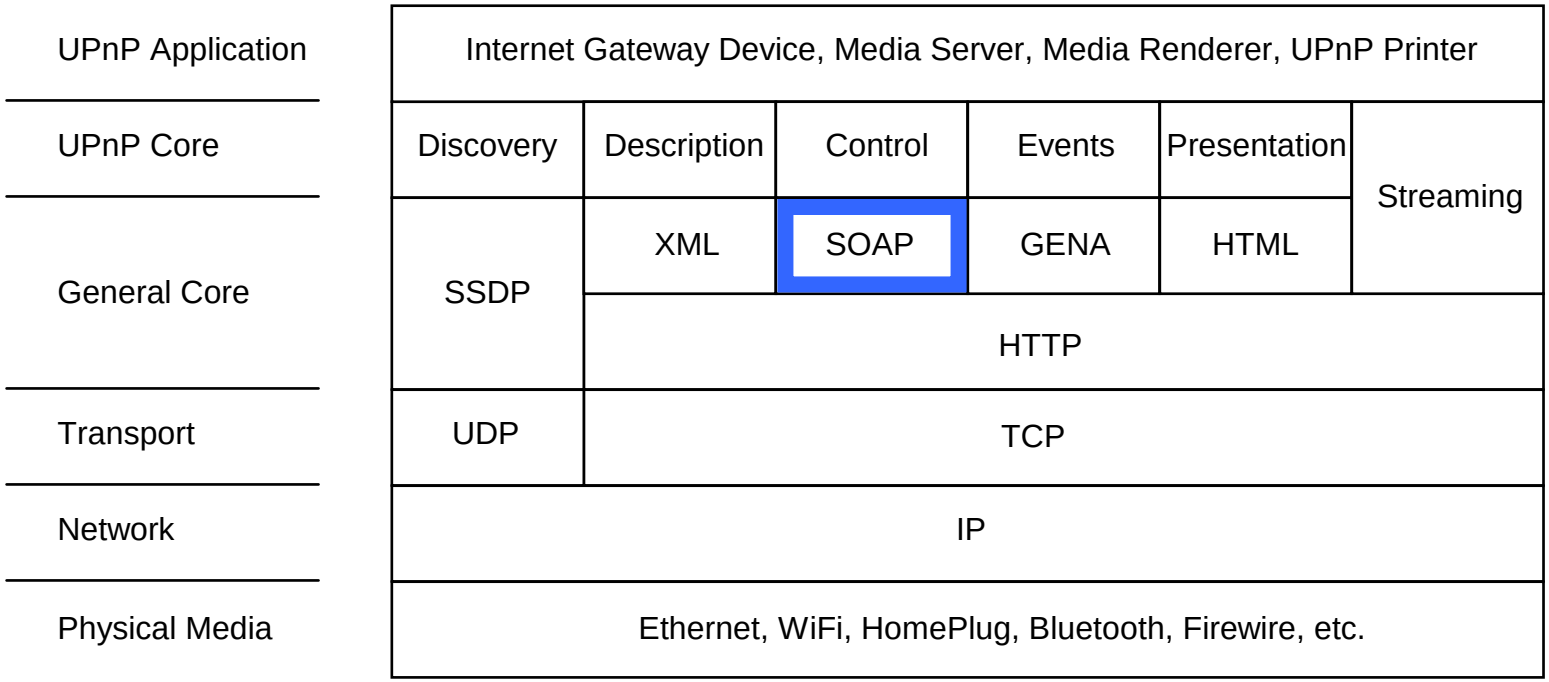
- Limited Resource Environment
- Defined Storage Format
- Low Syntax Volatility
  - Dedicated XML documents for a UPnP device
- Well-formed Documents are required
- Validated Documents are not required
  - Micro Parsers (non-validating) can be used

XML Sample

```
<?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



SOAP - Simple Object Access Protocol

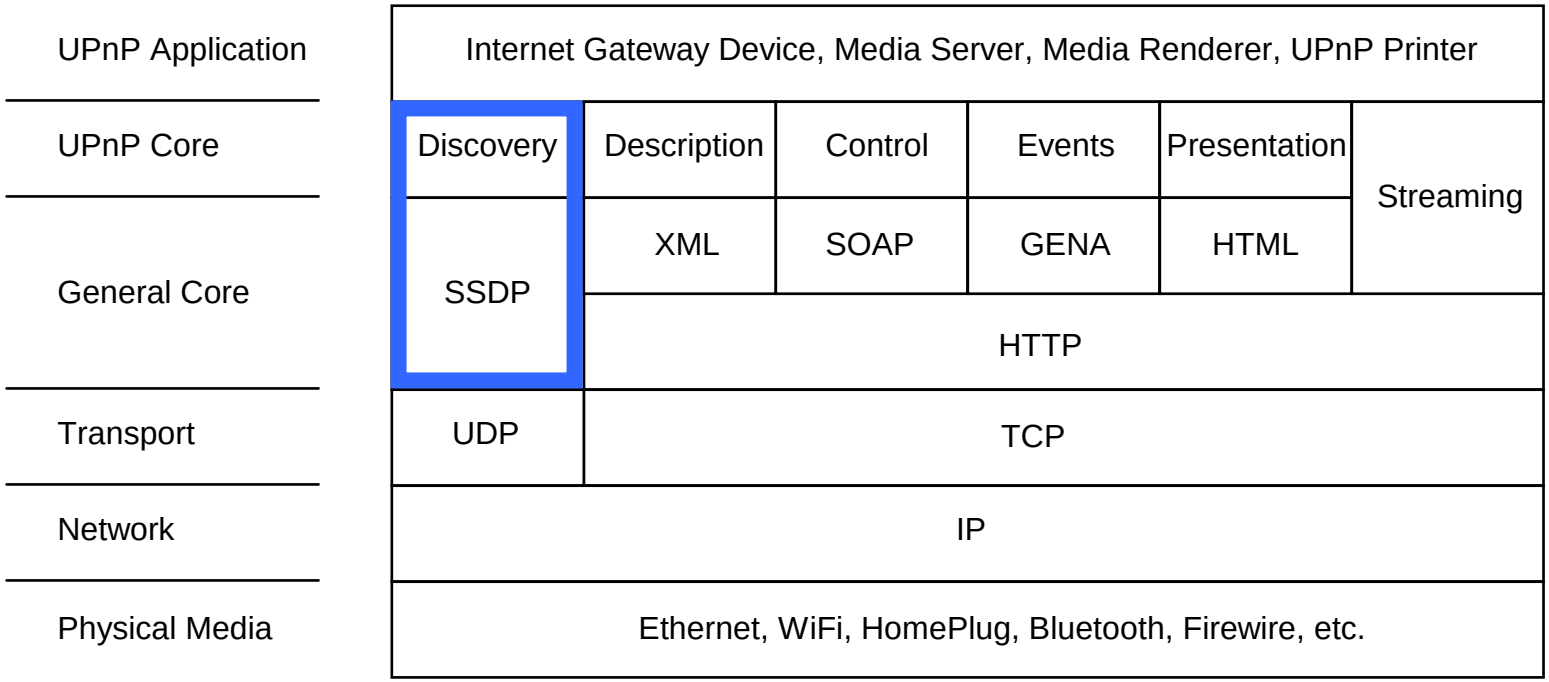
- XML objects over HTTP
- Envelope and Body objects
- Special HTTP header - Soap-Action
- Widely adopted in corporate Web Services
- UPnP and DLNA specify SOAP 1.1

SOAP Sample

```
<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.

UPnP Architecture



UPnP Device Discovery

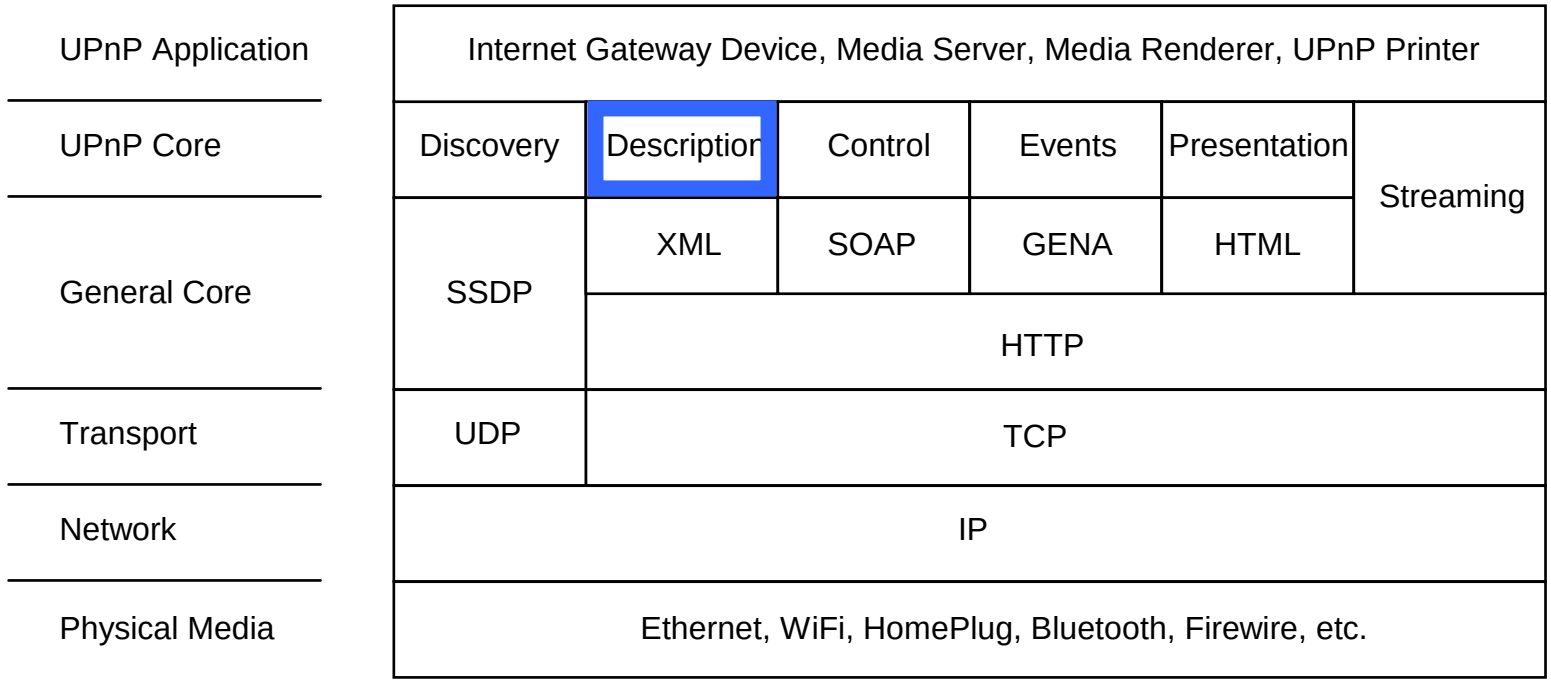
- Simple Search/Discovery Protocol (SSDP)
- UDP multicast based
- Control Points
  - Search (all, by type, by id)
  - Listen
- Devices
  - Respond to Search requests
  - Announce availability/shutdown

UPnP Device Discovery Sample

```
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-AEFEAA-234567-000017
```

CACHE-CONTROL - seconds until advertisement expires
LOCATION - URL of root device description
NT - Type of search
USN - UUID of this device

UPnP Architecture



UPnP Device Description

- XML over HTTP
- Description of
  - Device types (IGD, MR, MS, etc.)
  - Device services
  - Manufacturers information
  - Unique Device Identity
  - HTTP URLs for Actions, Events, Presentation

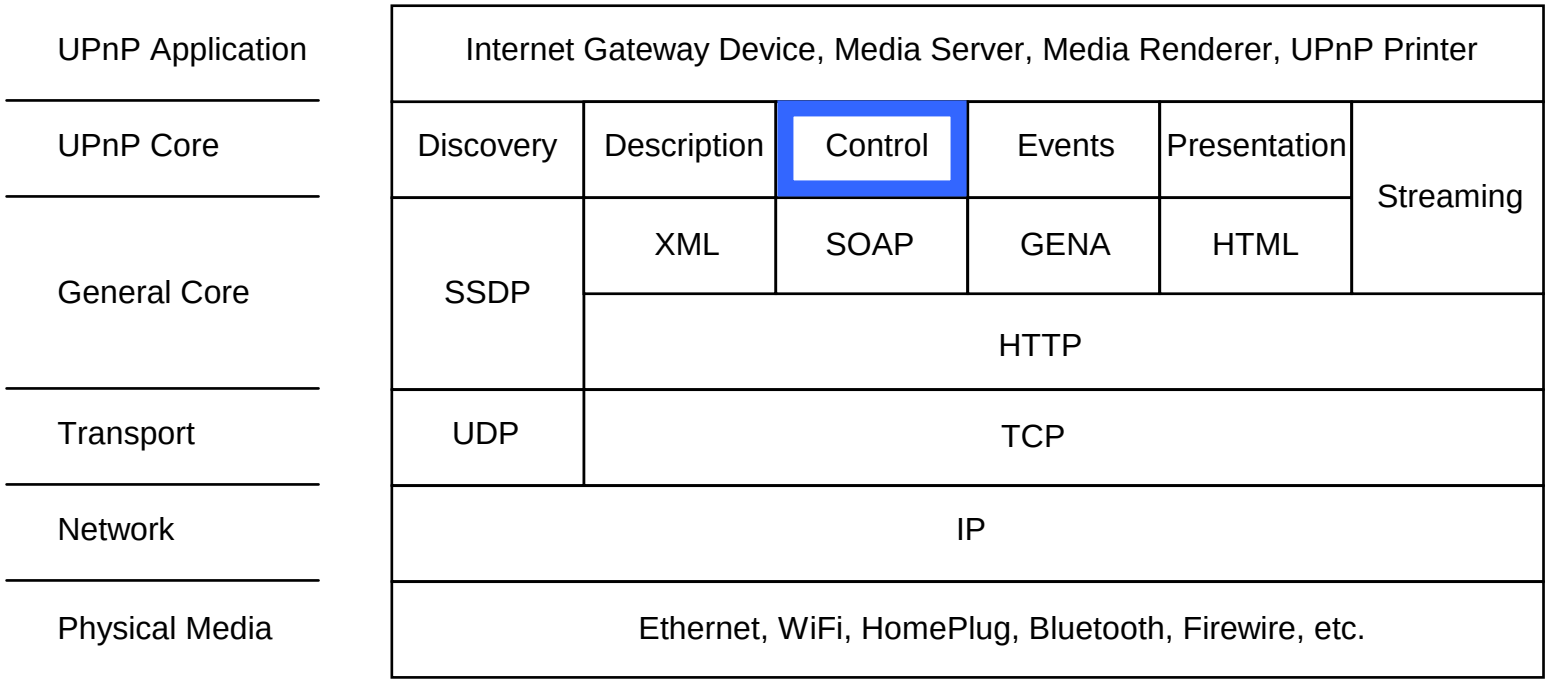
UPnP Device Description Sample

```
<?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>
```

UPnP Device Description Sample

```
<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>
   <eventSubURL>URL for eventing</eventSubURL>
  </service>
 </serviceList>
 <presentationURL>URL for presentation</presentationURL>
</device>
</root>
```

UPnP Architecture



UPnP Control Request

```
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>
```

UPnP Control Response

```
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">
     <Result>&lt;DIDL-Lite xmlns=&quot;urn:schemas-upnp-org:metadata-1-0/DIDL-Lite/&quot;
      xmlns:dc=&quot;http://purl.org/dc/elements/1.1/&quot; xmlns:upnp=&quot;urn:schemas-upnp-org:metadata-1-0/upnp/&quot;>
       &lt;container id=&quot;947&quot; parentID=&quot;0&quot; restricted=&quot;1&quot; childCount=&quot;5&quot;>
         &lt;dc:title>Playlists&lt;/dc:title>
         &lt;upnp:class>object.container&lt;/upnp:class>
       &lt;/container>
       &lt;container id=&quot;948&quot; parentID=&quot;0&quot; restricted=&quot;1&quot; childCount=&quot;15&quot;>
         &lt;dc:title>AudioItems&lt;/dc:title>
         &lt;upnp:class>object.container&lt;/upnp:class>
       &lt;/container>
       &lt;/DIDL-Lite>
     </Result>
     <NumberReturned>2</NumberReturned>
     <TotalMatches>2</TotalMatches>
   </u:BrowseResponse>
 </s:Body>
</s:Envelope>
```

UPnP Control Response

```
<u:BrowseResponse xmlns:u="urn:schemas-upnp-org:service:ContentDirectory:1">
  <Result>
    &lt;DIDL-Lite xmlns=&quot;urn:schemas-upnp-org:metadata-1-0/DIDL-Lite/&quot;
        xmlns:dc=&quot;http://purl.org/dc/elements/1.1/&quot;
        xmlns:upnp=&quot;urn:schemas-upnp-org:metadata-1-0/upnp/&quot;>
      &lt;container id=&quot;947&quot; parentID=&quot;0&quot;
          restricted=&quot;1&quot; childCount=&quot;5&quot;>
        &lt;dc:title>Playlists&lt;/dc:title>
        &lt;upnp:class>object.container&lt;/upnp:class>
      &lt;/container>
      &lt;container id=&quot;948&quot; parentID=&quot;0&quot;
          restricted=&quot;1&quot; childCount=&quot;15&quot;>
        &lt;dc:title>AudioItems&lt;/dc:title>
        &lt;upnp:class>object.container&lt;/upnp:class>
      &lt;/container>
    &lt;/DIDL-Lite>
  </Result>
  <NumberReturned>2</NumberReturned>
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```
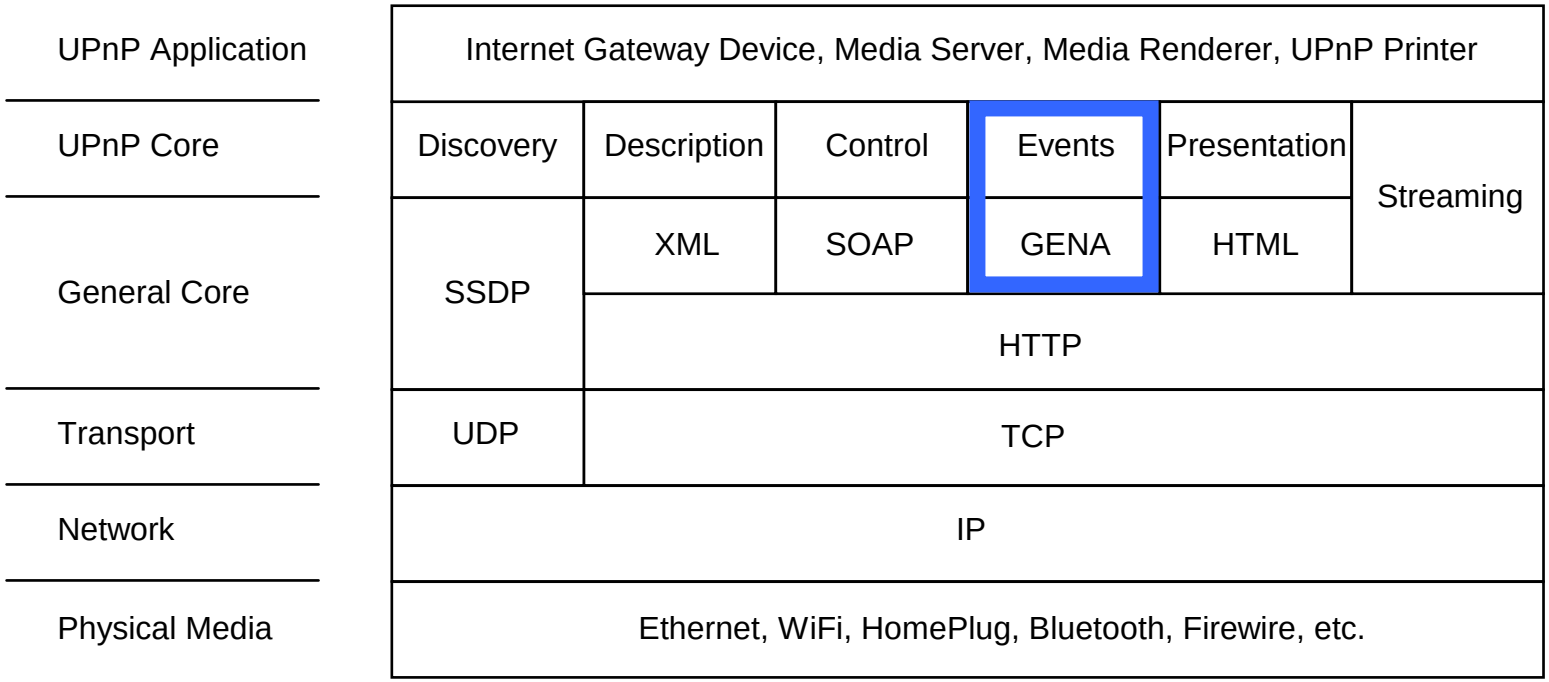

UPnP Architecture



UPnP Eventing

- 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

UPnP Eventing Sample

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

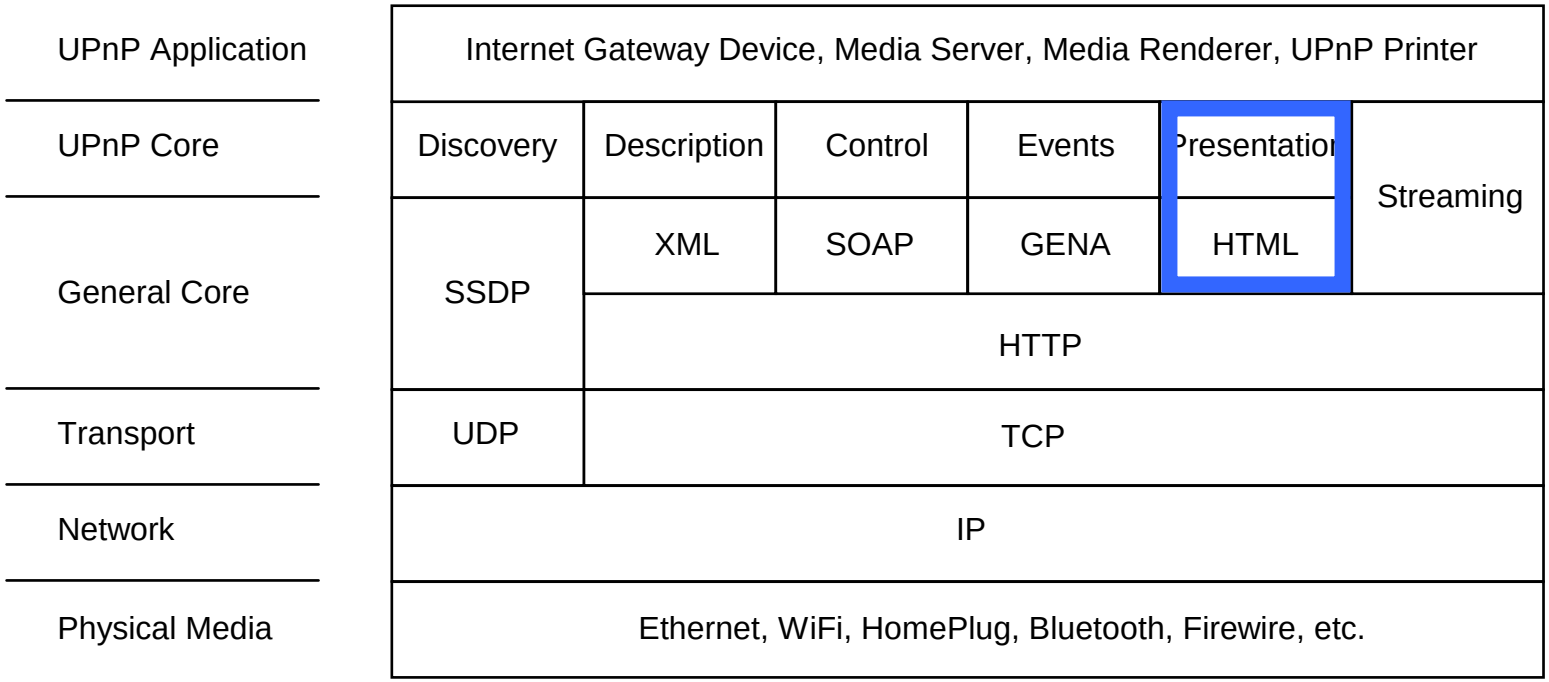
HTTP/1.1 200 OK
SID: uuid:BBFEAA-10244096-000037
TIMEOUT: 900

Timeout value is actual subscription duration seconds

UPnP Eventing Sample

```
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>
      &lt;Event xmlns=&quot;urn:schemas-upnp-org:metadata10/RCS/&quot;&gt;
        &lt;InstanceID val=&quot;0&quot;&gt;
          &lt;Mute channel=&quot;Master&quot; val=&quot;1&quot;/&gt;
        &lt;/InstanceID&gt;
      &lt;/Event&gt;
    </LastChange>
  </e:property>
</e:propertyset>
```

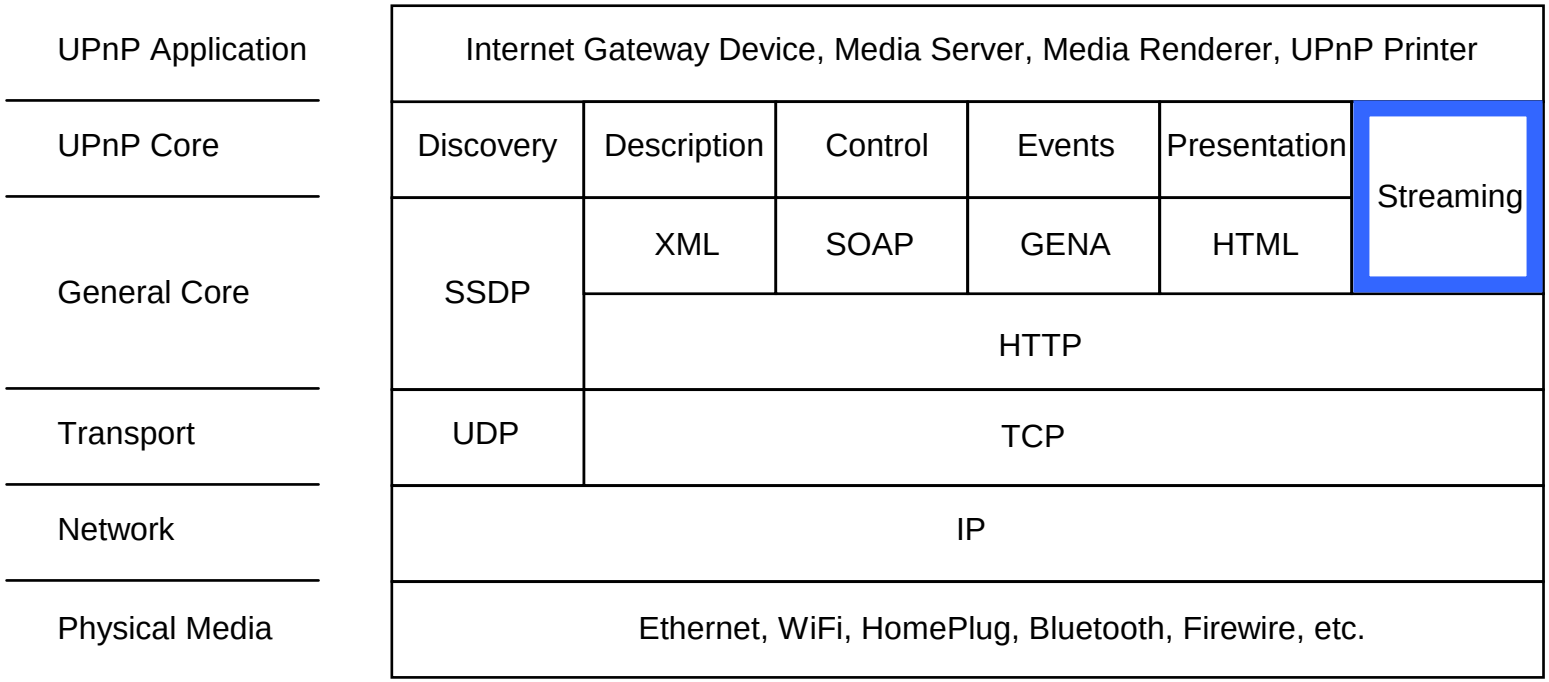
UPnP Architecture



UPnP Device Presentation

- 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

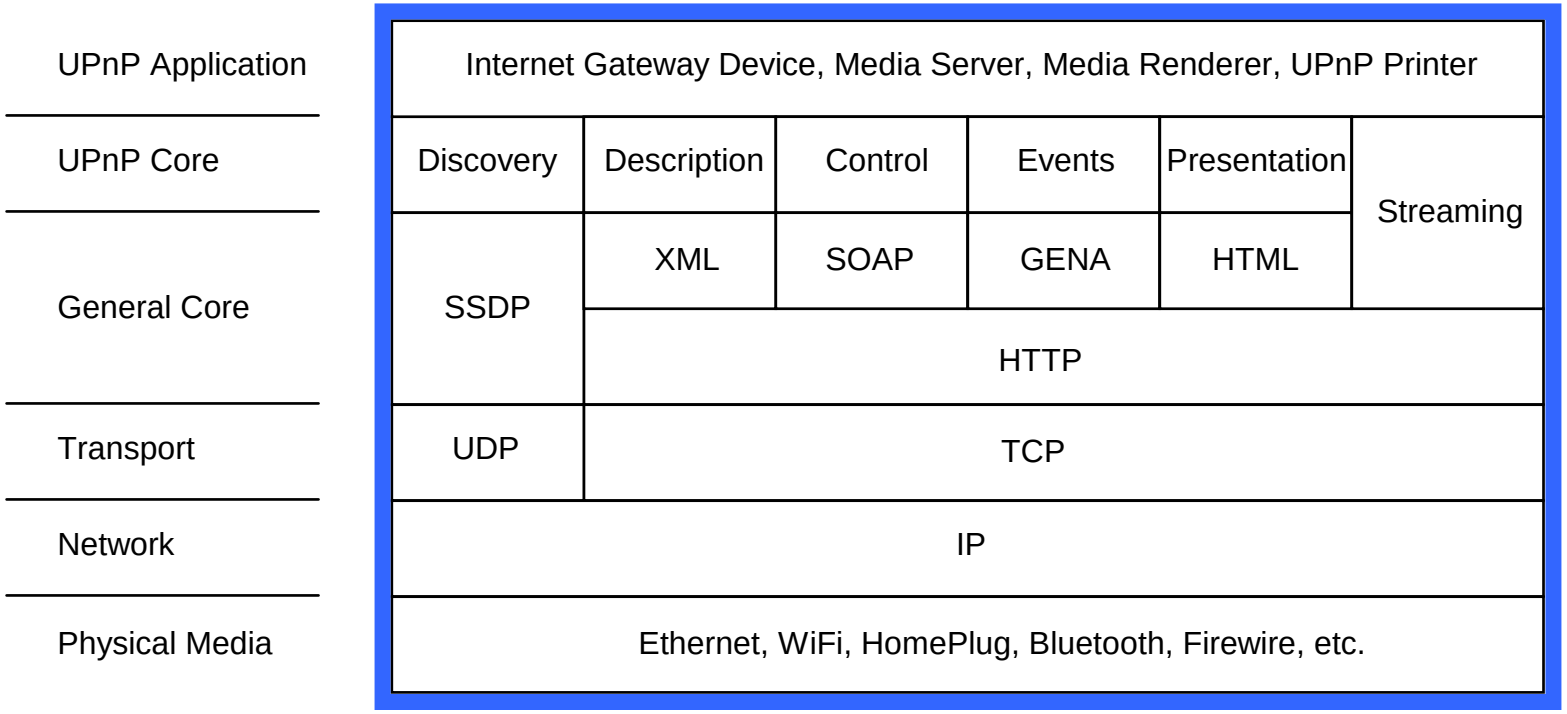
UPnP Architecture



Digital Media 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

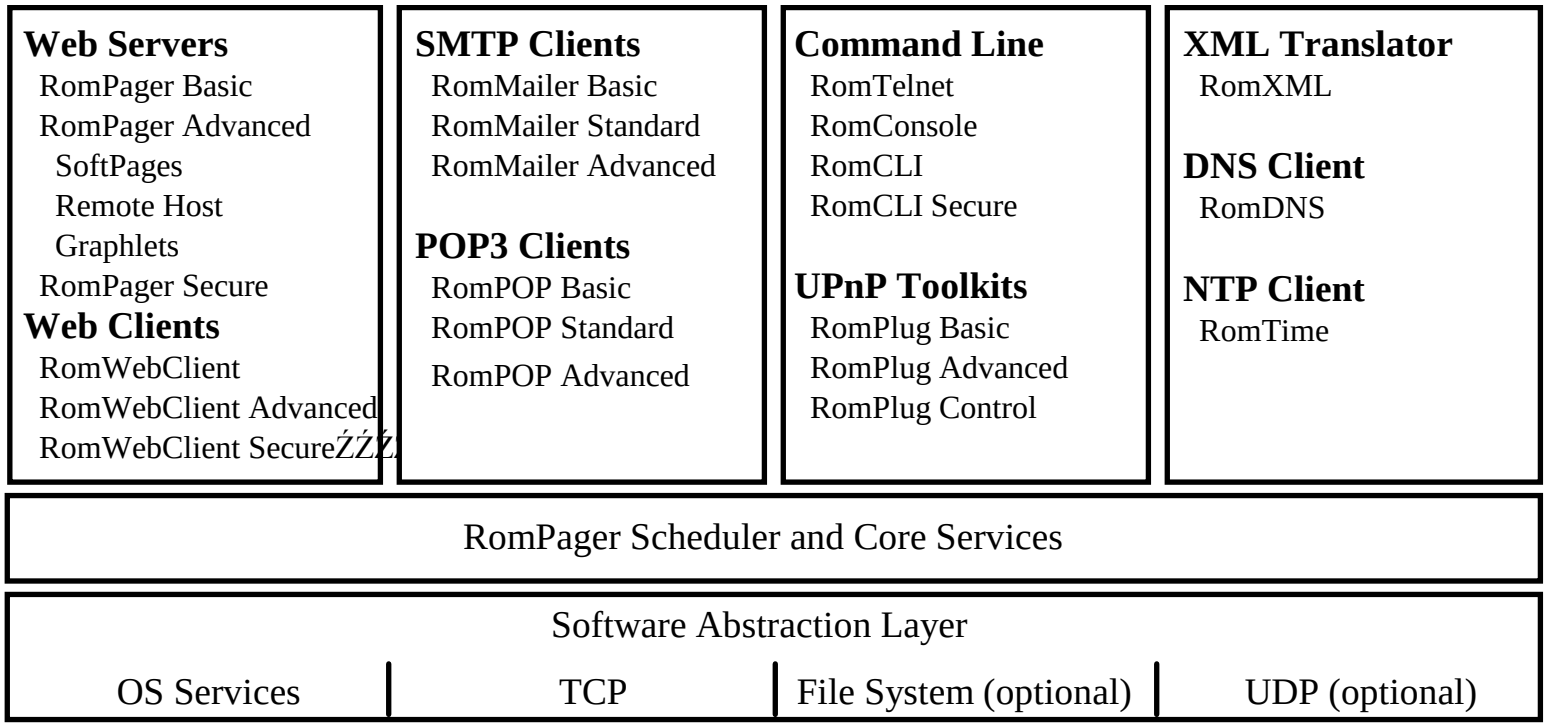
UPnP Architecture



A message from our sponsor...

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



RomPlug Toolkits

- Basic Device
  - Simple Discovery, Description, Presentation
  - No SOAP, or XML parsing required
- Advanced Device
  - Full UPnP Implementation
  - Optional IGD, MediaRender, 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


Allegro
www.allegrosoft.com