Patterns in Universal Plug & Play

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Introduction to Universal Plug & Play

Universal Plug & Play (UPnP, see [1]) is a lightweight architecture to extend the Plug & Play concepts to network devices and services (i.e. printer, camera, TV, map service,...). UPnP defines two roles of devices: *control points* who act as clients and *controlled devices* who act as servers[*]. Controlled devices are containers which embed services and other controlled devices. Services define the functionality offered by the device and control points use the services to control the device and monitor their status. The architecture defines a wire protocol based on IP, not an API, and is therefore language independent.

Steps and Patterns in UPnP

UPnP supports following steps: Addressing, Discovery, Description, Control, Eventing and Presentation.

The addressing steps ensures that each devices receives a valid IP-Address, either by DHCP or, when former is not present, Auto-IP. Auto-IP uses a distributed algorithm (following a pick and verify schema) to find a free IP-Address: the client randomly chooses an address from a known and suitable large address space and queries the local network if this address is already used by some client. If this is the case, the client repeats the steps of picking and verifying until an unused address is found.

Discovery defines how control points can find controlled devices. The underlying protocol SSDP (Simple Service Discovery protocol) uses announcement and bye-bye messages sent from controlled devices as well as search messages sent from control points. The Lease Pattern is used by SSDP to add robustness to the advertising step: the periodically sent announcement messages eventually time out when the device is not available, even if no bye-bye message has been sent. Due to multicast and the periodic messages, the control points are notified about the presence of a device, even if they haven't actively queried for devices.

During Description a control points receives the device and service descriptions (expressed in XML) of the controlled device. The device descriptions contain several standard and vendor specific device information and a list of embedded services and devices. The service description contains the actions and state variables of the service. This self description (similar to Introspection) of the device functionality allows dynamic control and eventing.

The Control step uses SOAP (Simple Object Access Protocol) to invoke actions of services. SOAP is a RPC technique that uses HTTP as the transport protocol and XML for marshalling.

The Eventing step uses GENA (General Event Notification Architecture) to inform control points of state changes occurred at controlled devices. GENA uses moderated subscriptions (which contain leases) to subscribe to event notifications. The use of leases adds robustness against node failures and network partitioning.

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[*] Most UPnP device will implement client and server functionality, the network appears then as peer-to-peer

A presentation page can be presented for user control. This step delivers a HTML (or WML) page to the control point, allowing a wide range of devices to act as a user control point (use of a standard protocol).

Lease and Locator Pattern

SSDP extends and combines the lease and locator pattern (see [2] and [3]) in an effective way. SSDP uses leases to provide a *soft state* of the availability of a device or service. The announcement messages are complemented by bye-bye messages, which redraw given announcements/leases (or clears the soft state immediately before it eventually times out). These additionally update messages add more actuality to the soft state. The soft state technique is used widely in Internet protocols to adapt and add robustness to changing environments.

Essentially, however, SSDP defines a distributed algorithm to locate devices and services. Each announcement messages embeds in addition to ID and type information also location information. A control point will eventually get notice of a device location by listening to these messages. Using the lease messages, no additionally messages are needed to distribute the information.

Using multicast, no central network component (location server) is needed to distribute the location information. This technique removes a single point of failure, but fails to scale to large networks.

Active queries supplement the announcement messages. Again, this adds more actuality to the state information kept in the client. These queries can be triggered by events (user enters a new environment or he actively queries for the current state) and help to balance the frequency of the update/lease messages (i.e. network traffic) and the actuality of the reflected state.

Summary and Discussion points

- The pick and verify schema of Auto-IP could be worth to be a pattern
- XML device descriptions provide Introspection functionality
- Soft states are an important concept that uses leases
- Lease renew messages can contain additional useful information
- Location information can be distributed by a distributed algorithm, avoiding a central component in the network

References

[1] **UPnP Device Architecture 1.0**, Microsoft Corp., http://www.upnp.org
[2] Michael Kircher and Prashant Jain, **Location Pattern**, EuroPLoP 2000 conference, Irsee, Germany, July 5-9, 2000
[3] Prashant Jain, and Michael Kircher, **Leasing Pattern**, PLoP 2000 conference, Allerton Park, Illinois, USA, August 13-16, 2000