An Architecture to Support the Invocation of Personal Services in Web Interactions

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Abstract
This paper proposes an architecture to enable Web service providers to interact with personal services. Personal services are vanilla HTTP services that are invoked from a browser, upon a request made by a service Provider, to deliver some service on the client side, i.e., on an execution environment defined by the browser’s user. Personal services can be used both to handle content manipulation and presentation or to deliver request-response interactions with different goals (e.g. user authentication). Unlike plugins, that are described to service providers on each and every HTTP request, personal services are explicitly searched by service providers using a novel agent, a Broker, that works in close cooperation with each browser. We have implemented this architecture and implemented an HTTP proxy to cope with it. For demonstration purposes we show how we can use personal services for personal authentication with an electronic identification (eID) card.

Keywords: Web interactions, personal services, name services, yellow pages, white pages, service handles

1 Introduction
Web-based interactions have become one fundamental part of Internet interactions, and browsers are the most frequent applications used as clients in those interactions. Web browsers were initially conceived as information presenters and navigators, but progressively became the omnipresent graphical interface of complex, Web-based applications.

Web-based applications often benefit from (or require) special handling services provided by client browsers. Plugins were invented for this, e.g. for handling special kinds of data provided in Web servers’ responses. But plugins are a nightmare to manage, they are browser-specific and they need to follow browsers’ updates.

In this paper we present a new paradigm to extend Web applications by using the concept of personal services. Personal services are vanilla HTTP services
that are explored from a browser to the benefit of its user. Personal services may run locally to browsers or not.

1.1 Personal services
To clarify the text, we will use the terms browser, service provider (SP) and personal service. The terms client and server will be avoided because they may be used in many ways: browsers are clients of SPs, SPs may be clients of personal services and these will be servers of both browsers and SPs.

Personal services are technically HTTP services. These services can be invoked by other services, namely SPs, in order to provide some service to (or from) a user. A personal service can either provide some kind of content handling task (e.g. present a media object) or can tackle request-response interactions (e.g. eID-based authentications).

The HTTP paradigm is based on client-server, unilateral request-response dialogues. The most common HTTP clients, the browsers, make a request to a server, collect its response and process it. In this paradigm it is not normal to have servers to make direct requests to other servers; instead, servers invoke other servers through a client redirection. We decided to kept this paradigm for dealing with personal services, in order to facilitate the adaptation of browsers to handle them. Namely, we enriched the HTTP redirection mechanism to fully handle the exploitation of personal services from SPs.

1.2 HTTP redirections
HTTP redirections enable an HTTP server to redirect a client request to an alternative URL (Uniform Resource Locator). The redirection may be performed in many ways, for dealing with different redirection reasons, using a specific HTTP status code of the 3xx class [4].

Although HTTP redirections were initially conceived for dealing with temporary or permanent relocations of SPs, currently they are also used to handle indirect calls of SPs to third-party services mediated by a browser (see Figure 1). An example of this is the OASIS Web Browser SSO Profile [6], using SAML (Security Assertion Markup Language), which is used to identify and authenticate a browser user with a central, third-party service acting as an Identity Provider (IdP).

The problem of using HTTP redirections to invoke personal services is that their exact location, in terms of TCP/IP address, are unknown to SPs; that depends of the client. Unlike with central, third-party services explored by SPs, which know their TCP/IP address, the location of personal services must be somehow provided by each browser on a case-by-case basis.

In [8] we explored the concept of personal services to extent the OASIS SSO authentication process with a Personal IdP (PIdP). This PIdP was able to interact with a local eID token in order to perform a user identification and authentication with it. However, we had to use a fixed IP address (127.0.0.1) and a fixed port (666) to reach the PIdP, which was not a clean and flexible
solution. In this paper we propose a solution to deal with this problem by allowing an SP to discover the presence of the intended PIIdP (which is a personal service) and to properly invoke it.

1.3 Contribution

In this paper we propose a solution for enabling SPs to discover useful personal services and to invoke them upon such discovery. To do so, we conceived:

1. A name system (Broker) that can be used by SPs to discover a personal service of interest;
2. A name resolution protocol, which provides a handle for invoking a particular personal service given its name; and
3. A personal service invocation protocol, using previously obtained handles.

The Broker is a service running locally to a browser that keeps track of all personal services available to the browser. It is not a browser extension or plugin, it is a separate service that can be used by any browser a user chooses to use. The Broker uses attribute-based descriptions of personal services to enable SPs to look for services of interest, similarly to the Yellow Pages service described in [7] and to the UDDI (Universal Description, Discovery & Integration) Web Services’ discovery paradigm [1]. Attribute-based descriptions are, in our opinion, flexible enough to handle the description of the functionalities of personal services that may be looked by SPs.

The Broker is responsible for instantiating all personal services, that are locally hosted to the browser, prior to their actual invocation by SPs. Thus, local personal services do not need to stay running all the time, they can be executed on demand, and just in time, to handle SP invocations. Remote personal services

Figure 1: Invocation of third-party services from a browser upon a redirection response returned by an SP.
are not controlled by the Broker, so it cannot instantiate them. Instead, the Broker is responsible to verify if the remote personal services are active.

Once activated, a personal service can be indirectly invoked from an SP through a browser using a new HTTP redirection mechanism (see Figure 2). The SP invocation is handle-based, i.e., the SP refers to the personal service using a previously fetched handle. The browser translates the handle into a local TCP/IP address, which is then used in an HTTP request to the personal service using data provided by the SP in the redirection reply. The personal service can reply to the SP, if required, using the existing HTTP redirection mechanism, very much like actual third-party reply to the SPs that invoked them (see Figure 1). However, personal services can also directly invoke their calling SP, or other SPs, if conceived to do so; that is not forbidden by our proposal.

The handle-based redirection to personal services has several advantages over a direct redirection using a TCP/IP address. Since it adds a layer of abstraction to the service invocation, forcing browsers to resolve the handle prior to invoke the personal service, the exact TCP/IP address of personal services remains hidden from SPs. This allows personal services to use variable addresses along time without disrupting their call from handles cached by SPs. It also allows SPs to get valid handles without requiring personal services to be running before being actually invoked or, alternatively, to be forced to use a fixed TCP/IP address. Finally, since personal services do not need to be running before being actually invoked, they cannot be discovered by SPs without the help of the Broker (e.g., by doing exhaustive redirections to several TCP ports bound to localhost addresses).

This paper is structured as follows. Section 2 presents the related work. Section 3 presents the architecture of our contribution. Section 4 presents the implementation of a prototype that was developed for experimenting our contribution. Section 5 presents an experimentation of our proposal with a personal service conceived for an eID-based personal authentication, presented in 8. Section 6 discusses the usage of the proposed architecture by active code running on Web resources loaded by browsers, namely JavaScript. Finally, Section 7 concludes the paper.

2 Related work

At first, browsers were mainly used for surfing the world-wide web, but now they are being used to access and execute more complex and complete Web applications, ranging from social media Web applications to productivity suits. Consequently, browsers’ manufacturers started to allow users to install plugins and extensions in order to expand the browsers’ capabilities, allowing users to have better experiences.

Plugins are applications that are executed from a browser and use a fixed and limited API (Application Programming Interface) it provides to access its own contents and user interface. They were created mainly to handle specific
Figure 2: Invocation of personal services from a browser upon a redirection response with a service handle returned by an SP. The personal service can terminate the HTTP request-response dialog (top diagram) or redirect it again to the SP, or even to another SP (bottom diagram). This last redirection is usually based on an URL provided by the SP that indirectly invoked the personal service.
content types (e.g. PDF documents) and browsers announce their availability to service providers (on HTTP request header fields). But, besides the increase of functionalities, plugins also brought some security issues (such as the identification of users from their browsers’ profile [3], as well as maintenance and universality problems (they need to keep up with the evolution of browsers and they are not provided for all browsers).

Grier et al. [5] proposed to use separate processes for keeping plugins away from browsers’ address space. This is similar to our proposal, but our goal is different. In fact, we want to enable SPs to interact (via HTTP requests and responses) with local, personal services in a browser-independent way, while plugins help browsers to deal with the contents they send and get from SPs.

Browsers’ extensions, on the other hand, are a modular approach to expand a browser’s functionality in all sorts of ways. However, unlike plugins, they are transparent to SPs. Therefore, they are unsuited for supporting our personal services, since we want SPs providers to be able to find out personal services of interest.

The possibility of using browsers’ extensions to run our personal services’ Broker could be a possibility, but it is preferable to have the Broker as process independent from all browsers, since it simplifies the configuration and the access to personal services in a browser-independent way. Naturally, the same applies to personal services, for which there is no added value in deploying them as browsers’ extensions.

Instead of relying in browser-dependent plugins or extensions, the AMA (Agência para a Modernização Administrativa) followed a different approach for interacting with what we call a personal service. In order to allow citizens to use their EId (a smartcard) on any browser to authenticate themselves in several services provided by the Public Administration, they decided to develop an external application entitled “plugin Autenticação.Gov” [2]. This application, which is exactly what we call a personal service, implements an HTTP server that will be waiting for eID-related requests on one of the following pre-defined TCP ports: 35153, 43456, 47920, 57379 or 64704. This application is invoked by JavaScript code running on the browser.

This last approach is similar to the one already mentioned in the introduction [8], which uses HTTP redirections instead of HTTP requests from JavaScript code. The advantages of using JavaScript are twofold: first, different ports can be used (which tolerates collisions in port allocations), since with JavaScript it is possible to test all pre-established ports sequentially until finding a hit, while this is impossible with HTTP redirection codes (because after a failure the control does not return to the SP that did the redirection); second, a service can be implemented together by JavaScript code and an external application. Its may drawback, on the other hand, is that JavaScript

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1Portuguese agency that coordinates the technical innovation in the Public Administration; it is in charge of the development and deployment of technical solutions for handling the Portuguese EId (Electronic Identification card, named Cartão de Cidadão) in computational environments.

2Autenticação.gov. [https://www.autenticacao.gov.pt]
code can make arbitrary calls to any local HTTP services/servers, which may lead to vulnerability exposures (e.g. The Filet-o-Firewall attack\(^3\)). Note that those vulnerabilities are smaller with HTTP redirection codes, because target personal services must cooperate with the redirecting service in order to return latter the control to the attacker (with another redirection). Thus, it is impossible for a malicious SP to conduct a request/response dialog with an HTTP service running locally to the client browser by using HTTP redirections.

From this last discussion it is clear that relying on JavaScript to find and invoke personal services is to open the door to vulnerability exploits, while doing it with requests/responses recognized by browsers, such as HTTP redirection codes, enables browsers to recognize intents to interact with local services and get instructions about it from users. This is why we based our work on HTTP redirections.

3 Architecture

The architecture that we propose to support the discovery and invocation of personal services is based on two main components: (i) a Broker service and (ii) a protocol to discover personal services, using a Broker, and to invoke them.

3.1 Broker

The Broker is an HTTP service that keeps record of a set of personal services. Personal services are themselves HTTP services, i.e., they must support an ordinary HTTP interface. The Broker is agnostic about the actual features that each personal service provides through HTTP.

3.1.1 Yellow- and white-pages paradigms

The Broker supports a yellow-pages service to enable SPs to list personal services of interest. This enables an SP to get a list of available personal services for a given purpose, before actually choosing one of them. The choice may even be given to the user that is interacting with the SP through their browser. The yellow-pages service returns a list of service descriptions that match a particular set of attributes provided by the SP. A service description is a set of attributes describing a personal service (see next section).

The Broker supports a white-pages service to provide a personal service handle to an SP. In this case, the SP must provide a set of attributes matching a single service.

3.1.2 Service naming paradigm

The naming model implemented by the Broker is based on services’ attributes, similarly to \(^7\). This option was motivated by the fact that, currently, plugins

\(^3\) Filet-o-Firewall: new vulnerabilities in UPnP expose the whole network. [https://www.kaspersky.com/blog/filet-o-firewall/4533](https://www.kaspersky.com/blog/filet-o-firewall/4533)
are associated to specific contents by a set of attributes describing the kind of data they are able to handle. This association between content attributes and plugins was introduced by the NPAPI interface, created by Netscape and used by most browsers until 2013, when the main browsers began their phase-out.

The set of attributes associated with each personal service is not limited. Each service can freely define the set of attributes that may be listed or looked upon by SPs. This enables SPs and personal services to choose the best way to find each other.

Two different sets of attributes are associated with personal servers: configuration and presentation attributes. Configuration attributes is a set of operational attributes that is visible only to the Broker. They are meant to be used only by the Broker for establishing a proper management of the services. Presentation attributes, on the other hand, are visible to SPs and are not mandated by the Broker. These are the attributes that SPs should use to find and make use of personal services. Therefore, in what concerns SPs, personal services are named solely with presentation attributes.

The presentation attributes should be (short) feature descriptions, for helping SPs to find the right personal service for a particular purpose. The number and actual name of presentation attributes is not limited or imposed by the Broker. For instance, content handling personal services may have a “Purpose” attribute with the “ContentHandling” value and a “ContentType” attribute associated to an existing MIME type. For identification and authentication personal services, they may have a “Purpose” attribute with the “Authentication” value and an “AuthenticationType” with a description of the supported authentication method. Note, however, that these examples are just illustrative, they are not mandatory, other attributes may be used. The choice of the right attributes should follow some posterior standardization process, for enabling SPs to know how to look for personal services of interest.

3.1.3 Name structures

Personal service names are formed by a set of presentation attributes. We chose to use the popular JSON (Java Script Object Notation [2]) format to define a set of presentation attributes associated with each personal service. Using JSON, a service name is an object where each member defines an attribute string associated with a value. Values can be strings, numbers, objects, arrays, boolean values (true/false) or no-values (null).

3.1.4 Name listing and resolution

An advantage that we have considered of using JSON for expressing service names was that we could rely on existing JSON querying syntaxes to implement both name listing and resolution processes. However, we decided to delegate such task to SPs and provide a minimal functionality on Brokers. In this sense, a Broker provides a very simple attribute matching functionality for selecting service names to be listed or resolved upon SPs’ requests.
For service name listing, the Broker accepts a case-insensitive, single attribute specification (attribute: value) for listing all services matching this object member in their names. It does not provide any support for regular expressions in the matching operation. The result of a listing request is a JSON array of service names (with all their presentation attributes) matching the listing query.

For service name resolution, the Broker accepts a case-sensitive, query object for resolving a service name fully matching all the members of the query object. The query object cannot match more than one service name. The resulting handle, returned to the browser, will contain the complete service name matching the query.

3.2 New HTTP status codes

Both calls to yellow- and white-pages are made by an SP to the browser with a new HTTP response message, i.e., a response with a new status code (provided within the Status-Line HTTP header field). We chose a set of status codes in the range 31X, namely 310, 311, 312 and 313, because both calls are a kind of redirection.

The status codes 310 to 313 are used for the following 4 different operations (see Figures 3 and 4):

- **310**: Call the Broker’s yellow-pages service to list personal services with a given attribute (Figure 3 top).
- **311**: Call the Broker’s white-pages service to resolve a personal service name (set of attributes given by a query object) into a handle (Figure 3 bottom).
- **312**: Call a personal service given a handle to it (see Figure 4).
- **313**: Redirect a result provided by the Broker to any of the previous calls.

A set of extra header fields in the HTTP response message are used to parametrize an SP request. We defined the following ones:

- **PSvc-Service** (mandatory): the value of this field is a JSON object with key-value pairs. For the yellow-pages service, it contains the attribute of the services to be listed. For the white-pages service, it contains the attributes of a service to get an handle to. Finally, for invoking a personal service it contains the handle for that service.

- **PSvc-Method** (optional): its value is the method to be used in an HTTP request when invoking a personal service. It may be obtained from the service’s presentation attributes. When not specified, it defaults to GET.

- **PSvc-Parameters** (optional): its value is a path plus query to be used in an HTTP request to invoke the personal service. The totality or only part of its value may be obtained from the service’s presentation attributes.
Figure 3: Yellow-pages (service listing, top diagram) and white-pages (name resolution, bottom diagram) services: request/response flows and relevant HTTP fields.
Figure 4: Personal service invocation: request/response flows and relevant HTTP fields. This diagram shows a complex example where a personal service returns some result to an SP; this may not be necessary for all cases, namely for content-handling personal services.

- **PSvc-Callback** (mandatory): its value is an URL to be used in HTTP requests to return the control back to the SP (upon a call to the Broker).

### 3.2.1 Handling status code 310-312 redirections

When a browser receives a status code 310 or 311 on a response message (from an SP), it transforms it into a HEAD request to the Broker. The normal reply to these messages is provided to the browser with a status code 313, which implies a further redirection to the SP with the Broker’s result. The redirection is made to a callback URL that must be provided in the “PSvc-Callback” header field.

When a browser receives a status code 312 on a response message (from an SP), it transforms it in a request to a personal service. Such transformation involves first a translation, by the Broker, of the given service handle to its TCP endpoint (hostname and port, see Figure 4). This endpoint is then combined with the value of the “PSvc-Parameters” field to build the URL to invoke the personal service. Finally, all header fields existing in the SP response, plus its
body, are copied to the personal service request.

The reply to such request is provided by the target personal service, which may call back the SP, if necessary, using the already existing HTTP redirection mechanisms and a callback provided by the SP (specified with a mechanism other than the “PSvc-Callback” header field). Note that if redirections are used to return the control from the personal service to the SP, the method (GET, POST, etc.) used to invoke the personal service is the same that will be used to call back the SP. This potential limitation can be overcome by returning the control to the SP from a Web page returned by the personal service, using or not JavaScript (see Section 5).

The HEAD messages used to invoke the yellow- and white-pages functions of the Broker are similar to GET messages, but their response has no body. Thus, Broker responses to SP calls are conveyed to the calling browser in the header field “PSvc-Service”. The redirection of the response from the browser to the SP depends on the service requested to the Broker:

- **Yellow-pages.** The reply contains the name query and a list of service descriptions that should be uploaded to the SP and possibly presented to the user through their browser. In this sense, the response to the SP should be made by a POST request, which is triggered by the Broker by replying with a 313 redirection to the SP’s callback URL (given by the “Location” header field).

The list of service descriptions, given by the “PSvc-Service” header field, will be a JSON array of the objects with the presentation attributes of those services.

```
PSvc-Service = {
    "operation" : "Yellow Pages",
    "request" : { attr_name : attr_value },
    "response" : [ services' presentation attributes ]
}
```

- **White-pages.** The reply contains a personal service handle that should be uploaded to the SP. Once reaching the SP, can be invoked immediately or later on, for instance, upon a user confirmation. As in the previous case, the response to the SP should be made by a POST request, which is triggered by the Broker by replying with a 313 redirection to the SP’s callback URL.

The service handle and its description, also given by the header field “PSvc-Service”, will be a JSON object with two elements: (i) the service’s presentation attributes and (ii) its handle.

```
PSvc-Service = {
    "operation" : "White Pages",
    "request" : { service attributes },
    "response" : {
        "service" : { service presentation attributes }
    }
}
```
The handle is an opaque datum that only makes sense for the Broker that produced it. In other words, neither browsers nor SPs have to interpret the contents of handles.

### 3.2.2 Brokers’ deployment

Different Broker deployment strategies can be considered. For instance, browsers can use their own configuration to manage their Brokers. In this case, they could use different Brokers, and Brokers could be part of browsers’ distribution packages, instead of independent applications. Different Brokers could use or not the same configuration files for the personal services.

This last approach does not create any technical problems to exploit personal services but it has the potential to introduce entropy in the users’ execution environments. In fact, it would be much simpler for a user to have a single Broker, independent from all browsers, with a well-known communication endpoint, that a user could recognise and get used to, to manage the exploitation of their personal services.

Consequently, the architecture that we uphold is the following:

- A single, per-user repository of personal services’ definitions. This repository can be a set of JSON-formated text files, editable with ordinary, text editing tools.

- A single, per-user Broker application. This application may be launched by any browser if not already running. The TCP endpoint used by the Broker should not be unique, to allow other Brokers to coexist, namely the ones of other users in multi-user systems.

In Unix-like systems one can use TCP over Unix sockets, which can be given a name under the user’s home directory file system hierarchy, to easily avoid clashes between endpoint names given to different Brokers. In Windows systems we need to use different TCP ports for a single loopback address or different loopback addresses.

### 3.3 Management of handles

Handles are opaque data structures for browsers, in the sense that they should not interpret their intrinsic value. The value of handles is defined by Brokers and should be used only by them to manage personal services. When a browser receives a handle-based service call, it first calls the Broker to get the current TCP endpoint name for the service corresponding to the handle (see Figure 4).

In the case the handle refers a local personal service, the Broker will launch it, if not already running; at the end, it redirects the browser to the correct TCP endpoint using again the 313 status code but with a “Location” field with
an reference to an internal, ongoing call to the personal service. This internal reference is signaled (i.e., differentiated from a regular URL) by a location string formed by a colon followed by a value with the internal reference, a value provided by the browser in the parameters of the HEAD request.

In the case the handle refers to a remote personal service, the Broker checks if the remote personal service is accessible and if so, it proceeds as if it were a local service.

In Figure 4 we can observe the complete sequence of requests and responses involving the SP, the browser, the Broker and the personal service. In this sequence the browser keeps a service request on hold, while waiting for a Broker’s response. Upon such response, the browser creates an HTTP request to the service using parameters extracted from both the SP response and the Broker response. The method used in the request is given by the SP in the “PSvc-Method” header field (or GET by default). Although not shown in the figure, the browser copies all the headers of the SP response to the personal service request, this way allowing a more flexible interaction between them.

### 3.4 Access control policies and mechanisms

Currently, browsers allow SPs to invoke HTTP services running in a browser’s host; all they have to do is to explore HTTP redirections to an TCP/IP address locally bound to the host itself (the “localhost” name, or an IP address 127.0.0.1, and some TCP port). As previously referred at the end of Section 1.2, this was explored in [8] to explore a single personal service.

An HTTP redirection to the localhost may look suspicious, however most browsers cope with it without warnings. From our experience, only Opera warns the user and asks for permission to proceed. In our case, the access to personal services requires service handles, and these can only be obtained upon a service name resolution. Note that personal services can rule out accesses using the previously referred redirection to localhost (i.e., with status codes 3xx other than the 312) by checking the presence of the special HTTP headers included by the browser upon a handle-based service invocation (not shown in Figure 4 for simplicity, but referred at the end of section 3.3).

Therefore, two architectural elements can implement access control policies regarding the access of SPs to personal services:

- Broker: it can allow (whitelisting) or prevent (blacklisting) some services from being listed or resolved by certain SPs.

- Browser: it can allow a handle to be used by any SP, allowing related services to share a handle, or restricting the exploitation of a handle only to the SP that received it from the browser’s Broker.

Regarding the first case, the implementation of an access control policy when dealing with service names, it does not need to be universally defined, it can be freely implemented by Brokers. In fact, users are free to pick any suitable Broker, and different Brokers can implement different protection mechanisms
and allow different protection policies, while keeping a standard communication protocol with local browsers and SPs.

Regarding the second case, it needs clarification because all browsers should follow a similar strategy. Furthermore, browsers should cope with their Brokers to provide a clean and well-defined access control policy. The easiest way to deal with such cooperation is to leave all access control decisions to Brokers, being them the sole entities responsible for taking care of such decisions. This can easily be implemented, since a handle-based call to a personal service needs to be resolved by the Broker to a TCP endpoint, and for that purpose the Broker receives the identity of the SP host (together with the service handle, see Figure 1).

3.5 Content transfer in service calls

When SPs call personal services, using the 312 redirection, they can transfer arbitrary data to services by adding it to the reply header and body. With the exception of the “Status” header field (always the first header field), the entire header and body are copied to the request that is created to invoke the personal service. The only header field that is added in this response-to-request transformation is the “Referer” one, identifying the SP (see Figure 1). Note that this is not what happens with the actual redirections, where both the header and the body of the response are ignored.

The same thus not happen when the personal service returns the control to the SP, because this is done with the actual redirections. However, the personal service is free to interact directly with the SP, without involving the browser in that dialog.

3.6 Security-related limitations

The redirection 313 was conceived to implement Brokers’ responses to calls triggered by redirections 310, 311 or 312. Therefore, browsers should restrict the use of redirections 313 only to their Broker, and deny their arbitrary use as other 3xx redirections orchestrated by SPs. Otherwise, they could be used to implement new attack vectors, where malicious SPs could force browsers to make unintended requests to victim servers.

3.7 Error handling

When wrong HTTP redirections occur, they result in HTTP access errors presented by browsers to users; no feedback is given to the agent that gave the redirection order. In our case, however, we can and should provide some error reports to SPs upon some errors that can occur while exploiting our special redirection mechanism.

We have identified the following relevant error situations, some of which should trigger well-defined error reporting interactions:
• The browser is not prepared to deal with personal services. In this case, SPs must be warned in advance if browsers support personal services, because the opposite is impossible. This capability can be signaled by a special field in all HTTP requests made by the browser: “PSvc-Version”. This field must contain the list of protocol versions supported by the browser to interact with personal services.

• The Broker cannot be called for listing services or resolving service names. The browser should report this error to its user and should carry on with the reply to the SP with an empty result.

• Several other errors may happen upon an SP call to the Broker or to a personal service. This case is more delicate than the former, since there is no standard response to be provided to the SP by either the browser or the Broker. We decided to use the SP callback path provided by the SP (in the “PSvc-Callback” header field), to carry on an error reporting call. In such call we use an header field, “PSvc-Error”, to convey four possible textual error codes:
  – “parameters”: when the SP request is malformed (has missing or wrong parameters).
  – “ambiguous”: when more than one service matches a White Pages’ request.
  – “handle”: when the service handle provided is no longer valid.
  – “service”: when the requested service cannot be found or activated.

For interactions between SPs and personal services not requiring a posterior SP callback, SPs can still handle this error by providing a callback path just for this purpose.

4 Implementation

We built a prototype for testing the previously described redirections and name service. In this prototype we did not change any browser; instead, we implemented an HTTP proxy which deals with the new redirections. This is not a suitable solution for all cases, since it cannot deal with redirections when they occur withing HTTPS sessions. However, it facilitated a lot the creation of a proof-of-concept implementation.

The core of the prototype is then an HTTP proxy and a Broker. Both where implemented in Java, using a set of classes and interfaces belonging to packages under com.sun.net: HttpServer for implementing HTTP servers, HttpHandler to define service handlers and HttpExchange for implementing HTTP interactions.

The proxy forwards GET and POST requests, adding to them the “PSvc-Version” header field. The subsequent responses of SPs are first analyzed, to handle the
new redirections. If not present, the response is forwarded to the client browser; otherwise, a new response is created by calling a Broker.

4.1 Configuration files

The interaction between the HTTP proxy and the Broker is helped by a file (broker.ept) stored in the .PS subdirectory of the user’s home directory. This file is the Broker’s contact endpoint; in Windows systems it is a regular file containing its TCP port (the IP address is implicitly 127.0.0.1); in Unix-like systems, it is a UNIX socket name. For each personal service there should be a separate file in the .PS directory. We used the extension .psd (from personal service description) to identify such files from the Broker. Each of these files should contain a single object description, in JSON, with two sub-objects: configuration and presentation (for the configuration and presentation attributes, respectively). The contents of the presentation object are free, while the configuration object should contain the following attributes that are looked for by the Broker:

- **dir**: the directory where the service should run; if absent, the Broker uses .PS.
- **cmd**: the command that starts the personal service, if not yet running.

Those attributes allow the Broker to act similarly to the well-known inetd Internet service daemon (or super-server).

For completeness, there is also a broker.psd file in the .PS directory with the configuration attributes for the Broker. It allows our HTTP proxy (or a modified browser) to launch the Broker if not yet running.

4.2 Interaction with personal services

The TCP port used by each personal service is allocated by the Broker and passed as a parameter when launching the personal service. The Broker allocates it for all local addresses and sets its to be reused by another process; the personal service binds it only to a local address (127.x.x.x).

Upon launching a personal service, the Broker keeps a local record of its process and TCP endpoint within its internal structure associated with the service. This structure is used each time an SP invokes the personal service using a handle to it. If the service is still alive, its TCP endpoint is returned to the Broker caller; otherwise, the personal service is launched again, possibly using a different TCP endpoint. This way, we are able to accommodate both personal services that terminate after completing a service request and those that stay alive after a first request.

In our implementation, a handle is a JSON object with the description of the service that requested it and a reference to the internal structure describing the service, encrypted with a symmetric key known only by the broker. This way, SPs cannot generate valid handles and cannot transfer handles among
themselves; they need to go through the client’s White Pages service for being subject to authorization clearance.

5 Experimentation

For experimenting the invocation of personal services we adapted the eID-based authentication protocol presented in [8]. The adaptation consisted in the following actions:

- The SP requesting a user authentication checks if the client supports the invocation of personal services (by checking the presence of the “PScv-Version” field).

- Upon a successful validation, the SP check if there is a service capable of performing the eID-based authentication protocol described in [8]. For this, it uses the White Pages’ service to lookup for a service with the following attributes:

  ```json
  {
    "Purpose": "authentication",
    "Device": "Portuguese eID"
  }
  ```

- If there is such a service, the SP invokes it with the redirection 312 using a GET method.

The existing personal service was not changed except for using the TCP port provided as parameter to wait for HTTP requests. Its configuration file, used by the Broker, was created with the following contents (for a Windows system deployment):

```json
{
  "configuration": {
    "dir": "Z:/PersonalServices/CCPersonalService",
    "cmd": [
      "java",
      "-jar",
      "CCPersonalService.jar"
    ]
  },
  "presentation": {
    "Purpose": "authentication",
    "Credentials": "digital signature",
    "Protocol": "certificate + digital signature",
    "Device": "Portuguese eID",
    "Device name": "Cartão de Cidadão"
  }
}
```
The experiment ran without any problems. The personal service handling the eID authentication, yet another Java application, was launched upon the first SP call and remained executing, tackling posterior requests. Comparing with the original protocol design, the SP no longer has to know the exact port where the personal service of interest is waiting for requests.

Figure 5: Capture of a dialog between a browser (its proxy, actually), an SP, a Broker and a personal service. The SP uses port 8080, the Broker uses port 12346 and the personal service uses port 10005. The invocation of the White Pages service can be observed in messages 5 to 8, while the invocation of the personal service using a previously obtained handle can be observed in messages 9 to 44.

Figure 5 shows the packet capture of the entire interaction involving the proxy, an SP, the Broker and the involved personal service. We left the browser out because it would not highlight any special aspect of the message exchange. The SP uses port 8080, the Broker uses port 12346 and the personal service uses port 10005.

The SP implements a demo service that manages client cookies, namely authentication cookies, created upon a successful eID-based authentication. In message 1 the server receives the initial request, which does not have any cookies, which it redirects to its own eID-based authentication service (using redirection 302, message 2). This service, invoked in message 3, starts by using the client’s White Pages to check whether it has the appropriate personal service (messages 4 and 5). The invocation of the White Pages service is visible in messages 6 and 7, and the result is conveyed to the SP in message 8. Once having a proper handle, the SP uses it to invoke the personal service of interest (messages 9, 10...
and 11). Upon that, the proxy uses the handle to get the TCP endpoint of the personal service (messages 12 and 13) and the service is invoked in messages 14 and 15 (using a GET method, specified by the SP). Thereafter, and until message 39, the personal service conducts the eID-based authentication while keeping a dialog with the user through the browser. This dialog terminates upon a successful eID authentication, which return an HTML content that performs an automatic POST of the authentication results to the SP (messages 40 to 44). Upon the validation of the results, the SP redirects the browser to the initial service called by the user, using again the redirection 302 (messages 45 to 49).

This experience does not show the invocation of the Yellow Pages service, because it was not necessary in this demonstration.

6 Access to Brokers by scripts of Web resources

As already mentioned in Section 2, a solution that is nowadays in place to invoke a personal service that deals with the eID-based authentication using the Portuguese identity card (Cartão de Cidadão) is based on the use of a list of fixed TCP endpoints and active contents (JavaScript scripts) that look for them. This solution poses an interesting question: should browsers allow JavaScript, or any other scripting language interpreted within the context of a Web resource, to invoke the browser’s Broker?

With the proposed model for providing responses to invocations to the Broker, that would not be possible. In fact, the proposed model uses the redirection 313 to return the control to an SP (a server), and not to a JavaScript client. Furthermore, the identification of the requester of the Broker’s services (provided in the “Referrer” header field) would have to be extracted from the DOM (Document Object Model) of the Web resource executing the script, in order to provide an accurate access control decision by the Broker (as discussed in Section 3.4).

Concluding, this is an interesting topic for future work and discussion.

7 Conclusions

In this paper we presented an architecture to allow SPs to interact with personal services of interest. Personal services are HTTP services that run under the control of the browser user, either on the same machine of the browser or in a different machine, and provide some service that may be useful for the SP. The example that we have used, throughout this paper, was a personal service developed for performing an eID-based authentication.

For enabling SPs to make request to personal services we developed a name service to help in that task. The name service allows SPs to discover personal services of interest, to get an handle for a particular personal service and to call that personal service using that handle. The name service is supported by a Broker, which is an application that runs and exists independently of browsers.
The Broker is responsible for knowing which personal services exist, for running them and for managing their communication endpoint.

The interaction between SPs, browsers and the Broker is mainly supported by a new set of 3xx redirections, complemented with some new HTTP header fields. The interaction includes the invocation of Yellow and White pages on the Broker and a handle-based call to a personal service.

The proposed architecture was implemented on an HTTP proxy and successfully tested with an adapted implementation of the authentication protocol described in [8].

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