IDEA GROUP PUBLISHING

701 E. Chocolate Avenue, Suite 200, Hershey PA 17033, USA
Tel: 717/533-8845; Fax 717/533-8661; URL-http://www.idea-group.com

ITP5207

This paper appears in *Managing Modern Organizations Through Information Technology*, Proceedings of the 2005 Information Resources Management Association International Conference, edited by Mehdi Khosrow-Pour.

Embedded SOAP Server on the Operating System Level for Ad-Hoc Automatic Real-Time Bidirectional Communication

Thomas B. Hodel, Florian Specker and Klaus R. Dittrich
University of Zurich, Dept of Information Technology, Winterthurerstr. 190, CH-8057 Zürich, Switzerland
{hodel, dittrich@ifi.unizh.ch}, specker@icu.unizh.ch

ABSTRACT

Applications using SOAP messages for communication purposes invoke one or several web-services and normally receive a return message for each call. In addition to this, our solution proposes that such applications automatically configure an embedded SOAP server on the operating system level so that a specified server can send an independent SOAP request to this application. The result is a generic framework for an ad-hoc automatic real-time bidirectional communication using/over SOAP messages.

In this paper we also describe our concept of extending the functionality of today's applications and operating systems in order to realize an ad-hoc automatic real-time bidirectional communication using SOAP via HTTP. Finally, we take a look at a concrete implementation of an application which uses SOAP in this customized way.

INTRODUCTION

When thinking about distributed systems, the first thing that comes to mind is the "trench" that lies between the single components of systems. This trench will inevitably be an obstacle to interprocessing communication.

The obvious need for calling remote methods to build a distributed system is the origin of some very different approaches to communication across component borders [6,2]. Most of them are aimed strictly at a specific problem and/or a specific environment. This prevented the traditional protocols from being used in a wide range of scenarios; SOAP has the potential to succeed where its predecessors have failed. Its pros (loose coupling, late binding, platform-, language- and vendor-independence, freely available specification and documentation, easy to implement) make it suitable for many applications, while its cons (resource-intensiveness, no native security model) are not enough to prevent it from being used in most of them.

APPROACHES

If a client needs bidirectional communication, SOAP does not provide it with a solution. Such a communication can be described as "bidirectional, synchronous as well as asynchronous". While the need for bidirectional communication (in the sense of sending messages in both directions) is obvious in itself, the need for synchronous as well as asynchronous communication can easily be explained. The Remote Procedure Calls are synchronous in the sense that one endpoint will wait for a call to be finished before sending the next call, but are asynchronous in the sense that the application server or client may initiate a transmission at any time (provided that the previous call of the same endpoint has been completed by that time).

To meet these needs, a SOAP server is needed at both endpoints. This does not comply with the traditional Client-Server model, but is necessary for the "server" to be able to send a message to the "client" without first having to wait for the "client´s" request. The result is similar to what is known as "peer-to-peer" [3,7], where each node acts as the client and server at the same time.

In order to provide the application client with the possibility of receiving SOAP messages, two solutions are feasible: the client either embeds its own protocol server or registers itself at an external protocol server which is already installed on the same machine.

EMBEDDED SOAP SERVER ON THE OPERATING SYSTEM LEVEL

An embedded SOAP server on the operating system level would enable bidirectional communication via SOAP and represent an additional solution, which one could investigate more closely. A possible scenario for such a SOAP Server Component (SSC) may look like Figure 1.

The operating system ships with a HTTP server and a SOAP router. Applications may register the methods that need to be callable via SOAP using the SOAP server API, if they provide a WSDL document containing a description of the services as far as the application can determine them (i.e. data type and the number of parameters, return values, etc.).

The SSC would register the application with its methods, completing the parts of the WSDL document which cannot be controlled by the application (e.g. the Transport Protocol, the Port numbers or the method names - since there may be two processes registering a method with the same name, the SSC must be able to distinguish them properly). The SSC should generate WSDL documents on the fly to allow dynamic registering and deregistering; furthermore, it should be able to generate WSDL documents containing only the methods provided by a specific application, especially when there is a significant number of applications that have registered methods. If abnormal termination of registered applications that leads to invalid register entries is an issue, the registrations process could be designed as a form of leasing, as known from DHCP. Registrations would only be valid for a specified amount of time, after which they would have to be renewed in order not to become purged.

If being independent of the SOAP binding is desired, the SSC should be capable of generating SOAP responses even when communicating via a SMTP binding. This should be done transparently to the applications registering in order to achieve a true independence from the binding the SSC uses.

A Routing Table would allow an incoming message to be passed to the process of the application which registered itself at the SSC for that

Figure 1. Diagram of the Presented SOAP System Component (SSC)

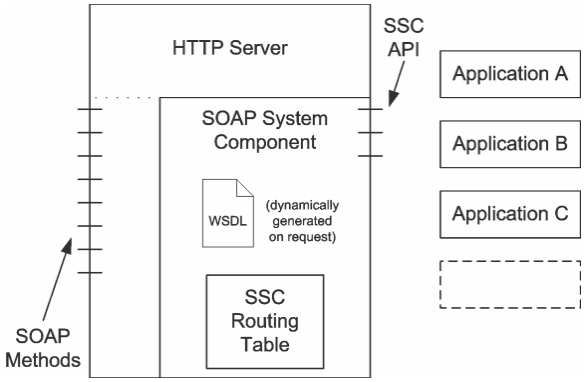
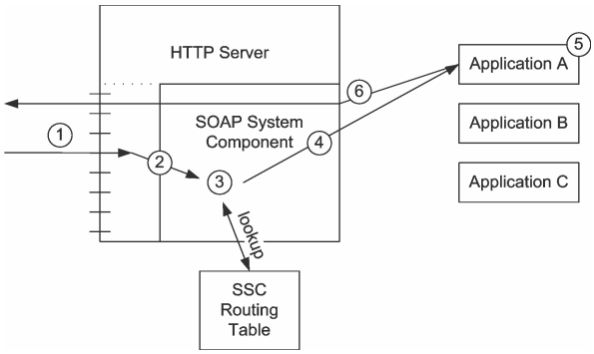


Figure 2. Incoming SOAP Message is Passed to Correct Application



method. As can be seen in Figure 2, an incoming message would be processed as follows:

1. the message arrives at the HTTP server
2. the HTTP server calls the SSCs SOAP router to handle the message
3. the SOAP router determines which process the message should be passed to by means of the Routing Table
4. the message is passed to the application which registered for the method
5. the application processes the message
6. the application sends a response to the SSC which then relays it to the sender of the original message

A SSC, as introduced above, would give application developers a powerful and easy-to-use possibility for bidirectional SOAP communication. The integration into the operating system would ease the administration and the enforcement of security policies, especially in large installations. Obstacles such as traffic-blocking firewalls would be easier to overcome and security measures, for example, using SSL to encrypt the communication, authentication to restrict the use of the services, or logging facilities, would only have to be implemented once and could be centrally administrated.

However, a tight integration into the operating system would open the door for new vulnerabilities and exploits, as is always the case with additional services. Buffer Overflows in such an integrated component would allow Computer Worms and Crackers to do a lot of damage, and security leaks in the logical separation of registered applications would render the SSC a comfortable place for man-in-the-middle attacks to bypass the security measures of encrypted communication. Finally, there is a danger of platform dependence (or at least dependence on a specific implementation), since a SSC without proper specification could break with the platform independence of SOAP.

EVALUATION

A method of communication established by components using SOAP, and realizing the described automatic bidirectional communication based on the concept of an embedded SOAP server on the operating system level, is a crucial service for business. As example we are offering this service within a collaborative word processing system [5]. Therefore we begin by briefly introducing the underlying concept.

TeNDaX is a **Te**xt **N**ative **Da**tabase e**X**tension. It enables the storage of text in current databases in a native form so that editing text is finally represented as real-time transactions. Under the term 'text editing' we understand the following: writing and deleting text (characters), copying & pasting text, defining text layout & structure, inserting tables, pictures, and so on i.e. all the actions regularly carried out by word processing users. With 'real-time transaction' we mean that editing text (e.g. writing a character/word, setting the font for a paragraph, or pasting a section of text) invokes one or several database transactions so that everything which is typed appears within the editor as soon as these objects are stored persistently. Instead of creating files and storing them on a file system, the content of documents is stored in a special way in the database, which enables very fast real-time transactions for all editing processes.

The database schema and the above-mentioned transactions are created in such a way that everything can be done within a multi-user environment, as is known within the database technology field. As a consequence, many of the achievements (with respect to data organization and querying, recovery, integrity and security enforcement, multi-user operation, distribution management, uniform tool access, etc.) are now, by means of this approach, also available for word processing.

TeNDaX proposes a radically different approach, centered on natively representing text in fully-fledged databases, and incorporating all necessary collaboration support. Under collaboration support we understand functions such as editing, awareness, fine-grained security, sophisticated document management, versioning, business processes, text structure, data lineage, metadata mining, and multi-channel publishing - all within a collaborative, real-time and multi-user environment.

Collaborative Editor System

First of all the runtime behaviour and the communication between the client and the server are introduced. Later we go on to describe the server and Error Handling. The focus lies on the points introduced by the components for the automatic SOAP communication

1. The server is started and initialises itself; it is now ready to serve the clients and awaits their registrations.
2. A client starts up and invokes its embedded HTTP server. It probes for a free Port in the private Port range, and binds the HTTP server to this. A WSDL document describing the methods offered by the client, and how to call them, is generated according to the actual settings.
3. The client authenticates and registers at the server, handing over the WSDL document created in the step above.
4. The server adds the client to the list of registered clients. Since there might be clients who communicate using protocols other than SOAP, this list must contain additional information, such as the protocol the client expects, as well as further details. In this case, all of these further details are described in the WSDL document the server just received. For now, the server saves it to be able to communicate with the client in the future. The client is now registered and ready to work.
5. Every action which the user of our client takes is reported to the server. If the user has permission to carry out the changes he tries to make, the server grants them, and it informs the other clients to whom the changes are relevant. If the user is not permitted to

make these changes, the client is informed about the illegality by the server, and may in turn inform the user about it.
6. After the user has completed his work (e.g. he quits the client), the client deregisters from the server and stops its embedded HTTP server. After that, it can exit cleanly.
7. Upon the clients deregistration, the server removes the clients entry from its list of registered clients and deletes its WSDL document.
8. After deregistration of the last registered client, the server may be stopped.

The Collaborative Editor

The client must be able to (de)register itself at the server, to open, close, create and delete documents, and request the committing of the changes the user tries to do to an opened document. All of these tasks can be carried out using the classic Client-Server model [4]. For SOAP communication, any existing library can be used, and quite a lot of them offer SOAP client functionality. However with regard to the next requirement, the classic Client-Server model fails: the client must be notified if someone else's changes on a document opened by the client have been committed. This is the reason why we also need to have a SOAP server on the client side as well.

Collaborative Editor Server

The server must be able to (de)register the clients, to process their requests, and to notify the affected clients about committed changes on documents. SOAP support on the server side is no big thing.

Error Handling

Using SOAP for the Client-Server communication not only introduces new possibilities and flexibility, but also new sources of possible errors. Several things can go wrong when trying to send a SOAP message from one endpoint to another. Some of these problems can be solved by the client (or, less favourably, by the user) on its own, so good Error Handling constitutes a large part of the usability of a client.

If, for example, the other endpoint is unreachable, the problem could be anywhere between the client and the server. A router between them may have crashed, or a network cable may have been plugged. The application client can't do much in such a situation, but the user possibly could, if the client tells him what to do (check cables, check the connection state, check the connection settings, etc.). If other network problems such as timeouts due to network overload, or connection resets due to a server crash occur, the client could at least display an error message explaining what happened, and assist the user in calling Technical Support to solve the problem.

Nasty things, like internal errors of the HTTP servers or configuration errors, could be detected automatically by each endpoint, by calling a test method. If, for example, the client notices that its embedded HTTP server is not responding, it could try to restart and reconfigure it to solve the issue. If that doesn't help, it could still ask the user for help, and send an exact error message to the developers.

As SOAP is a stateless protocol, endpoints will not notice a connection failure or an abnormal termination of the communication partner until they try to send a message. Since it might also be useful to notice problems during inactivity, the concept of Heartbeats [1] could be implemented. The client, as well as the server, sends control messages to each other at defined intervals; if they have not received such a control message for a while, they know that the other endpoint has terminated abnormally, or that a connection error has occurred. If the server registers the client's Heartbeats as missing, it automatically deregisters the client. If, on the other hand, the client registers the server's Heartbeats as missing, it should try to reconnect; if this fails, it should check if the server can be pinged, so that it can give the user accurate information about the problem.

While the errors described above should be the most likely, it is possible that others will occur.

Proof-of-Concept

The Exchange Component is only a small part of the client. The task was to write an implementation of the interfaces in the package tdb.sys.exchange.

Client

The most important object of the SOAP Communication Layer is SOAPServer in the server package, the class to which all the calls to SOAPExchange are forwarded. It acts as a proxy of the application server, hiding all the details of the communication from the application client. This is the place where the SOAP methods on the application server are called.

The SOAP server in the application client is implemented using Jakarta Tomcat and Apache Axis. The service itself is implemented in a single class. All this does, is to push the incoming message into the TDBUpdateMessageQueue after removing its brackets. To allow UpdateListener to get a reference on TDBUpdateMessageQueue, Update became a Singleton, ensuring that it will only be instantiated once, and that every object running in the same Java VM can easily get a reference on it.

Server

To minimise the number of complex types to be sent across the wire, methods which expect "unnecessary" complex types have been wrapped. Only the ID of these objects is passed to the wrapper method, which fetches the appropriate object to pass it on to the original method.

The last change on the server side was to distinguish between clients connected via Caché JDBC and clients connected via SOAP to inform them about changes in opened documents. The clients connected via Caché JDBC are informed as they were previously, while the ones connected via SOAP are informed by the SOAPUpdater: This class calls the "processMessage" method of the SOAP server embedded into the client.

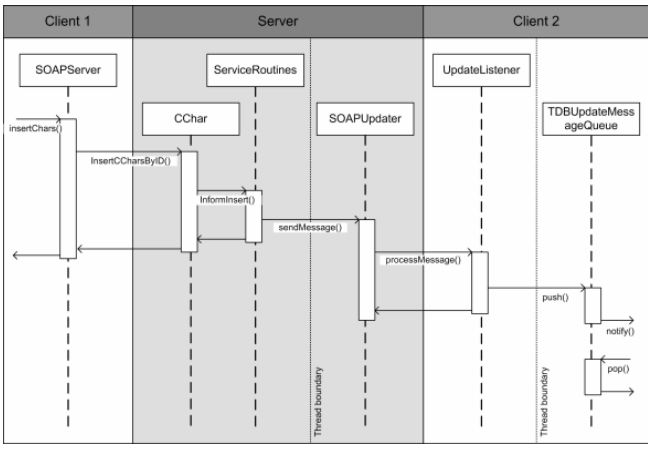
Automatic Bidirectional Communication

The following part traces in detail the chain (see Figure 3) of calls caused by a character insertion, in order to understand the whole process more fully.

Startup

On application startup, SOAPExchange is instantiated and initialised. It initialises the SOAPServer, which creates a new session on the server (NewCSessionByID, the wrapper method for NewCSession, will set the session's "ClientConnection" attribute to "SOAP"), and Update. Up-

Figure 3. Chain of Calls Caused by the Insertion of a Character



date instantiates the classes needed for the update system, and then starts Tomcat to wait for messages about changes in opened documents.

Operations: The behaviour of the file operations (creating, deleting, opening or closing) have remained the same as in the original implementation of the Collaborative Editor client [4].

The process of inserting a character into a document is not trivial, since the change has to be propagated to other clients that have the same document opened. This process in the SOAP implementation differs remarkably from the one in the JDBC implementation.

Editing a Document: The user presses a key, and the insertChars() method of SOAPExchange is called on. It is passed on to SOAPServer, the class that now calls InsertCCharsByID() on the server via SOAP. InsertCCharsByID() is the wrapper method for InsertCChars(); it opens the CDocument and the CSession objects with the IDs passed from the client and calls the traditional InsertCChars(). If everything is all right, InformInsert() from the ServiceRoutines is called, which starts a new thread with GenericMessage() to inform the other clients about the change. For the clients connected using SOAP, this is done by SOAPUpdater.sendMessage(). It calls the processMessage() of the client's UpdateListener, the one that is running as embedded SOAP server. The SOAP-specific part of the process ends with the pushing of the received message into the TDBUpdateMessageQueue.

Shutdown: Unlike the JDBC-based implementation which uses stateful connections, the SOAP implementation doesn't need to close any existing connections. The Shutdown process is reduced to deleting the existing session object from the server, together with "DocumentSessions" that might still exist at that time.

Benchmarks

When comparing the behavior of the Collaborative Editor client connected via JDBC with one connected via SOAP, the overhead introduced by SOAP notably delays the real-time bidirectional communication between the client and the server. In order to be able to estimate the performance loss caused by this overhead, we have indicated the time taken by some regularly used methods in the table below.

As illustrated, JDBC outperforms SOAP by a factor of 10.7 to 90.5. This is the price to be paid for the advantages SOAP has to offer. The figures are put into perspective if we consider that opening and closing a document are not used as often as reading or writing a character, where the factor only ranges from 10.7 to 27.4.

Method Name	*Caché JDBC*	*SOAP*	*Performance Loss Factor*
Open CDocument	(3,4,9)	(80,194,467)	48.5
Close CDocument	(2,2,9)	(167,181,231)	90.5
GetCChars	(3,19,57)	(173,203,234)	10.7
InsertCChars	(9,10,24)	(217,274,833)	27.4

[JDBC, SOAP: The numbers printed are milliseconds (minimum, median, and maximum) of 10 measurements; Performance Loss Factor: med(JDBC)/med(SOAP)]

CONCLUSION

The implementation illustrates the advantages of SOAP: the tight coupling between the client and the server has been loosened, and the already existing platform independence has been upgraded to language independence. The Collaborative Editor is still usable, although it reacts with a small delay. Of course, the overhead introduced with SOAP restricts the scalability of TeNDaX.

To improve the usability of the SOAP-enabled operating systems for ad-hoc automatic real-time bidirectional communication the primary target will be user interaction and failure tolerance.

REFERENCES

[1] M. K. Aguilera, W. Chen, and S. Toueg, "A timeout-free failure detector for quiescent reliable communication," presented at 11th International Workshop on Distributed Algorithms, WDAG'97, Saarbrucken, 1997.

[2] H. Attiya and J. Welch, *Fundamentals, Simulations, and Advanced Topics*: McGraw-Hill, 1998.

[3] D. Barkai, *Peer-to-Peer Computing: Technologies for Sharing and Collaborating on the Net*: Intel Press, 2002.

[4] T. B. Hodel and K. R. Dittrich, "A collaborative, real-time insert transaction for a native text database system," presented at Information Resources Management Association (IRMA 2004), New Orleans (USA), 2004.

[5] T. B. Hodel and K. R. Dittrich, "Concept and prototype of a collaborative business process environment for document processing," *Data & Knowledge Engineering*, vol. Special Issue: Collaborative Business Process Technologies, 2004.

[6] L. Lamport, Lynch, N., "Distributed computing: Models and methods," in *Handbook of Theoretical Computer Science*: Elsevier Science Publishers, 1990, pp. 1158-1199.

[7] A. Oram, *Peer-to-Peer, Harnessing the Power of Disruptive Technologies*: O'Reilly, 2001.