

# Defending Against Denial of Web Services Using Sessions

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**Abstract** — With Web Services being accepted and deployed in both research and industrial areas, the security related issues become important. Denial of Web Services (DoWS), as an easily constructed attack approach, is a potential threat for the deployment of Web services, especially on a wide area network. In this paper, we introduce the session based ideas into the access of Web services and develop a fair share based filtering algorithm to improve the resistance capability of a Web service to DoWS. The implementation of our framework on the Java platform is presented. The preliminary experiment and its result show that our framework can improve the resistance capability of a Web service to DoWS without modification to the existing client side programming models. The extra overload introduced by our framework to the server side is low.

**Keywords:** Web Service, Denial of Service, WSDL, Session

## 1. Introduction

According to [1], “A Web service is a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically Web Service Definition Language (WSDL) [2]). Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards.” Web services, as a new building block in distributed computing environment, are beginning to be deployed by more and more organizations for their Enterprise Application Integration (EAI) in their LAN. However, most organizations are still hesitating to deploy Web services in a WAN. One important reason is the security of Web services. Currently, the society of Web services have produced a series of specifications in order to enhance the security of Web services from basic WS-Security [3] that aims at end-to-end security to WS-Trust [4], WS-SecureConversation [5] and WS-SecurePolicy [6] that aim at securing exchange of multiple messages in multiple trust domains with different local policies. All of

the existing specifications do not touch denial of Web services (DoWS) anyhow.

From the definition of Web services above, we can see that a typical Web service request is an XML encoded SOAP message. Each Web services hosting environment has some time-consuming XML processing steps such as serialization, deserialization and parsing in order to understand a service request. DoWS is an attack that takes advantage of this feature. It will degrade or even deny the normal access to a Web service by flooding useless but legal SOAP requests from an attacker. This is not difficult to perform if the attacker can get the WSDL file of the target Web service. We can imagine that the attacker can create many mimic Web service method requests given the WSDL file as other normal users do. Although someone may argue that for an attacker, it is not easy to construct a valid service request with WS-Security protection, the fact is that even the validation of the identity information embedded in a SOAP request needs XML processing time as well. According to [20], the evolution of attack sophistication in these years is towards distributed attack tools, so it is not difficult to generate many SOAP requests in order to attack a specific Web service.

In the real E-Business world, a series of Web services will be deployed as a workflow to fulfill a complex task automatically. If these Web services are federated among several physical organizations, for example, using Liberty identity federation protocols[7, 8] or WS-Federation [9], then denial of any of these Web services is much more dangerous than DoS of a traditional Web site because DoS of a traditional Web site will only influence one physical organization, whereas DoWS here will influence many physical organizations.

One obvious approach against DoWS is access control of the WSDL file of a Web service, for example, only the authorized users can retrieve this WSDL file. Unfortunately, this is not the final solution. The attackers still have many ways to get this WSDL file, like buying the information from a third party, sniffing the information on the wire to find the address and related operations of a web service if this web service is not protected appropriately, for example, the SOAP messages are not encrypted. Furthermore, some web services have to embrace everyone by default, for example, the web services interfaces from Google, MSN, etc. In fact, if we

only depend on access control of WSDL files to attack DoWS, then in the worst case, if an attacker cannot get the related WSDL file using the easier approaches listed above, he will just compromise a valid user account in order to get the related WSDL file. The conclusion is that we still need other approaches against DoWS if the WSDL document of a web service is exposed.

In this paper, we will present a framework that allocates the processing capability of Web services according to the user information bound to its WSDL file, like the session information in other Http applications. By this approach, even an attacker can get one valid WSDL file using the above tricks, since all Web service method invocation requests will bind the same user information or session with them, our framework can recognize that the abnormal huge request flows are from this user, and either shut down the connections coming from this user or limit the number of his service requests. For the random requests in which the user information is invalid, our framework will shut down the connections immediately.

The rest of the paper is organized as follows. Section 2 summarizes the related work according to their deployment locations and indicate how they relate to DoWS. Section 3 presents the design of an architecture and its components against DoWS. Section 4 describes an implementation of our framework in the Java/Axis based Web services hosting environment and compare the resistance capability to DoWS before and after the deployment of our framework. Section 5 discusses some security issues related to our work and Section 6 concludes.

## 2. Related Work

Denial of Service (DoS) and the related detection and defenses have been an active area for long time. There is much existing work focusing on it. While many of the approaches proposed in the related work can be reused to attack DoWS, we expect to expose new approaches to attack DoWS using some specific features or semantics in Web services. In the following, we will discuss the related work by their deployment locations [10] and indicates how they relate to DoWS.

Victim network: this is where most approaches of defenses are located at. Our work belongs to this category as well. Three main technologies are used: signature based detection [14], abnormal pattern based detection and filtering [13], and security protocols [12,15] against DoS. Our work is a kind of combination of the last two approaches above. We will filter connections according to the user information that is recorded in the WSDL file during the retrieving stage and tagged in all request messages.

Source network: the goal of detection mechanisms deployed at the source network is to prevent network customers from generating DoS attacks. For example, [11] present a framework which is located at the exit router of a network that observe the incoming and outgoing flows for each peer (the machine in this network

and the machine outside this network). First, they get one normal model for each type of flow such as TCP, ICMP or UDP from the actual flow statistics, and then compare the flow pattern of each peer with the corresponding normal traffic model. The abnormal flow pattern will be identified as an attack. DoWS defenses, as an instance of [11] on the TCP layer, can benefit from this work directly, or extend it by adding a new SOAP flow type into it. Since our work is deployed at the victim network, we will not discuss this category again in this paper.

Intermediate network: the deployment at intermediate network can detect and prevent DoS effectively by coordination of several routers or overlay network proxies. For example, in [18], the authors uses the routers to trace back the legality of every source IP before forwarding it to the destination. In [16, 17], they build a secure Internet server on an overlay network, which to some extent, avoid adding a new detection component into the routers directly that is usually unrealistic for wide deployment. Our work is not directly related to this category, so we will not discuss it again in this paper.

Before we close this section, we need to point out that there are little work focusing on DoWS and the related defenses when we write this paper.

## 3. Design

From the viewpoint of DoS, when accessing many Web pages sites, there is no work to put onto the requestors side except for typing some valid URLs in the browser. This is not true when accessing a Web service. The requestor must get a valid WSDL file for a Web service before accessing it. This two-phase based access gives us more chances to control the access of a Web service than a Web pages site. Our idea is very simple: during the retrieving stage of a WSDL file, we can customize different versions for different users by binding the user information into the WSDL file, like establishing WSDL level sessions for the users. During the accessing stage of a Web service, we can verify and filter the service requests according to the session information tagged in these requests. Thus, even the attackers use distributed denial of attacks approaches, since these requests are from few session Ids, we can easily find them and filter them out.

### 3.1 Architecture

Our architecture is based on the two-phase access model as shows in Figure 1 and Figure 2. During the first phase, when a user logins into a Web service container that hosts the different Web services and tries to retrieve a WSDL file for a specific Web service, the container will bind the related user information to a customized WSDL version for this user and return this file. A question arises here: what kind of user information should be bounded to the WSDL file and how? The most direct answer is to bind the user login information (user name) into the Web

service port address location part in WSDL. This is one of the approaches to implement a session for Web applications as well.

During the second phase, when the user sends a Web service request to the target service with the session information in the target address, the Web services container can recognize the user name by reading only the address information out from the request without invocation of any XML related components. Based on the current working load information, the filter component in Figure 2 will decide that whether or not this request can be passed into the Web services engine. The detailed algorithm is described in Section 3.3. Only if the answer is yes, can the request be passed to the Web services container.

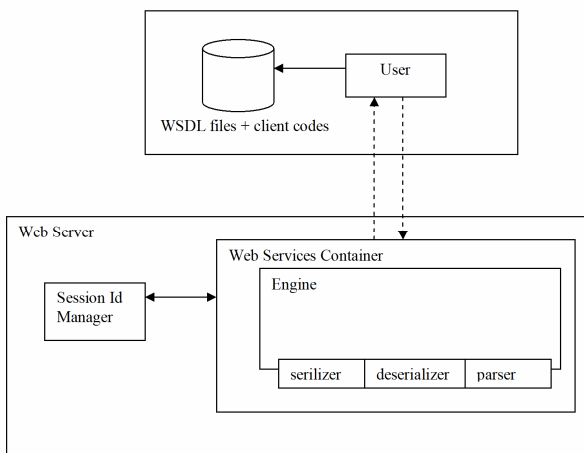


Figure 1. Phase 1: retrieving WSDL files

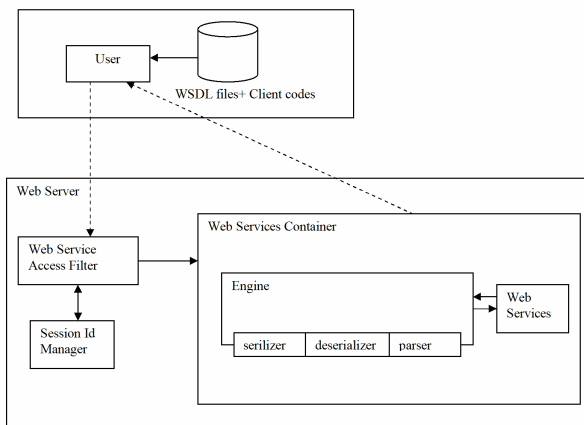


Figure 2. Phase 2: accessing a Web service

### 3.2 Session Id Manager (SIM)

SIM is used to combine the user name with the Web service port name and hash them into a unique session id during phase 1; and decode the incoming session id into the original service port name in phase 2. The session ids are used as the hash keys for the filter to distinguish different legal requests as well. For example, a Web service port address of “http://localhost:8080/axis/services/Version” will be

translated to a session id of “http://localhost:8080/axis/services/E6aozsMhZgAwWC HkMF1ldA==”, when a user name, say bob is bounded to it using some hash algorithm.

### 3.3 Web Services Access Filter

A fair shared Web services system with the resistance to DoWS is our first objective. In other words, when the work load of a Web services system is beyond a threshold due to DoWS, we still need to guarantee the requests from normal requestors to come in and to be processed within reasonable time.

Now we describe the filtering algorithm towards the above objective. We extract the following parameters as the input for the filtering algorithm.

*Number of total Maximum Processed Requests per unit time (NMPR)*: this parameter defines the maximum processing capability of a Web services system. Obvious, it depends on the underlying hardware and software, also the unit time selected. It has a constant value.

*Current total Number of Processed Requests (CNPR)*: this parameter is obvious by its name. All of the parameter below including this one is assumed to be the value in the current unit time, so in different unit time, the values of these parameters will vary.

*Current Work Load (CWL)*: this parameter is equal to CNMPR/NMPR.

*Current Number of Sessions (CNS)*: this parameter will be used by the filter to decide whether or not the system is fairly used by many users or only occupied by few users in a high working load condition. The latter may indicates a potential DoWS attack.

*Current Number of Processed Requests from a Session id (CNPRS)*: this parameter is obvious by its name.

*Current Number of Maximum Permitted Requests for a user (CNMPR)*: the value of this parameter is dependent on other parameters, such as CNS, CWL, and Threshold.

*Threshold*: a value beyond which the algorithm will be switched to the DoWS defense stage.

*Number of Maximum Processed Requests per unit time for any Session id (NMPRS)*: this parameter limit the requests from the same session to a value when the work load is beyond the Threshold.

*Number of Sessions that shows good Fairness per unit time(NSF)*: this parameter defines a constant value that can show that the system is fairly and normally used by multiple users.

The algorithm itself is below:

```

FilterUserReq(incomingRequest)
{// for the current unit time
if ((incomingRequest.sessionId is in Blacklist) ||
    (incomingRequest.sessionId is in Redlist))
{ block this request; return;}
if ((CWL < 1) &&
    ((CNS > NSF) ||
    (incomingRequest.sessionId is not found in the processed requests container)
    ))
{
    Let the request come in and update the related parameters; return;
}
else if ((CWL < 1) &&
    (incomingRequest.sessionId is found in the processed requests container))
{
    CNMPR = NMPR / CNS;

    if ((CWL > Threshold) && (CNMPR > CNPRS(incomingRequest.sessionId))
        CNMPR = NMPRS;

    if (CNPRS(incomingRequest.sessionId) < CNMPR)
    {
        Let the request come in and update the related parameters; return;
    }
    else {block this request; put incomingRequest.sessionId into Blacklist; return;}
}
}

```

This algorithm use three identity containers: Redlist, Blacklist, and the processed requests container. Redlist stores the valid session Ids, and Blacklist stores the session Ids used by DoWS. The processed requests container records the number of processed requests for each valid session Id in the current unit time. It will be refreshed to be empty when the next unit time starts. The algorithm distinguish two stages divided by *Threshold*. When the current work load is below *Threshold*, we can think that the Web services system is still running under a low or middle level work load, so there is few control on the incoming requests. All existing sessions will share the work load. When the work load is above *Threshold*, our algorithm will begin to actively defend against possible DoWS attacks by monitoring and limiting the number of requests from each session to *NMPRS*. For instance, when an attacker sends a huge of requests to a Web service system, the filter will let them come in. When the work load is beyond *Threshold*, the filter will deny any requests from the attacker according to the requests session ids. Thus, the left work load in this unit time can only be used by other requests with normal session ids.

## 4. Implementation and Evaluation

We have implemented this framework and deployed it on a Web services container of Java/Apache Tomcat [21]/Apache Axis [22]. An evaluation of our framework performed on this implementation shows the different resistance capability without and with DoWS awareness.

### 4.1 Implementation

First, our implementation and discussion in this section is based on the Http protocol that is the most common binding protocol for Web services currently. The Web services container of Java/Apache Tomcat/Apache Axis uses the concept “Servlet” [23] as its base. A servlet is a Java programming language class that can receive a request, process it, and return a

response. In terms of Http, an HttpServlet can receive an Http request and bounce an Http response. A HttpServlet, by default, supports some common request methods, such as *Get*, *Post* by its *doGet* and *doPost* methods. For some more complicated applications, a Servlet can use the pipelined filters for both requests and responses, so that a request or a response can be customized by these filters before arriving or after leaving it. Obviously, the DoWS filter we introduced in Section 3.3 can be deployed as a filter here. An HttpServlet can support the sessions by cookies or customized URLs. Figure 3 shows how a Servlet works.

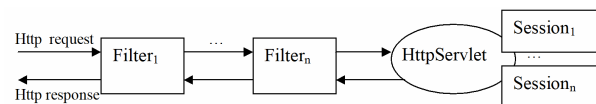
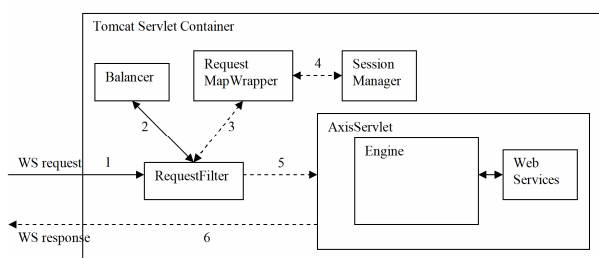


Figure 3. Basic concepts behind a HttpServlet

Apache Tomcat is a Java Web container that supports Servlets. Apache Axis is a Web services container that can process Web services requests. It has a Web service engine that can be wrapped by an AxisServlet when using Axis in Tomcat. The engine is the core of Axis, which will involve the time-consuming XML processing stages as showed in Figure 1.

We implemented the procedure of phase 1 as proposed in Section 3.1 using the modified AxisServlet. In the first step, a user bob logs into the Web services system and browsed some available Web services for him. In the second step, bob finds an interesting service, say Version and downloads its WSDL. Finally, bob generates the client side codes according to this WSDL file. According to our introduction in Section 3, the Web service port name has been customized into a session id for this user name.

Figure 4 shows the components we developed and integrated into the underlying platform for phase 2. Whenever a Web service request comes in, the RequestFilter will intercept it and pass it to the Balancer. The Balancer will use the filter algorithm to make a decision. If the request with the associated session id is permitted to come in, the RequestFilter will invoke the RequestMapWrapper that will invoke the SessionManager to translate the session id to the original service name and replace the session id of the incoming http request with this original name. Now, the Web services engine in Axis can recognize this request and process it. If the request is refused by the Balancer, the filter will drop it directly. In the latter case, the steps of 3,4,5 and 6 will not be executed.

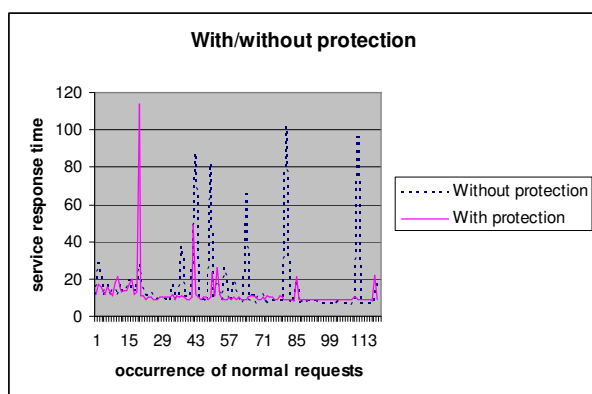


**Figure 4. Components of DoWS aware Web services container**

## 4.2 Experiment Description and Result Evaluation

The experiment is performed on our implementation described in Section 4.1. The basic software configuration of the test bed includes Java 1.5, Apache Tomcat 5.5.16, and Apache Axis 1.3. The testbed consists of a set of 4 client nodes (grisu1-grisu4) and one server node (grisu0) all part of a 32-node cluster. Each node is a dual AMD Athlon CPU 2.1GHz with 4GB of RAM. All of these machines are interconnected by Gigabit Ethernet and are located on the same physical switch. The 4 client nodes include 3 attack clients and a normal client. The target Web service is a simple version service in Axis 1.3. The service processing time for a single request is about 7~10ms.

In our experiment, we allocate the values to the constant parameters of the filter algorithm as  $NMPR = 3000$ ,  $Threshold = 0.8$ ,  $NMPRS = 120$ ,  $NSF = 800$ , unit time = 1 minute. The experiment is designed so that the 3 attack clients (with different user names) flood their requests to the Web service as quick as they can. The normal client will send 120 requests to the service in about 1 minute with a constant frequency. This experiment is performed on the original Axis 1.3 without DoWS protection and on our implementation framework with DoWS protection individually. Figure 5 shows the results.



**Figure 5. DoWS experiment result**

In figure 5, the unstable response time for the normal client requests indicates that the original Axis suffers

from DoWS. With our framework, the influence of DoWS are limited to a short period (for the first 20 normal requests in Figure 5). After that, the filtering algorithm will identify the user sessions that launch this DoWS and deny their requests directly. We explain briefly how our filtering algorithm works in this experiment. First, the requests from the attackers will be processed as normal requests. The processing capability of the Version service is shared among these 4 clients. In a few seconds, the number of flooding attacking requests will get their upper bound that is 750 per session according to the algorithm. In some other cases, see 5 attacking sessions plus 1 normal session, the flooding attacking requests mixed with few normal requests will occupied 80 percent (the threshold) workload of this service. At this point, the filtering algorithm will check the number of sessions and detect most requests are from few users (a sign of DoWS), and then switch to the protection stage in which the maximum number of requests from each session is limited to a reasonable value (in this experiment, it is set to 120) during the left time of this unit time. In either case above, any further requests from attacking sessions are discarded directly and only the normal requests can pass in. Thus they achieve good response time as Figure 5 shows. As the last thing, the overload introduced by our framework is very low (about 1ms).

## 5. Discussion

An important feature of our work is the session based filter. Our assumption is that attackers cannot sniff many valid session identities easily. The only approach is to sniff at the target Web service's side or nearby area. This is much difficult than randomly comprise some machines on the Internet and install the attacking codes as most denial of services tools do. In the current implementation, we do not focus on who can login and retrieve a WSDL file. This is important as well because if some attackers can easily register and get many user names, they can retrieve many valid session identities by themselves directly. A simple solution is to set up a PKI and link each user name with a certificate that can be traced back to a trusted person or organization.

Furthermore, the phase of retrieving a WSDL is a generic phase. The essential thing is to establish a session identity that can be understandable by both consumers and the target service. For example, the service can put the session identity into the Service Level Agreement (SLA) or even send it by secure emails to the consumers.

## 6. Conclusion

In this paper, we present a framework to protect Web services against DoWS. We use a session based approach in this framework so that each valid Web service request have to present its session identity with it. On the services side, We designed a fair share based filtering algorithm that can allocate the processing capability of a service

among different users using the recorded session information. This filtering algorithm can guarantee that when the working load is high, the requests from DoWS will be discarded, so the normal request can still come in and get processed with a reasonable response time.

The preliminary experiment shows that our framework can effectively improve the resistance capability of a Web service to DoWS. The experiment shows as well that the overload introduced by our framework is low.

## 7. Acknowledgements

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