Security and Privacy Considerations for the OASIS Security Assertion Markup Language (SAML)

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Contributors:

Jeff Hodges, Oblix
Chris McLaren, editor (cmclaren@netegrity.com)
Prateek Mishra, Netegrity
RL "Bob" Morgan, University of Washington
Tim Moses, Entrust
Evan Prodromou, Securant
Marlena Erdos, IBM

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1. Introduction

This non-normative document describes and analyzes the security and privacy properties of the OASIS Security Assertion Markup Language (SAML) defined in the core SAML specification **[SAMLCore]** and the SAML specification for bindings and profiles **[SAMLBind]**. The intent in this document is to provide input to the design of SAML, and to provide information to architects, implementors, and reviewers of SAML-based systems about the following:

- The threats, and thus security risks, to which a SAML-based system is subject
- The security risks the SAML architecture addresses, and how it does so
- The security risks it does not address
- Recommendations for countermeasures that mitigate those risks

Note that terms used in this document are as defined in the SAML glossary **[SAMLGloss]** unless otherwise noted.

The rest of this section describes the background and assumptions underlying the analysis in this document. Section 4 provides a high-level view of security techniques and technologies that should be used with SAML. Section 5 analyzes the specific risks inherent in the use of SAML.

2. Privacy

SAML includes the ability to make statements about the attributes and authorizations of authenticated entities. There are very many common situations in which the information carried in these statements is something that one or more of the parties to a communication would desire to keep accessible to as restricted as possible a set of entities. Statements of medical or financial attributes are simple examples of such cases.

Parties making statements, issuing assertions, conveying assertions, and consuming assertions must be aware of these potential privacy concerns and should attempt to address them in their implementations of SAML-aware systems.

2.1. Ensuring Confidentiality

Perhaps the most important aspect of ensuring privacy to parties in a SAML-enabled transaction is the ability to carry out the transaction with a guarantee of confidentiality. In other words, can the information in an assertion be conveyed from the issuer to the intended audience, and only the intended audience, without making it accessible to any other parties?

It is technically possible to convey information confidentially (a discussion of common methods for providing confidentiality occurs in the Security portion of the document in Section 4.2) and all parties to SAML-enabled transactions should analyze each of their steps in the interaction to ensure that they are taking the appropriate steps to ensure that information that should be kept confidential is actually being kept so.

It should also be noted that simply obscuring the contents of assertions may not be adequate protection of privacy. There are many cases where just the availability of the information that a given user (or IP address) was accessing a given service may constitute a breach of privacy (for example, an the information that a user accessed a medical testing facility for an assertion may be enough to breach privacy without knowing the contents of the assertion). Partial solutions to these problems can be provided by various techniques for anonymous interaction, outlined below.

2.2. Notes on Anonymity

2.2.1. Definitions that Relate to Anonymity

There are no definitions of anonymity which are satisfying for all cases. Many definitions **[Anonymity]** deal with the simple case of a sender and a message, and discuss "anonymity" in terms of not being able to link a given sender to a sent message, or a message back to a sender.

And while that definition is adequate for the "one off" case, it ignores the aggregation of information that is possible over time based on behavior rather than an identifier.

Two notions which may be generally useful, and that relate to each other, can help define anonymity.

The first notion is to think about anonymity as being "within a set", as in this comment from "Anonymity, Unobservability, and Pseudonymity" **[Anonymity]**:

> "To enable anonymity of a subject, there always has to be an appropriate set of subjects with potentially the same attributes....
>
> ...Anonymity is the stronger, the larger the respective anonymity set is and the more evenly distributed the sending or receiving, respectively, of the subjects within that set is".

This notion is relevant to SAML because of the use of authorities. Even if a Subject is "anonymous", that subject is still identifiable as a member of the set of Subjects within the domain of the relevant authority.

In the case where aggregating attributes of the user are provided, the set can become much smaller. For example, if the user is "anonymous" but has the attribute of "student in Course 6@mit.edu". Certainly, the number of Course 6 students is less than the number of MIT-affiliated persons which is less than the number of users everywhere.

Why does this matter? It matters because of the second notion. This idea is that non-anonymity leads to the ability of an adversary to harm expressed in Dingledine, Freedman, and Molnar's Freehaven document **[FreeHaven]**:

> "Both anonymity and pseudonymity protect the privacy of the user's location and true name. Location refers to the actual physical connection to the system. The term "true name"' was introduced by Vinge and popularized by May to refer to the legal identity of an individual. Knowing someone's true name or location allows you to hurt him or her."

This leads to a unification of the notion of anonymity within a set and ability to harm, from the same source **[FreeHaven]**:

> "We might say that a system is partially anonymous if an adversary can only narrow down a search for a user to one of a 'set of suspects.' If the set is large enough, then it is impractical for an adversary to act as if any single suspect were guilty. On the other hand, when the set of suspects is small, mere suspicion may cause an adversary to take action against all of them."

SAML-enabled systems are limited to "partial anonymity" at best because of the use of authorities. An entity about whom an assertion is made is already identifiable as one of the pool of entities in a relationship with the issuing authority.

The limitations on anonymity can be a lot worse than simple authority association, depending on how identifiers are employed, as reuse of pseudonymous identifiers allows accretion of potentially identifying information (see Section 2.2.2). Additionally, users of SAML-enabled systems can also make the breach of anonymity worse by their actions (see Section 2.2.3).

2.2.2. Pseudonymity & Anonymity

Apart from legal identity, any identifier for a Subject can be considered a pseudonym. And even notions like "holder of key" can be considered as serving as the equivalent of a pseudonym in linking an action (or set of actions) to a Subject. Even a description such as "the user that just requested access to object XYZ at time 23:34" can serve as an equivalent of a pseudonym.

The point is, that with respect to "ability to harm" it makes no difference whether the user is described with an identifier or described by behavior (i.e. use of a key, or performance of an action).

What does make a difference is how often the particular equivalent of a pseudonym is used.

[3] gives a taxonomy of pseudonyms starting from personal pseudonyms (like nicknames) that are used all the time, through various types of role pseudonyms (e.g. Secretary of Defense), on to "one time use" pseudonyms.

Only one time use pseudonyms can give you anonymity (within SAML, consider this as "anonymity within a set").

The more often you use a given pseudonym, the more you reduce your anonymity and the more likely it is that you can be harmed. In other words re-use of a pseudonym allows additional potentially identifying information to be associated with the pseudonym. Over time this will lead to an accretion that can uniquely identify the identity associated with a pseudonym.

2.2.3. Behavior and Anonymity

As Joe Klein can attest, anonymity isn't all it is cracked up to be.

Klein is the "Anonymous" who authored Primary Colors. Despite his denials he was unmasked as the author by Don Foster, a Vassar professor who did a forensic analysis of the text of Primary Colors. Foster compared that text with texts from a list of suspects that he devised based on their knowledge bases and writing proclivities.

It was Klein's idiosyncratic usages that did him in (though apparently all authors have them).

The relevant point for SAML is that an "anonymous" user (even one that is never named) can be identified enough to be harmed by repeated unusual behavior. Here are some examples:

- A user who each Tuesday at 21:00 access a database that correlates finger lengths and life span starts to be non-anonymous. Depending on that user's other behavior, she or he may become "traceable" **[Pooling]** in that other "identifying" information may be able to be collected.
- A user who routinely buys an usual set of products from a networked vending machine, certainly opens themselves to harm (by virtue of booby-trapping the products).

2.2.4. Implications For Privacy

Origin site authorities (i.e. Authentication Authorities and Attribute Authorities) can provide a degree of "partial anonymity" by employing one-time-use identifiers or keys (for the “holder of Key” case).

This anonymity is "partial" at best because the Subject is necessarily confined to the set of Subjects in a relationship with the Authority.

This set may be further reduced (thus further reducing anonymity) when aggregating attributes are used that further subset the user community at the origin site.

Users who truly care about anonymity must take care to disguise or avoid unusual patterns of behavior that could serve to “de-anonymize” them over time.

3. Security

3.1. Background

Communication between computer-based systems is subject to a variety of threats, and these threats carry some level of associated risk. The nature of the risk depends on a host of factors, including the nature of the communications, the nature of the communicating systems, the communication mediums, the communication environment, the end-system environments, and so on. Section 3 of the IETF guidelines on writing security considerations for RFCs **[Rescorla-Sec]** provides an overview of threats inherent in the Internet (and, by implication, intranets).

SAML is intended to aid deployers in establishing security contexts for application-level computer-based communications within or between security domains. By serving in this role, SAML addresses the "endpoint authentication" aspect (in part, at least) of communications security, and also the "unauthorized usage" aspect of systems security. Communications security is directly applicable to the design of SAML. Systems security is of interest mostly in the context of SAML's threat models. Section 2 of the IETF guidelines gives an overview of communications security and systems security.

3.2. Scope

Some areas that impact broadly on the overall security of a system that uses SAML are explicitly outside the scope of SAML. While this document does not address these areas, they should always be considered when reviewing the security of a system. In particular, these issues are important, but beyond the scope of SAML:

- Initial authentication: SAML allows statements to be made about acts of authentication that have occurred, but includes no requirements or specifications for these acts of authentication. Consumers of authentication assertions should be wary of blindly trusting these assertions unless and until they know the basis on which they were made. Confidence in the assertions must never exceed the confidence that the asserting party has correctly arrived at the conclusions asserted.
- Trust Model: In many cases, the security of a SAML conversation will depend on the underlying trust model, which is typically based on a key management infrastructure (e.g., PKI, secret key). For example, SOAP messages secured by means of XML Signature **[XMLSig]** are secured only insofar as the keys used in the exchange can be trusted. Undetected compromised keys or revoked certificates, for example, could allow a breach of security. Even failure to require a certificate opens the door for impersonation attacks. PKI setup is not trivial and must be implemented correctly in order for layers built on top of it (such as parts of SAML) to be secure.

3.3. SAML Threat Model

The general Internet threat model described in the IETF guidelines for security considerations **[Rescorla-Sec]** is the basis for the SAML threat model. We assume here that the two or more endpoints of a SAML transaction are uncompromised, but that the attacker has complete control over the communications channel.

Additionally, due to the nature of SAML as multi-party authentication and authorization statement protocol, cases must be considered where one or more of the parties in a legitimate SAML transaction—who operate legitimately within their role for that transaction—attempt to use information gained from a previous transaction maliciously in a subsequent transaction.

In all cases, the local mechanisms that systems will use to decide whether or not to generate assertions are out of scope. Thus, threats arising from the details of the original login at an authentication authority, for example, are out of scope as well. If an authority issues a false assertion, then the threats arising from the consumption of that assertion by downstream systems are explicitly out of scope.

The direct consequence of such a scoping is that the security of a system based on assertions as inputs is only as good as the security of the system used to generate those assertions. When determining what issuers to trust, particularly in cases where the assertions will be used as inputs to authentication or authorization decisions, the risk of security compromises arising from the consumption of false but validly issued assertions is a large one. Trust policies between asserting and relying parties should always be written to include significant consideration of liability and implementations must be provide an audit trail. .

4. Security Techniques

The following sections describe security techniques and various stock technologies available for their implementation in SAML deployments.

4.1. Authentication

Authentication here means the ability of a party to a transaction to determine the identity of the other party in the transaction. This authentication may be in one direction or it may be bilateral.

4.1.1. Active Session

Non-persistent authentication is provided by the communications channel used to transport a SAML message. This authentication may be unilateral—from the session initiator to the receiver—or bilateral. The specific method will be determined by the communications protocol used. For instance, the use of a secure network protocol, such as RFC 2246 **[RFC2246]** or the IP Security Protocol **[IPsec]**, provides the SAML message sender with the ability to authenticate the destination for the TCP/IP environment.

4.1.2. Message-Level

XML Signature **[XMLSig]** provides a method of creating a persistent "authentication" that is tightly coupled to a document. This method does not independently guarantee that the sender of the message is in fact that signer (and indeed, in many cases where intermediaries are involved, this is explicitly not the case).

Any method that allows the persistent confirmation of the involvement of a uniquely resolvable entity with a given subset of an XML message is sufficient to meet this requirement.

4.2. Confidentiality

Confidentiality means that the contents of a message can be read only by the desired recipients and not anyone else who encounters the message while it is in transit.

4.2.1. In Transit

Use of a secure network protocol such as RFC 2246 **[RFC2246]** or the IP Security Protocol **[IPsec]** provides transient confidentiality of a message as it is transferred between two nodes.

4.2.2. Message-Level

XML Encryption **[XMLEnc]** is a draft specification for the selective encryption of XML documents. This encryption method provides persistent, selective confidentiality of elements within an XML message.

Until XML Encryption is an accepted standard, confidentiality may be implemented in transit (and not end-to-end) by reliance on transports that provide in-transit confidentiality (as described in Section 4.2.1 above).

4.3. Data Integrity

Data integrity is the ability to confirm that a given message as received is unaltered from the version of the message that was sent.

4.3.1. In Transit

Use of a secure network protocol such as RFC 2246 **[RFC2246]** or the IP Security Protocol **[IPsec]** may be configured so as to provide for integrity check CRCs of the packets transmitted via the network connection.

4.3.2. Message-Level

XML Signature **[XMLSig]** provides a method of creating a persistent guarantee of the unaltered nature of a message that is tightly coupled to that message.

Any method that allows the persistent confirmation of the unaltered nature of a given subset of an XML message is sufficient to meet this requirement.

4.4. Notes on Key Management

Many points in this document will refer to the ability of systems to provide authentication, data integrity, and non-repudiation via various schemes involving digital signature and encryption. For all these schemes the security provided by the scheme is limited based on the key management systems that are in place. Some specific limitations are detailed below:

4.4.1. Access to the Key

It is assumed that if key-based systems are going to be used for authentication, data integrity, and non-repudiation, that security is in place to guarantee that access to the key is not available to inappropriate parties. For example, a digital signature created with Bob's private key is only proof of Bob's involvement to the extent that Bob is the only one with access to the key.

In general, access to keys should be kept to the minimum set of entities possible (particularly important for corporate or organizational keys, etc.) and should be protected with pass phrases and other means. Standard security precautions (don't write down the passphrase, don't leave a window with the key accessed open when you're away from a computer, etc.) apply.

4.4.2. Binding of Identity to Key

For a key-based system to be used for authentication there must be some trusted binding of identity to key. Verifying a digital signature on a document can determine if the document is unaltered since its signature, and that it was actually signed by a given key. However, this is no way confirms that the key used is actually the key of a specific individual.

This key-to-individual binding must be established. Common solutions include local directories that store both identifiers and key—which is simple to understand but difficult to maintain—or the use of certificates.

Certificates, which are in essence signed bindings of identity-to-key are a particularly powerful solution to the problem, but come with their own considerations. A set of trusted root Certifying Authorities (CAs) must be identified for each consumer of signatures—i.e. "Who do I trust to make statements of identity-to-key binding". Verification of a signature then becomes a process of verifying first the signature (to determine that the signature was done by the key in question and that the message has not changed) and then verification of the certificate chain (to determine that the key is bound to the right identity).

Additionally, with certificates steps must be taken to ensure that the binding is currently valid—a certificate typically has a "lifetime" built into it, but if a key is compromised during the life of the certificate then the key-to-identity binding contained in the certificate becomes invalid while the certificate is still valid on its face. Also certificates often depend on associations that may end before their lifetime expires (for example certificates that should become invalid when someone changes employers, etc.) This problem is solved by Certificate Revocation Lists (CRLs) which are lists of certificates from a given CA that have been revoked since their issue. Another solution is the Online Certificate Status Protocol (OCSP) which defines a method for calling servers to ask about the current validity of a given certificate. Some of this same functionality is incorporated into the higher levels of the XML Key Management Specification (XKMS) which allows requests to be made for "valid" keys.

A proper key management system is thus quite strong but very complex. Verifying a signature ends up being a three-stage process of verifying the document-to-key binding, then verifying the key-to-identity binding, then verifying the current validity of the key-to-document binding.

4.5. TLS/SSL Cipher Suites

The use of SSL 3.0 or TLS 1.0 (RFC 2246) **[RFC2246]** over HTTP is recommended at many places in this document. However TLS/SSL can be configured to use many different cipher suites, not all of which are adequate to provide "best practices" security. The following sections provide a brief description cipher suites and recommendations for cipher suite selection.

4.5.1. What Is a Cipher Suite?

Note: *While references to the US Export restrictions are now obsolete, the constants naming the cipher suites have not changed. Thus, SSL_DHE_DSS_EPORT_WITH_DES40_CBC_SHA is still a valid cipher suite identifier, and the explanation of the historical reasons for the inclusion of "EXPORT" has been left in place in the following summary.*

A cipher suite combines four kinds of security features, and is given a name in the SSL protocol specification. Before data flows over a SSL connection, both ends attempt to negotiate a cipher suite. This lets them establish an appropriate quality of protection for their communications, within the constraints of the particular mechanism combinations which are available. The features associated with a cipher suite are:

1. The type of key exchange algorithm used. SSL defines many; the ones that provide server authentication are the most important ones, but anonymous key exchange is supported. (Note that anonymous key exchange algorithms are subject to "man in the middle" attacks, and are **not recommended** in the SAML context.) The "RSA" authenticated key exchange algorithm is currently the most interoperable algorithm. Another important key exchange algorithm is the authenticated Diffie-Hellman "DHE_DSS" key exchange, which has no patent-related implementation constraints.[1]
2. Whether the key exchange algorithm is freely exportable from the United States of America. Exportable algorithms must use short (512-bit) public keys for key exchange and short (40-bit) symmetric keys for encryption. These keys are currently subject to breaking in an afternoon by a moderately well-equipped adversary.
3. The encryption algorithm used. The fastest option is the RC4 stream cipher; DES and variants (DES40, 3DES-EDE) are also supported in "cipher block chaining" (CBC) mode, as is null encryption (in some suites). (Null encryption does nothing; in such cases SSL is used only to authenticate and provide integrity protection. Cipher suites with null encryption do not provide confidentiality, and **should not be used** in cases where confidentiality is a requirement.)
4. The digest algorithm used for the Message Authentication Code. The choices are MD5 and SHA1.

For example, the cipher suite named SSL_DHE_DSS_EXPORT_WITH_DES40_CBC_SHA uses SSL, an authenticated Diffie-Hellman key exchange (DHE_DSS), is export grade (EXPORT), uses an exportable variant of the DES cipher (DES40_CBC), and uses the SHA1 digest algorithm in its MAC (SHA).

A given implementation of SSL will support a particular set of cipher suites, and some subset of those will be enabled by default. Applications have a limited degree of control over the cipher suites that are used on their connections; they can enable or disable any of the supported cipher suites, but cannot change the cipher suites which are available.

[1] RSA patents have all expired, hence this issue is mostly historical.

4.5.2. *Cipher Suite Recommendations*

The following cipher suites adequately meet requirements for confidentiality and message integrity, and can be configured to meet the authentication requirement as well (by forcing the presence of X.509v3 certificates). They are also well supported in many client applications. Support of these suites is recommended:

- TLS_RSA_WITH_3DES_EDE_CBC_SHA (when using TLS)
- SSL_RSA_WITH_3DES_EDE_CBC_SHA (when using SSL)

However, the IETF is moving rapidly towards mandating the use of AES, which has both speed and strength advantages. Forward-looking systems would be wise as well to implement support for the AES cipher suites, such as:

- TLS_RSA_WITH_AES_128_CBC_SHA

5. SAML-Specific Security Considerations

The following sections analyze the security risks in using and implementing SAML and describe countermeasures to mitigate the risks.

5.1. SAML Assertions

At the level of the SAML assertion itself, there is little to be said about security concerns—most concerns arise during communications in the request/response protocol, or during the attempt to use SAML by means of one of the bindings. However, one issue at the assertion level bears analysis: An assertion, once issued, is out of the control of the issuer.

This fact has a number of ramifications. For example, the issuer has no control over how long the assertion will be persisted in the systems of the consumer; nor does the issuer have control over the parties with whom the consumer will share the assertion information. These concerns are over and above concerns about a malicious attacker who can see the contents of assertions that pass over the wire unencrypted (or insufficiently encrypted).

While efforts have been made to address many of these issues within the SAML specification, nothing contained in the specification will erase the requirement for careful consideration of what to put in an assertion. At all times, issuers should consider the possible consequences if the information in the assertion is stored on a remote site, where it can be directly misused, or exposed to potential hackers, or possibly stored for more creatively fraudulent uses. Issuers should also consider the possibility that the information in the assertion could be shared with other parties, or even made public, either intentionally or inadvertently.

5.2. SAML Protocol

The following sections describe security considerations for the SAML request-response protocol itself, apart from any threats arising from use of a particular protocol binding.

5.2.1. *Denial of Service*

The SAML protocol is susceptible to a denial of service (DOS) attack. Handling a SAML request is potentially a very expensive operation, including parsing the request message (typically involving construction of a DOM tree), database/assertion store lookup (potentially on an unindexed key), construction of a response message, and potentially one or more digital signature operations. Thus, the effort required by an attacker generating requests is much lower than the effort needed to handle those requests.

5.2.1.1. Requiring Client Authentication at a Lower Level

Requiring clients to authenticate at some level below the SAML protocol level (for example, using the SOAP over HTTP binding, with HTTP over TLS/SSL, and with a requirement for client-side certificates that have a trusted Certificate Authority at their root) will provide traceability in the case of a DOS attack.

If the authentication is used only to provide traceability then this does not in itself prevent the attack from occurring, but does function as a deterrent.

If the authentication is coupled with some access control system, then DOS attacks from non-insiders is effectively blocked. (Note that it is possible that overloading the client-authentication scheme could still function as a denial-of-service attack on the SAML service, but that this attack needs to be dealt with in the context of the client authentication scheme chosen.)

Whatever system of client authentication is used, it should provide the ability to resolve a unique originator for each request, and should not be subject to forgery. (For example, in the traceability-only case, logging the IP address is insufficient since this information can easily be spoofed.)

5.2.1.2. Requiring Signed Requests

In addition to the benefits gained from client authentication discussed in Section 5.2.1.1, requiring a signed request also lessens the order of the asymmetry between the work done by requester and responder. The additional work required of the responder to verify the signature is a relatively small percentage of the total work required of the responder, while the process of calculating the digital signature represents a relatively large amount of work for the requester. Narrowing this asymmetry decreases the risk associated with a DOS attack.

Note however that an attacker can theoretically capture a signed message and then replay it continually, getting around this requirement. This situation can be avoided by requiring the use of the XML Signature element `<ds:SignatureProperties>` containing a timestamp; the timestamp can then be used to determine if the signature is recent. In this case, the narrower the window of time after issue that a signature is treated as valid, the higher security you have against replay denial of service attacks.

5.2.1.3. Restricting Access to the Interaction URL

Limiting the ability to issue a request to a SAML service at a very low level to a set of known parties drastically reduces the risk of a DOS attack. In this case, only attacks originating from within the finite set of known parties are possible, greatly decreasing exposure both to potentially malicious clients and to DOS attacks using compromised machines as zombies.

There are many possible methods of limiting access, including placing the SAML responder inside a secured intranet, implementing access rules at the router level, etc.

5.3. SAML Protocol Bindings

The security considerations in the design of the SAML request-response protocol depend to a large extent on the particular protocol binding (as defined in the SAML bindings specification **[SAMLBind]**) that is used. Currently the only binding sanctioned by the OASIS SAML Committee is the SOAP binding.

5.3.1. SOAP Binding

Since the SAML SOAP binding requires no authentication and has no requirements for either in-transit confidentiality or message integrity, it is open to a wide variety of common attacks, which are detailed in the following sections. General considerations are discussed separately from considerations related to the SOAP-over-HTTP case.

5.3.1.1. Eavesdropping

Since there is no in-transit confidentiality requirement, it is possible that an eavesdropping party could acquire both the SOAP message containing a request and the SOAP message containing the corresponding response. This acquisition exposes both the nature of the request and the details of the response, possibly including one or more assertions.

Exposure of the details of the request will in some cases weaken the security of the requesting party by revealing details of what kinds of assertions it requires, or from whom those assertions are requested. For example, if an eavesdropper can determine that site *X* is frequently requesting authentication assertions with a given confirmation method from site *Y*, he may be able to use this information to aid in the compromise of site *X*.

Similarly, eavesdropping on a series of authorization queries could create a “map” of resources that are under the control of a given authorization authority.

Additionally, in some cases exposure of the request itself could constitute a violation of privacy. For example, eavesdropping on a query and its response may expose that a given user is active on the querying site, which could be information that should not be divulged in cases such as medicial information sites, political sites, and so on. Also the details of any assertions carried in the response may be information that should be kept confidential. This is particularly true for responses containing attribute assertions; if these attributes represent information that should not be available to entities not party to the transaction (credit ratings, medical attributes, and so on), then the risk from eavesdropping is high.

In cases where any of these risks is a concern, the countermeasure for eavesdropping attacks is to provide some form of in-transit message confidentiality. For SOAP messages, this confidentiality can be enforced either at the SOAP level or at the SOAP transport level (or some level below it).

Adding in-transit confidentiality at the SOAP level means constructing the SOAP message such that, regardless of SOAP transport, no one but the intended party will be able to access the message. The general solution to this problem is likely to be XML Encryption **[XMLEnc]**. This draft specification allows encryption of the SOAP message itself, which eliminates the risk of eavesdropping unless the key used in the encryption has been compromised. Alternatively, until XML Encryption is widely supported, deployers will need to depend on the SOAP transport layer, or a layer beneath it, to provide in-transit confidentiality.

The details of how to provide this confidentiality depend on the specific SOAP transport chosen. Using HTTP over TLS/SSL (described further in Section 5.3.2) is one method. Other transports will necessitate other in-transit confidentiality techniques; for example, an SMTP transport might use S/MIME.

In some cases, a layer beneath the SOAP transport might provide the required in-transit confidentiality. For example, if the request-response interaction is carried out over an IPsec tunnel, then adequate in-transit confidentiality may be provided by the tunnel itself.

5.3.1.2. Replay

There is little vulnerability to replay attacks at the level of the SOAP binding. Replay is more of an issue in the various profiles. The primary concern about replay at the SOAP binding level is the potential for use of replay as a denial-of-service attack method.

In general, the best way to prevent replay attacks is to prevent the message capture in the first place. Some of the transport-level schemes used to provide in-transit confidentiality will accomplish this goal. For example, if the SAML request-response conversation occurs over SOAP on HTTP/TLS, third parties are prevented from capturing the messages.

Note that since the potential replayer does not need to understand the message to replay it, schemes such as XML Encryption do not provide protection against replay. If an attacker can capture a SAML request that has been signed by the requester and encrypted to the responder, then the attacker can replay that request at any time without needing to be able to undo the encryption. This is a particular issue since the SAML request does not include information about the issue time of the request, thus making it difficult to determine if replay is occuring. The only recourse is to design systems that use the unique key of the request (its `RequestID`) to determine if this is a replay request or not.

Additional threats from the replay attack include cases where a “charge per request” model is in place. Replay could be used to run up large charges on a given account.

Similarly models where a client is allocated (or purchases) a fixed number of interactions with a system, the replay attack could exhaust these uses unless the issuer is careful to keep track of the unique key of each Request.

5.3.1.3. Message Insertion

The message insertion attack for the SOAP binding amounts to the creation of a request. The ability to make a request is not a threat at the SOAP binding level.

5.3.1.4. Message Deletion

The message deletion attack would either prevent a request from reaching a responder, or would prevent the response from reaching the requestor.

In either case, the SOAP binding does not address this threat. The SOAP protocol itself, and the transports beneath it, may provide some information depending on how the message deletion is accomplished.

Examples of reliable messaging systems that attenuate this risk include reliable HTTP (HTTPR) **[HTTPR]** at the transport layer and the use of reliable messaging extensions in SOAP such as Microsoft's SRMP for MSMQ **[SRMPPres]**.

5.3.1.5. Message Modification

Message modification is a threat to the SOAP binding in both directions.

Modification of the request to alter the details of the request can result in significantly different results being returned, which in turn can be used by a clever attacker to compromise systems depending on the assertions returned. For example, altering the list of requested attributes in the `<AttributeDesignator>` elements could produce results leading to compromise or rejection of the request by the responder.

Modification of the request to alter the apparent issuer of the request could result in denial of service or incorrect routing of the response. This alteration would need to occur below the SAML level and is thus out of scope.

Modification of the response to alter the details of the assertions therein could result in vast degrees of compromise. The simple examples of altering details of an authentication or an authorization decision could lead to very serious security breaches.

In order to address these potential threats, a system that guarantees in-transit message integrity must be used. The SAML protocol and the SOAP binding neither require nor forbid the deployment of systems that guarantee in-transit message integrity, but due to this large threat, it is **highly recommended** that such a system be used. At the SOAP binding level, this can be accomplished by digitally signing requests and responses with a system such as XML Signature **[XMLSig]**. The SAML specification allows for such signatures see the SAML Core Specification **[SAMLCore]** Section 5 for further information.

If messages are digitally signed (with a sensible key management infrastructure, see Section 4.4) then the recipient has a guarantee that the message has not be altered in transit, unless the key used has been compromised.

The goal of in-transit message integrity can also be accomplished at a lower level by using a SOAP transport that provides the property of guaranteed integrity, or is based on a protocol that provides such a property. SOAP over HTTP over TLS/SSL is a transport that would provide such a guarantee.

Encryption alone does not provide this protection, as even if the intercepted message could not be altered per se, it could be replaced with a newly created one.

5.3.1.6. Man-in-the-Middle

The SOAP binding is susceptible to man-in-the-middle (MITM) attacks. In order to prevent malicious entities from operating as a man in the middle (with all the perils discussed in both the eavesdropping and message modification), some sort of bilateral authentication is required.

A bilateral authentication system would allow both parties to determine that what they are seeing in a conversation actually came from the other party to the conversation.

At the SOAP binding level, this goal could also be accomplished by digitally signing both requests and responses (with all the caveats discussed in Section 5.3.1.5 above). This method does not prevent an eavesdropper from sitting in the middle and forwarding both ways, but he is prevented from altering the conversation in any way without being detected.

Since many applications of SOAP do not use sessions, this sort of authentication of author (as opposed to authentication of sender) may need to be combined with information from the transport layer to confirm that the sender and the author are the same party in order to prevent a weaker form of “MITM as eavesdropper”.

Another implementation would depend on a SOAP transport that provides, or is implemented on a lower layer that provides, bilateral authentication. The example of this is again SOAP over HTTP over TLS/SSL with both server- and client-side certificates required.

Additionally, the validity interval of the assertions returned functions as an adjustment on the degree of risk from MITM attacks. The shorter the valid window of the assertion, the less damage can be done if it is intercepted.

5.3.2. Specifics of SOAP over HTTP

Since the SOAP binding requires that conformant applications support HTTP over TLS/SSL with a number of different bilateral authentication methods such as Basic over server-side SSL, certificate-backed authentication over server-side SSL, these methods are always available to mitigate threats in cases where other lower-level systems are not available and the above listed attacks are considered significant threats.

This does not mean that use of HTTP over TLS with some form of bilateral authentication is mandatory.. If an acceptable level of protection from the various risks can be arrived at through other means (for example, by an IPsec tunnel), full TLS with certificates is not required. However, in the majority of cases for SOAP over HTTP, using HTTP over TLS with bilateral authentication will be the appropriate choice.

Note, however, that the use of transport-level security (such as the SSL or TLS protocols under HTTP) only provides confidentiality and/or integrity and/or authentication for “one hop”. For models where there may be intermediaries, or the assertions in question need to live over more than one hop, the use of HTTP with TLS/SSL does not provide adequate security.

5.4. Profiles for SAML

The SAML bindings specification **[SAMLBind]** in addition defines profiles for SAML, which are sets of rules describing how to embed and extract SAML assertions into a framework or protocol. Currently there are three profiles for SAML that are sanctioned by the OASIS SAML Committee:

- Two web browser-based profiles that support single sign-on (SSO):
    - The browser/artifact profile for SAML
    - The browser/POST profile for SAML
- The SOAP profile for SAML

5.4.1. Web Browser-Based Profiles

The following sections describe security considerations that are common to the browser/artifact and browser/POST profiles for SAML.

Note that user authentication at the source site is explicitly out of scope, as are all issues that arise from it. The key notion is that the source system entity must be able to ascertain that it is the same authenticated client system entity that it is interacting with in the next interaction step. One way to accomplish this is for these initial steps to be performed using TLS as a session layer underneath the protocol being used for this initial interaction (likely HTTP).

5.4.1.1. Eavesdropping

The possibility of eavesdropping exists in all web browser cases. In cases where confidentiality is required (bearing in mind that any assertion that is not sent securely, along with the requests associated with it, is available to the malicious eavesdropper), HTTP traffic needs to take place over a transport that ensures confidentiality. HTTP over TLS/SSL **[RFC2246]** and the IP Security Protocol **[IPsec]** meet this requirement.

The following sections provide more detail on the eavesdropping threat.

5.4.1.1.1. Theft of the User Authentication Information

In the case where the subject authenticates to the source site by revealing authentication information, for example, in the form of a password, theft of the authentication information will enable an adversary to impersonate the subject.

In order to avoid this problem, the connection between the subject's browser and the source site must implement a confidentiality safeguard. In addition, steps must be taken by either the subject or the destination site to ensure that the source site is genuinely the expected and trusted source site before revealing the authentication information. Using HTTP over TLS can be used to address this concern.

5.4.1.1.2. Theft of the Bearer Token

In the case where the authentication assertion contains the assertion bearer authentication protocol identifier, theft of the artifact will enable an adversary to impersonate the subject.

Each of the following methods decreases the likelihood of this happening:

- The destination site implements a confidentiality safeguard on its connection with the subject's browser.
- The subject or destination site ensures (out of band) that the source site implements a confidentiality safeguard on its connection with the subject's browser.
- The destination site verifies that the subject's browser was directly redirected by a source site that directly authenticated the subject.
- The source site refuses to respond to more than one request for an assertion corresponding to the same assertion ID.
- If the assertion contains a condition element of type AudienceRestrictionConditionType that identifies a specific domain, then the destination site verifies that it is a member of that domain.
- The connection between the destination site and the source site, over which the assertion ID is passed, is implemented with a confidentiality safeguard.
- The destination site, in its communication with the source site, over which the assertion ID is passed, must verify that the source site is genuinely the expected and trusted source site.

5.4.1.2. Replay

The possibility of a replay attack exists for this set of profiles. A replay attack can be used either to attempt to deny service or to retrieve information fraudulently. The specific countermeasures depend on which specific profile is being used, and thus are discussed in Sections 5.4.2.1 and 5.4.3.1.

5.4.1.3. Message Insertion

Message insertion attacks are not a general threat in this set of profiles.

5.4.1.4. Message Deletion

Deleting a message during any step of the interactions between the browser, SAML assertion issuer, and SAML assertion consumer will cause the interaction to fail. It results in a denial of some service but does not increase the exposure of any information.

The SAML bindings and profiles specification provides no countermeasures for message deletion.

5.4.1.5. Message Modification

The possibility of alteration of the messages in the stream exists for this set of profiles. Some potential undesirable results are as follows:

- Alteration of the initial request can result in rejection at the SAML issuer, or creation of an artifact targeted at a different resource than the one requested

- Alteration of the artifact can result in denial of service at the SAML consumer.
- Alteration of the assertions themselves while in transit could result in all kinds of bad results (if they are unsigned) or denial of service (if they are signed and the consumer rejects them).

To avoid message modification, the traffic needs to be transported by means of a system that guarantees message integrity from endpoint to endpoint.

For the web browser-based profiles, the recommended method of providing message integrity in transit is the use of HTTP over TLS/SSL with a cipher suite that provides data integrity checking.

5.4.1.6. Man-in-the-Middle

Man-in-the-middle attacks are particularly pernicious for this set of profiles. The MITM can relay requests, capture the returned assertion (or artifact), and relay back a false one. Then the original user cannot access the resource in question, but the MITM can do so using the captured resource.

Preventing this threat requires a number of countermeasures. First, using a system that provides strong bilateral authentication will make it much more difficult for a MITM to insert himself into the conversation.

However the possibility still exists of a MITM who is purely acting as a bidirectional port forwarder, and eavesdropping on the information with the intent to capture the returned assertion or handler (and possibly alter the final return to the requester). Putting a confidentiality system in place will prevent eavesdropping. Putting a data integrity system in place will prevent alteration of the message during port forwarding.

For this set of profiles, all the requirements of strong bilateral session authentication, confidentiality, and data integrity can be met by the use of HTTP over TLS/SSL if the TLS/SSL layer uses an appropriate cipher suite (strong enough encryption to provide confidentiality, and supporting data integrity) and requires X509v3 certificates for authentication.

5.4.2. Browser/Artifact Profile

Many specific threats and counter-measures for the Browser/Artifact profile are documented normatively in the SAML bindings specification **[SAMLBind]** Section 4.1.1.7. Additional non-normative comments are included below.

5.4.2.1. Replay

The threat of replay as a reuse of an artifact is addressed by the requirement that each artifact is a one-time-use item. Systems should track cases where multiple requests are made referencing the same artifact, as this situation may represent intrusion attempts.

The threat of replay on the original request that results in the assertion generation is not addressed by SAML, but should be mitigated by the original authentication process.

5.4.3. Browser/POST Profile

Many specific threats and counter-measures for the Browser/POST profile are documented normatively in the SAML bindings specification **[SAMLBind]** Section 4.1.2.5. Additional non-normative comments are included below.

5.4.3.1. Replay

Replay attacks amount to resubmission of the form in order to access a protected resource fraudulently. The profile mandates that the assertions transferred have the one-use property at the destination site, preventing replay attacks from succeeding.

5.4.4. SOAP Profile

This profile defines methods for securely attaching SAML assertions to a SOAP document. SOAP documents are used in multiple contexts, specifically including cases where the message is transported without an active session, the message can be persisted, and the message is routed through a number of intermediaries. Such a general context of use suggests that users of this profile must be concerned with a variety of threats. In particular, no consideration has been given to the issue of sender or receiver authentication. Therefore, if required, the sender may need to authenticate the receiver using some authentication technique dependent on the context of use. Further, the receiver may need to authenticate the sender using some techniques dependent on the context of use. In the latter case, there is a possibility that the receiver may authenticate the sender utilizing the attached SAML assertions as a credential together with other information.

The SAML bindings and profiles specification **[SAMLBind]**, Section 4.2.3, provides more information about security considerations for this profile.

5.4.4.1. Holder of Key

This profile has one or more authorities issuing assertions that contain <SubjectConfirmation> elements that basically say "This assertion is valid if it is presented with proof that the presenter is the holder of the specified key".

A sender inserts these assertions in a message and the entire message (payload and assertions) are digitally signed using the specified key—thus providing proof to the receiver that the sender of the message held the key specified in the assertions.

5.4.4.1.1. Eavesdropping

Eavesdropping continues to be a threat in the same manner as for the SAML SOAP binding, as discussed in Section 5.3.1.1. The routable nature of SOAP adds the potential for a large number of steps and actors in the course of a message's lifetime, which means that the potential incidences of eavesdropping are increased as the number of possible times a message is in transit increases.

The persistent nature of SOAP messages adds an additional possibility of eavesdropping, in that stored items can be read from their store.

To provide maximum protection from eavesdropping, assertions should be encrypted in such a way that only the intended audiences can view the material. This removes threats of eavesdropping in transit, but does not remove risks associated with storage by the receiver or poor handling of the clear text by the receiver.

5.4.4.1.2. Replay

Binding of assertions to a document opens the door to replay attacks by a malicious user. Issuing a `HolderOfKey` assertion amounts to “blessing the user’s key” for the purpose of binding assertions to documents. Once a `HolderOfKey` assertion has been issued to a user, that user can bind it to any document or documents he chooses.

While each assertion is signed, and bound by a second signature into a document, which prevents a malicious third-party (who has no access to the private key required for the binding signature) from binding the assertions to arbitrary documents, there is nothing preventing a malicious **user** (who by definition has access to the private key) from detaching a signed assertion from the document it arrived in and rebinding it to another document.

There are two lines of defense against this type of attack. The first is to consider carefully to whom you issue `HolderOfKey` assertions (can they be trusted with the right to attach the assertion to any document?) and what kind of assertions you issue as `HolderOfKey` assertions (do you want to give up control over the binding of this particular statement to a given document?). The second is a short lifetime on the assertion, to narrow the window of opportunity for this attack.

The capture and resubmission of the entire message (SAML assertions and business payload) is a threat. One counter-measure is to add information about time, or a sequence number to the digital signature included in the SOAP header. The receiver can use this information to detect duplicate messages.

5.4.4.1.3. Message Insertion

There is no message insertion attack at the level of the `HolderOfKey` format of the SOAP profile.

5.4.4.1.4. Message Deletion

There is no message deletion attack at the level of the `HolderOfKey` format of the SOAP profile.

5.4.4.1.5. Message Modification

The double signing in this profile prevents most message modification attacks. The receiver is always able to verify the signature on the assertion itself (and should be able to verify that the key used in that signing act is associated with the putative signer by means of X509v3 certificate, Certificate Revocation List checks, and so on), which provides a guarantee that the assertion is unaltered.

The receiver can also verify the binding signature to ensure that the message to which the assertion is attached is unaltered.

The profile is secure against modification within the context of an existing trust relationship. The remaining threats (compromised keys, revoked certificates being used, and so on) are outside the scope of SAML.

Note that the threat of message modification by the holder of the key exists, as discussed in the discussion of replay attacks in Section 5.4.4.1.2.

5.4.4.1.6. Man-in-the-Middle

An MITM attack is impossible for the `HolderOfKey` format of the SOAP profile, since the assertion specifies the key that must be used for the binding signature, and the assertion itself is protected against tampering by a signature.

The MITM can eavesdrop (if communication is not protected by some confidentiality scheme) but cannot alter the document without detection.

Note that a MITM could alter parts of the document unprotected by the signature (i.e. the other header elements within the <Signature> element). For example, a MITM could remove an included <KeyInfo> block from a <Signature> without affecting the validity of the signature. Theoretically this could force an XKMS lookup or other network call that could be perverted to malicious ends. However this does not pose a threat for the HolderOfKey profile since (1) the assertion has issuer info (so you know who originated the assertion came) (2) the signed assertion includes the key for the binding signature.

5.4.4.2. Sender Vouches

This profile has one or more authorities issuing assertions that contain <SubjectConfirmation> elements that basically say “Trust these if you trust the issuer and the entity who signed them”.

A collects these assertions and inserts them in a message. The sender then signs over the entire message, with the signature being used to indicate that these assertions (which are themselves signed by their issuers) are vouched for by the sender.

5.4.4.2.1. Eavesdropping

Eavesdropping continues to be a threat in the same manner as for the SAML SOAP binding, as discussed in Section 5.3.1.1. The routable nature of SOAP adds the potential for a large number of steps and actors in the course of a message’s lifetime, which means that the potential incidences of eavesdropping are increased as the number of possible times a message is in transit increases.

The persistent nature of SOAP messages adds an additional possibility of eavesdropping, in that persisted items can be read from their store.

To provide maximum protection from eavesdropping, assertions should be encrypted in such a way that only the intended audiences can view the material. This removes threats of eavesdropping in transit, but does not remove risks associated with storage by the receiver or poor handling of the clear text by the receiver.

5.4.4.2.2. Replay

The fact that the sender does all binding prevents a variety of replay attacks that reuse the assertion with different documents. In this case the assertions are directly signed into the document, so separating them from the document for reuse would not benefit a malicious user. (i.e. The assertions are only as valid as the binding signature of the sender, so reusing them with a different key does not pose a risk).

Authorities should note that once a "SenderVouches" assertion has been issued, there is no control over who may use it. Any entity coming into contact with the assertion can separate these assertions and use them by signing them with their own keys. Consumers of SenderVouches assertions must, therefore, carefully decide which senders to allow to vouch for what assertions.

The capture and resubmission of the entire message (SAML assertions and business payload) is a threat. One counter-measure is to add information about time, or a sequence number to the digital signature included in the SOAP header. The receiver can use this information to detect duplicate messages.

5.4.4.2.3. Message Insertion

There is no message insertion attack at the level of the `SenderVouches` format of the SOAP profile.

5.4.4.2.4. Message Deletion

There is no message insertion attack at the level of the `SenderVouches` format of the SOAP profile.

5.4.4.2.5. Message Modification

The binding signature should prevent any message modification attacks. Selection of what parts of the document to sign should be made carefully with the possibility of this attack in mind.

Receivers should consider only the portions of the document actually bound by signature to the assertions as valid with respect to the assertions.

5.4.4.2.6. Man-in-the-Middle

The requirement for a signature here should prevent MITM attacks. Note that the verifiability of the signature is key to this step: Not only must a receiver be able to verify that a document was signed with a key, but he also needs to be able to verify the binding of key to identity. This may be accomplished by including an X509v3 certificate with the digital signature, which the receiver verifies by some means (XKMS, OCSP, CRLs) and further maps onto a known identity for the signer.

If this step is skipped, then MITM becomes a possibility: The MITM captures the original document, alters it, and passes along this new document signed with a key that purports to be from the original sender (but which is actually held by the MITM).

The MITM can eavesdrop (if communication is not protected by some confidentiality scheme) but cannot alter the document without detection.

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