Security Engineering

MSc in Computer Science
EIT Master on Security and Privacy

Lecture 15 –WebApplicationSecurity II
Massacci Fabio
(SAML presentation courtesy of Dieter Gollmann)

Why Web Application Security is Important?

- Let's look at the process again
  - Authentication
    - Client identifies itself (NB ITself, not HERself or HIMself)
    - System challenges client's authentication
    - Client responds and systems let it go
  - Authorization
    - Application decides if it has the rights to do stuff
    - Client does stuff it is authorized to do
    - If Clients tries to do unauthorized stuff, application blocks it
- WebApplication addresses the problem of
  - "What if the "it" on the other side is not who s/he claims to be"?
  - What if the "it" on the other side does not send the right data?
    - "What if there is a bug in the application enforcing access?"

Why should you care?

- After all your case study is a Remotely Operated Tower
  - Lots of sensors, true but they are all controlled by a remote location and they are all specialized protocols and techniques
  - Why should we bother of web application security, XSS, SQLInjection, etc. etc.
- New Trends in Technologies
  - Convergence of IT and OT Networks
  - HMI Interfaces
  - Engineering Workstations

Now and Then for Critical Infrastructures

- Good old times
  - Operational Network is physically distinct from IT
  - Devices have very limited capabilities and used a very specialized language
  - Maintenance is performed by member of staff who used specialized machines owned by the company
- All this is expensive and difficult to manage
- Now
  - OT commands travels over IT network
  - Devices are general purpose with management Web Interface (eg Java)
  - Maintenance is performed by outsourced contractor who brings his laptop inside to diagnose/update stuff
- All this is cheap and easy to manage BUT

The Shadow PC

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- **A true story**
  - A Energy Provider detect a severe malware attack on their IT network trying to get on the OT network
  - They block the network and do forensics
  - They finally track the source of the attack to one building in a remote site across the ocean in an Island
  - BUT … there is no computer in that building according their IT department…
  - They go and physically inspect it and there is no computer, it has power transmission machines but really no computer to control them…
- **What happened?**

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The Airport Shutdown

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- **The hacker – CNN March 10, 1997**
  - the unidentified hacker broke into a Bell Atlantic computer system, causing a crash that disabled the phone system at the airport for six hours.
  - The crash knocked out phone service at the control tower, airport security, the airport fire department, the weather service, and carriers that use the airport.
  - Also, the tower's main radio transmitter and another transmitter that activates runway lights were shut down, as well as a printer that controllers use to monitor flight progress.
- **The contractor - Sep 26, 2014**
  - Somebody went in and shutdown everything that had to do with landing at this airport," said ABC News aviation and military consultant Steve Ganyard, a former Marine colonel.
  - "They shut down the lights, they shut down the instrument landing system. There was nobody to talk to."

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You don't believe it do you?

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- **Recall "Personal Invulnerability" in Johnson's paper:**
  - Accidents only happen to incompetent people, or to systems or equipment designed by incompetent people
    - "accidents only happen when someone messes up, and I will not mess up, so no accidents will happen to me or the systems with which I work."
  - Because few engineers consider themselves to be incompetent, they are inclined to think that accidents will not happen to them or to the systems with which they are involved.
    - C. Johnson "Why System Safety Professionals Should Read Accident Reports"
- **Let's search on the web for CODASYS**

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The Telco Controller on Shodan

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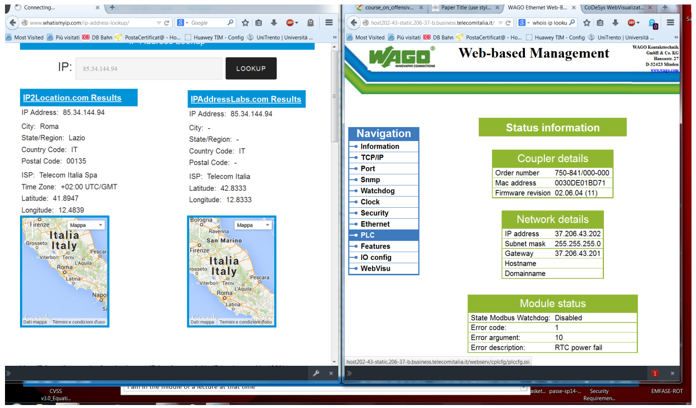

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A bit of history explains a lot of things

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- **How and "why" the internet was invented?**
- **TCP/IP + all services (DNS, etc.)**
  - Protocols to communicate among nodes of a trusted network (US Military + few Universities)
  - Essential to survive nuclear attacks → resilience is key
- **HTTP + Web (JS, etc.)**
  - Protocol to communicate presentation of scientific data
  - Essential to be easy to use → usability is key
- **Participants are all trusted**
  - They won't lie on who they are and
  - They won't send wrong data

Web Application Security Revisited – I

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- **At home**
  - Paolo: Daddy, I need 10€ to go to the movies
  - Fabio: Pick them from the wallet
  - Paolo: Where is the wallet?
  - Fabio: Near the entrance
  - Paolo: Thanks
- **On the internet**
  - 192.37.15.6: Daddy, I need 10€ to go to the movies
  - Fabio: pick them from the e-wallet
  - 192.37.15.6: where is the e-wallet?
  - Fabio: on 193.37.18.67/server
  - 192.37.15.6: Thanks
  - Fabio: oh sh…

Web Application Security Revisited - II

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- **At home**
  - Luigi: Daddy, I need 500€
  - Fabio: What for?
  - Luigi: Going to buy A NEW LEGO MINDSTORM!!
  - Fabio: No need to shout, I can hear you. Anyhow, forget it.
- **On the internet**
  - 192.37.15.6: Daddy, I need 500€
  - Fabio: What for?
  - 192.37.15.6: Going to buy QQQ***… 1GB of Qs…***QQQQQQQQ$%&//()=?éç°°è:;BATRFSIAa new Lego Mindstrom
  - Fabio: /dev/null… restarting on 193.37.18.67/server
  - 192.37.15.6: Thanks
  - Fabio: oh sh…

The long road to a PDP decision

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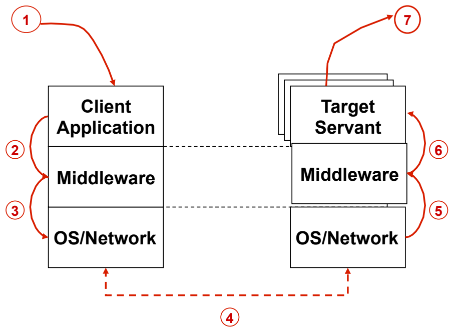

1. User ask for access
2. App transfer info to Middelware
3. Middleware pass info to OS/Network
4. Info sent over the network
5. OS/pass info up to middleware
6. Middleware up to App
7. App finally makes a decision with what it got

Remote User AAA

- How can Server make decision on Client?
- Identification with challenge-response
  - Client sends identity
  - Server responds with random number
  - Client computes f(r,h(P)) and sends back
    - F and H are 1-way functions
    - P is the shared secret
  - Server compares value from user with own computed value, if match user authenticated
- Access control of application resources managed by server → conceptually just implementation

HTTP Basic Authentication

- Client:
  - GET /index.html HTTP/1.0
- Server:
  - HTTP/1.1 401 Unauthorized
  - WWW-authenticate Basic realm="SecureArea"
- Client:
  - GET /index.html HTTP/1.0}
  - Authorization: Basic
  - am9ldXNlcjphLmluQy5E
- Server:
  - HTTP/1.1 200 Ok (plus document)
- Password sent in the clear, base64 encoded.
- Not really secure:
  - Step (4) → anybody who can see the user's reply learns the password.

HTTP Digest Authentication

- Challenge-response protocol (RFC 2617).
- Server
  - sends random challenge (nonce) to user.
- Client
  - replies with hash (digest) of username+password+nonce +uri:
  - h(h(username:realm:password):nonce:h(method:digest-uri))
- Better security but still vulnerable to off-line dictionary attacks.

Terminology: Nonces

- The term "nonce" was proposed Needham & Schroeder for unique values that are used only once.
- A nonce can be a counter value, a time stamp, or a random number.
- A nonce is not necessarily unpredictable.
- Depending on the security goals, unpredictable nonces may be required.

Off-line dictionary attacks

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- **Use the password P to encrypt a randomly generated session key Ks; use session key to encrypt further data.**
  - A → B: $encrypt_P(Ks)$
  - B → A: $encrypt_{Ks}(data)$
- **Vulnerable to off-line dictionary attack.**
  - Attacker guesses password P,
  - decrypts first message and gets a candidate session key K's
  - decrypt the second message with K's.
  - if result is meaningful text, → got P!

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Encrypted Key Exchange (EKE)

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- **Step 0:**
  - user A generates a random public key/private key pair PubKa, PrivKa.
- **Step 1:**
  - A sends public key pubKa to B, encrypted under the password P (symmetric encryption).
- **Step 2:**
  - B randomly generates session key Ks;
  - sends Ks to A encrypted first under Ka (public-key enc.) and then under P (symmetric enc.)
- **Protocol**
  - A → B: encryptP(PubKa)
  - B → A: encryptP(encryptPubKa(Ks))
  - A → B: encryptKs(data)

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RADIUS

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- **RADIUS: Remote Authentication Dial-In User Service (RFC 2865).**
  - Centralized authentication, authorization, and accounting service.
  - Used for dial-up, virtual private network, wireless network access.
- **RADIUS client and RADIUS server have**
  - common shared secret (password).
- **Access-Request:**
  - user name, user password, authenticator, ID of client, Port ID which the user is accessing.

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RADIUS (2)

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- **RADIUS server validates the sending client.**
- **The server has a user database**
  - a user entry in the database lists the requirements which must be met to allow access.
  - A request from a client for which the server does not have a shared secret MUST be silently discarded.
- **Always includes verification of password, can also specify client(s) or port(s) to which the user is allowed access.**
- **Challenge-response authentication optional.**

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RADIUS (3)

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- When password is present in the request, it is hidden using a method based on MD5.
- Passwords divided in blocks p1, p2, ..., pn.
- Ciphertext blocks c1, c2,..., cn.
- Secret S, random authenticator RA:
  - c1 = p1 ⊕ MD5(S || RA)
    c2 = p2 ⊕ MD5(S || c1)
    .
    .
    .
    cn = pn ⊕ MD5(S || cn-1)
- Without challenge response still vulnerable to dictionary attacks but more difficult

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Only secure a part of the picture

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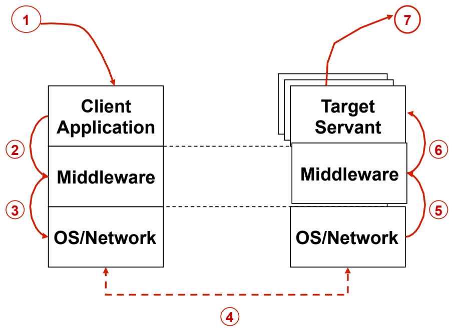

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Basic Problems still hanging

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- At network level not yet very secure
  - The OS may be subverted
  - The Network may be spoofed/manipulated etc.
  - More details in the last part of the course on infrastructure (Network/OS) security
- We need to secure the application but
  - The applications may have bugs → see OWASP top 10 lecture
  - The application may be a controller… it is not a server → may have no clue who you are

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It Takes 3 to Tango a AAA

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- The Asserting Party
  - Who asserts information about a subject (has authority to grant/deny access to a user)
  - Asserts that a user has been authenticated and has been given associated attributes.
    - E.g.: This user is John Doe, has the email address john.doe@acompany.com, and was authenticated into this system using a password mechanism.
- The Relying Party
  - Who wants to grant/deny access to a user on information supplied to it by the asserting party.
  - It is up to the relying party as to whether it trusts the assertions provided to it.
- The Client

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SAML Overview

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- **SAML**
  - User authentication in distributed system uses Web Services.
  - SAML requirements driven by use cases.
- **Main use case: Web Single Sign-On (SSO).**
  - Allows users to gain access to website resources in multiple domains without having to re-authenticate after initially logging in to the first domain.
  - The domains need to form a trust relationship before they can share an understanding of the user's identity
- **New incarnation**
  - OpenAuth protocol → same concept with OpenData buzzword

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Web Single Sign-On (SSO)

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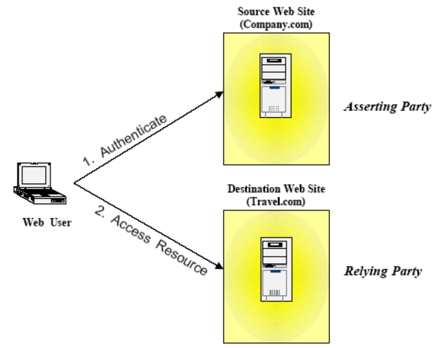

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Travel Bookings

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- **Scenario**
  - Authenticated users of Company.com need to access protected resources at Travel.com in order to make travel arrangements.
- **Company.com users**
  - should not need to have to re-authenticate to Travel.com
  - Only certain privileged users may book international travel
- **SSO scenario (without control on user) is just the "login with Gmail button" scenario**

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Goods Purchasing

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- **Authenticated users of Company.com use an internal purchasing system to place orders for office supplies from Supplier.com.**
- **Supplier.com needs to know**
  - user data → name and shipping address.
  - User authorization → whether user is authorized to purchase goods of that value or larger

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Alternative: Browser cookies

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- In the past, most SSO products used browser cookies to maintain state so that re-authentication is not required.
- However, browser cookies are not transferred between DNS domains.
- So, a cookie from www.abc.com will not be sent in any HTTP messages to www.xyz.com.
- This could even apply within an organization that has separate DNS domains.

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Centralized Tower Control Center

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- Central portal system maintaining the authentication information for all users, linked to a number of satellite systems.
- Satellite systems use access management products from a variety of vendors.
- Users should only be required to be authenticated once, and can either go initially to the satellite system or the central portal.
- The portal is the asserting party for the whole system, the satellite systems are the relying parties.

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SSO interoperability

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- With proprietary cross-domain SSO products, organizations that want to perform cross-domain SSO have to use the same SSO product in all the domains.
- This holds for SSO within one organization and for SSO across trading partners.
- A solution based on web services can address this interoperability issue.

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SAML Concepts

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- Assertion: A package of information that supplies one or more statements made by a SAML authority.
  - *Authentication statements* say "This subject was authenticated by this means at this time."
  - *Attribute statements* provide specific details about the subject (e.g., a user holds "Gold" status).
  - *Authorization decision statements* say what the subject is entitled to do.
- Protocol: SAML defines a request/response protocol for obtaining assertions.

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SAML Concepts

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- Bindings: Detail how the SAML protocol maps onto transport and messaging protocols.
  - SAML-SOAP binding (SAML over SOAP over HTTP).
  - Reverse SOAP (PAOS) binding.
  - HTTP post binding
  - SAML URI binding
- Profiles: Technical descriptions of particular flows of assertions and protocol messages that define how to use SAML for a particular purpose; derived from use cases.

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SOAP over HTTP binding

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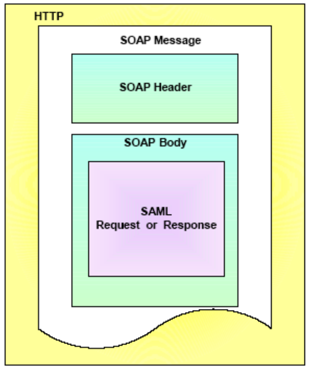

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SAML Profiles

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- Browser/Artifact Profile: Pull model
- Browser/POST Profile: Push model: assertions POSTed (using the HTTP POST command) directly to the relying party.
- Profiles assume:
  - Use of a standard commercial web browser using either HTTP or HTTPS.
  - The user has been authenticated at the local source site.
  - The assertion's subject refers implicitly to the user that has been authenticated.

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Browser/Artifact Profile

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- Scenario
  - A user has an authenticated session on the local source site and wants to access a resource on the destination web site and is directed there.
- In the HTTP message, an HTTP query variable is passed called an artifact:
  - a base-64 encoded string consisting of a unique identity of the source site (Source ID) and a unique reference to the assertion (AssertionHandle).
- The destination site (relying party) sends a SAML request containing the artifact to the local site (asserting party).
- The assertions about the user are transferred back in a SAML response.

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Browser/Artifact Profile

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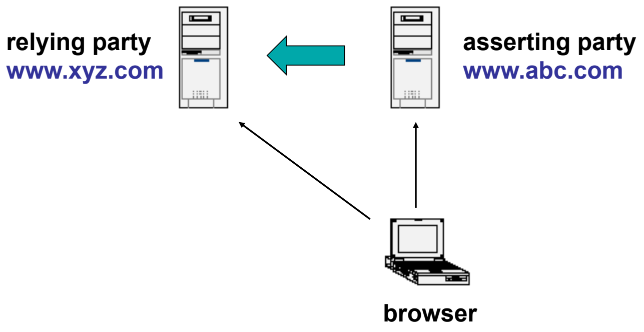

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Detailed Processing for the Source-Site-First Scenario

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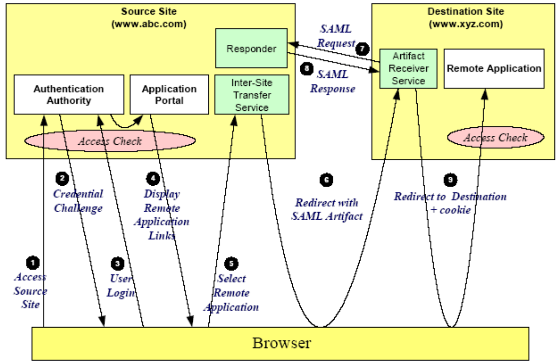

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Browser/POST Profile

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- **Scenario**
  - A user has an authenticated session on the local source site (asserting party) and wants to access a resource on the destination web site (relying party).
- **An HTML form with the assertion about the user is provided back to the browser from the source site.**
  - The form contains a button (or other type of trigger, or JavaScript "auto-submit" action) that causes a POST of the assertion to the destination site to occur.
- **The destination site makes its decisions based on the assertions contained within the POST message.**

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Browser/POST Profile

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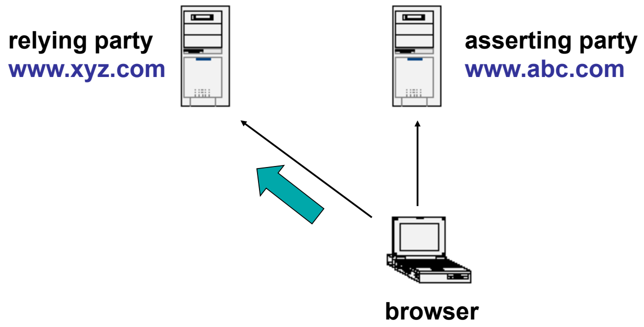

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Summary

- **SAML addresses an aspect of access control in distributed applications:**
  - the entity managing the resource need not know about the subject requesting access.
- **SAML defines message flows, but not protocols.**
  - We need protocols whereby an entity that can authenticate the subject transmits this information to the entity managing the resource.
- **How does the relying party trust what is being asserted?**
  - How do prevent man-in-the-middle attacks?
  - The primary security mechanism is for the relying and asserting party to have a pre-existing trust relationship, typically involving a Public Key Infrastructure (PKI).

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Security Analysis

- **We need to add a bit of crypto for message and origin authntication**
  - Where message integrity and message confidentiality are required,
    - HTTP over SSL 3.0 or TLS 1.0 is recommended.
  - When an assertion is requested from an asserting party,
    - bi-lateral authentication is required
    - SSL 3.0 or TLS 1.0 using server and client authentication are recommended.
  - When an assertion is pushed to a relying party,
    - the response message be digitally signed using the XML digital signature standardì
- **TLS/SSL we will see them in Infrastructure/Network Security Part**

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