Cryptographic protocols (II)

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Credit card payment protocol

Credit card payment

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- Is it a real card?

Credit card payment

- Is it a real card?
- Is the pin protected?

Behavior in the usual case

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Behavior in the usual case

1. The waiter introduces the credit card
2. The waiter enters the amount m of the transaction
3. The terminal authenticates the card
4. The costumer enters his secret pin If the amount m is greater than 100 euros (and in only 20% of the cases)
   4.1 The terminal asks for authentication of the card
   4.2 The bank provides authentication

More details

4 actors: Bank, Customer, Card, and Terminal

Bank owns:

- a secret signing key sk_B
- a public verification key pk_B
- a secret symmetric encryption key per card K_{CB}

Card owns:

- Data: last name, first name, card's number, expiration date
- Signature's value $VS = \{\mathsf{hash}(Data)\}_{\mathsf{sk}_B}$
- a secret symmetric encryption shared with the bank K_{CB}

Terminal owns:

- the public verification key pk_B

Credit card payment protocol (in short)

The terminal reads the card:

$$1. \quad Ca \quad \rightarrow \quad T \quad : \quad Data, \{\mathsf{hash}(Data)\}_{\mathsf{sk}_B}$$

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The terminal asks for the secret pin:

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3. $Cu \rightarrow Ca :$ 1234
4. $Ca \rightarrow T :$ ok

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3. $Cu \rightarrow Ca : 1234$
4. $Ca \rightarrow T :$ ok

The terminal calls the bank

5. $T \rightarrow B :$ auth?
6. $B \rightarrow T : N_B$
7. $T \rightarrow Ca : N_B$
8. $Ca \rightarrow T : \{N_B\}_{K_{Cb}}$
9. $T \rightarrow B : \{N_B\}_{K_{Cb}}$
10. $B \rightarrow T :$ ok

Some flaws

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But:

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$\Rightarrow$ "YesCard" built by Serge Humpich (France, 1998)

How does the “YesCard” work?

Logical flaw

$$
\begin{array}{lllll}
1. & Ca & \rightarrow & T & : & Data, \{\text{hash}(Data)\}_{\text{sk}_B} \\
2. & T & \rightarrow & Cu & : & \text{pin?} \\
3. & Cu & \rightarrow & Ca & : & 1234 \\
4. & Ca & \rightarrow & T & : & \text{ok}
\end{array}
$$

How does the “YesCard” work?

Logical flaw

1.	Ca	$\rightarrow$	T	:	$Data, \{\text{hash}(Data)\}_{\text{sk}_B}$
2.	T	$\rightarrow$	Cu	:	pin?
3.	Cu'	$\rightarrow$	Ca'	:	5678
4.	Ca'	$\rightarrow$	T	:	ok

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Logical flaw

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2. $T \rightarrow Cu$: pin?
3. $Cu' \rightarrow Ca'$: 5678
4. $Ca' \rightarrow T$: ok

There is always someone to debit

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Logical flaw

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$\longrightarrow$ creation of a fake card

1.	Ca'	$\rightarrow$	T	:	$XXXX, \{\text{hash}(XXXX)\}_{\text{sk}_B}$
2.	T	$\rightarrow$	Cu'	:	pin?
3.	Cu'	$\rightarrow$	Ca'	:	0000
4.	Ca'	$\rightarrow$	T	:	ok

The SSL/TLS protocol

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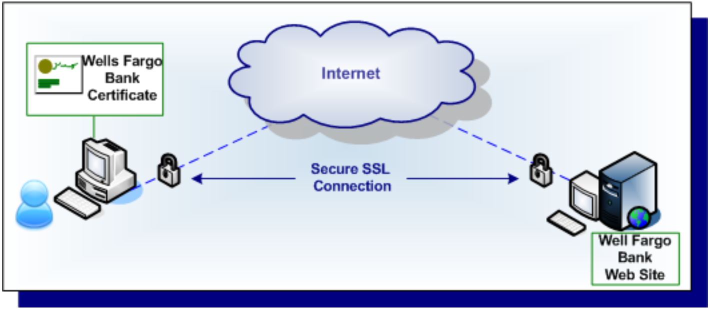
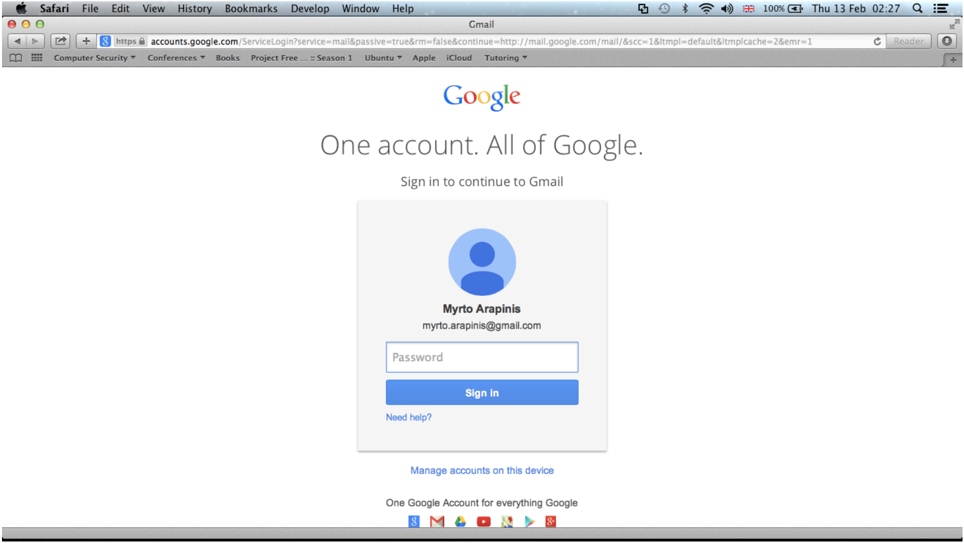
Goals: Confidentiality, Integrity, Non repudiation

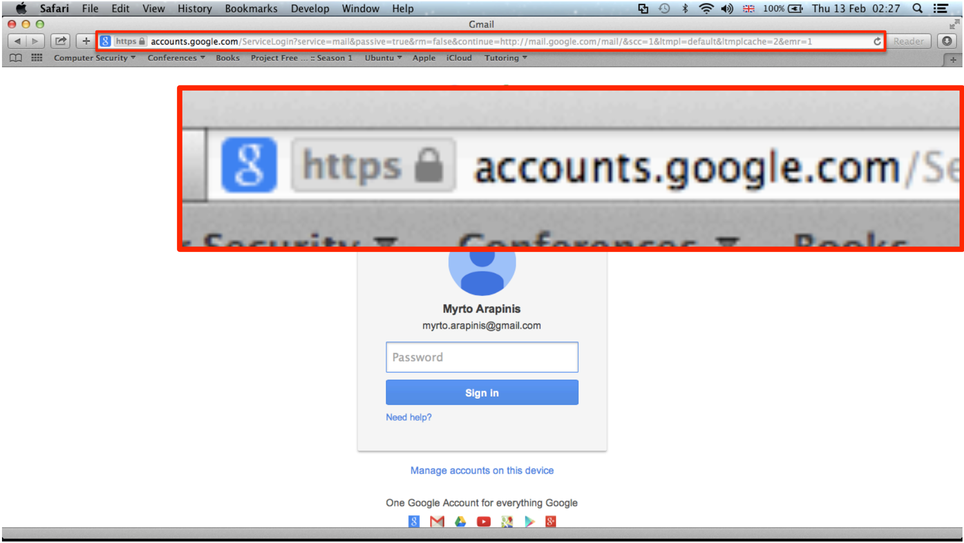


SSL/TLS use X.509 certificates and hence asymmetric cryptography to exchange a symmetric key. This session key is then used to encrypt subsequent communication. This allows for **data/message confidentiality**, and message authentication codes for **message integrity** and thus, **message authentication**.

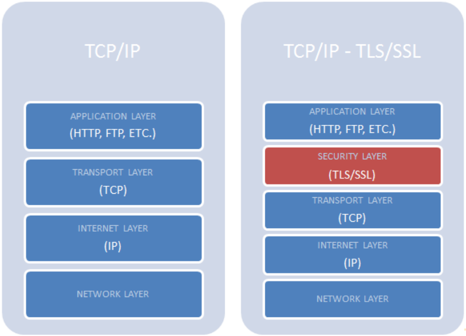
SSL/TLS protocol



SSL/TLS protocol

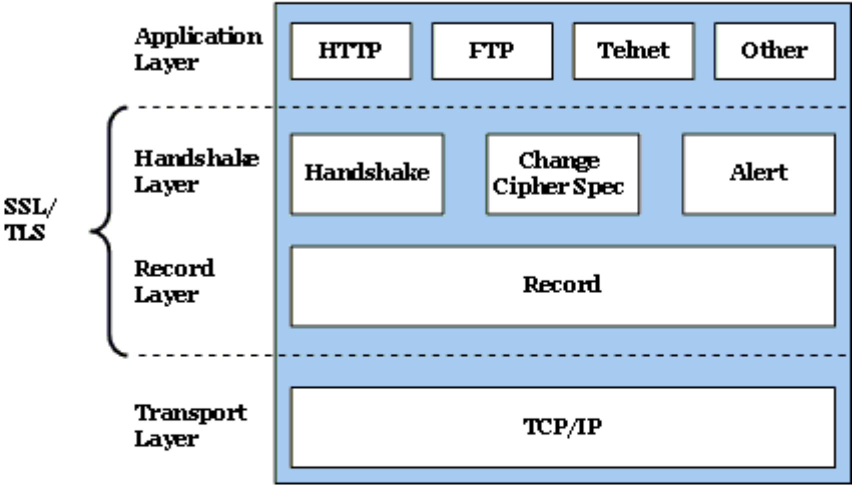


TCP/IP protocol stack

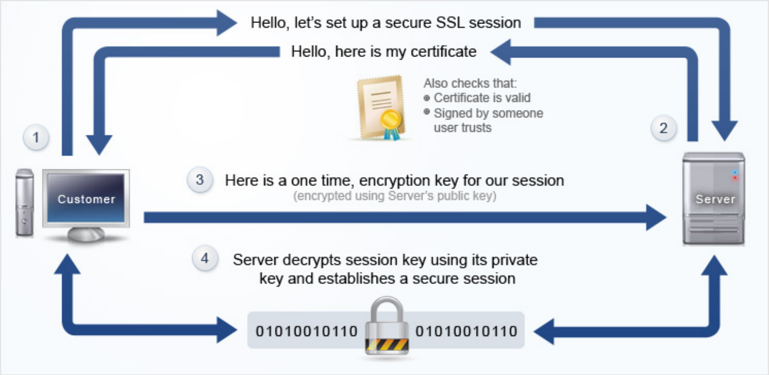


- TCP/IP provides end-to-end connectivity and is organized into four abstraction layers which are used to sort all related protocols according to the scope of networking involved
- The SSL/TLS library operates above the transport layer (uses TCP) but below application protocols

SSL/TLS protocol layers



SSL/TLS handshake protocol



SSL/TLS renegotiation

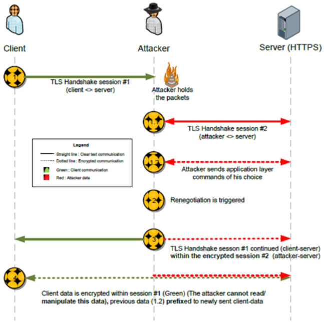
Client and server are allowed to initiate renegotiation of the session encryption in order to:

- Refresh keys
- Increase authentication
- Increase cipher strength
- ...

Client or server can trigger renegotiation by sending a hello meesage

SSL/TLS renegotiation weaknesses

- Renegotiation has priority over application data!
- Renegotiation can take place in the middle of an application layer transaction!



(Detailed on the board)

Incorrect implicit assumtion: the client doesn't change through renegotiation

Marsh Ray's plaintext injection attack on HTTPS

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$\Rightarrow$ **Server uses victim's account to send a pizza to attacker!**

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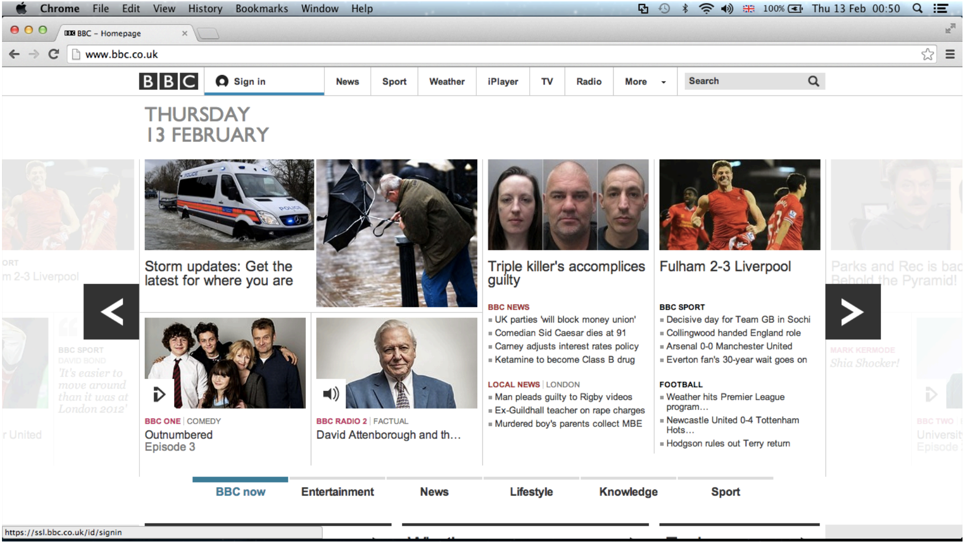
⇒ **the attacker gets the user name and password of the victim!**

The SAML Signle Sign On (SSO) protocol

SAML SSO protocol



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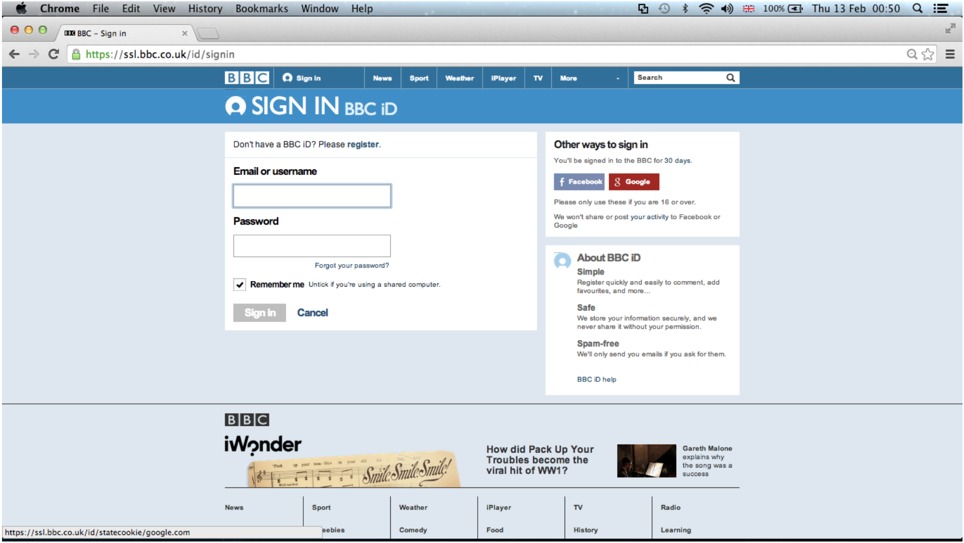

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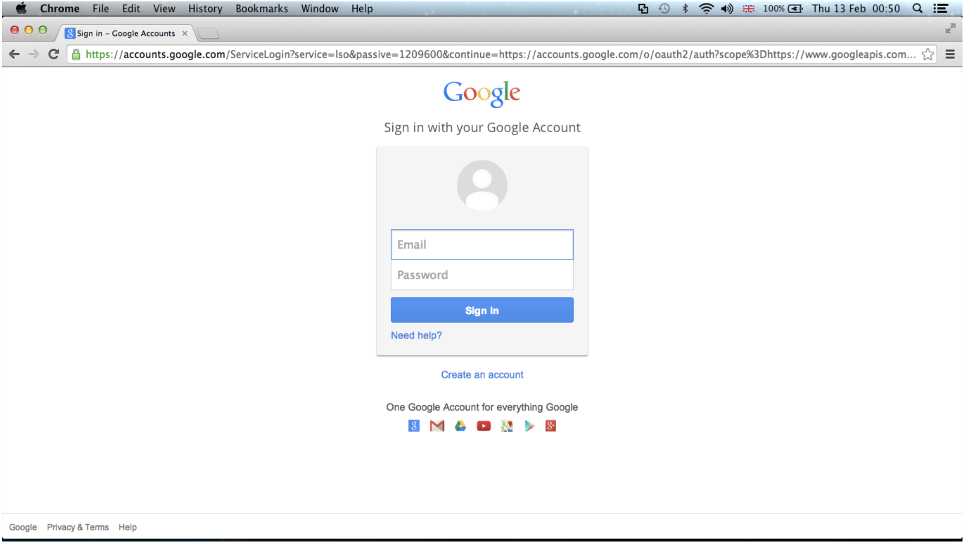
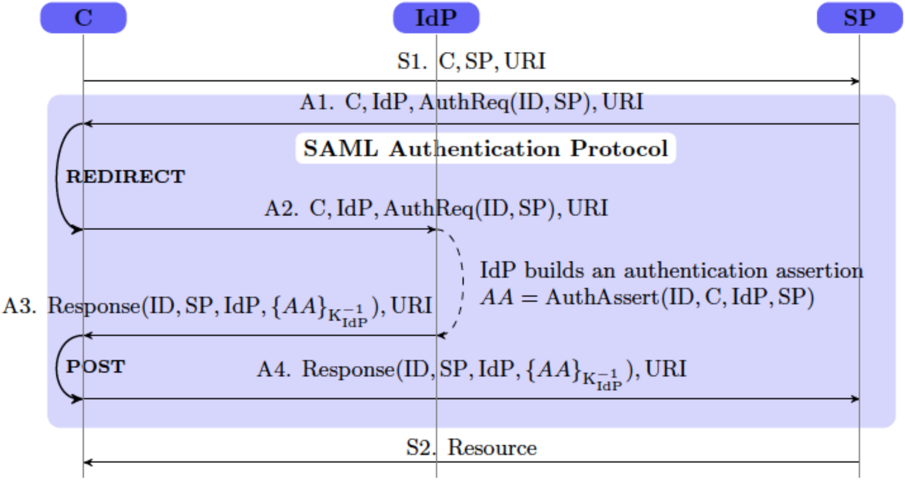


SAML SSO protocol (OASIS 2005)



Google's implementation of SSO

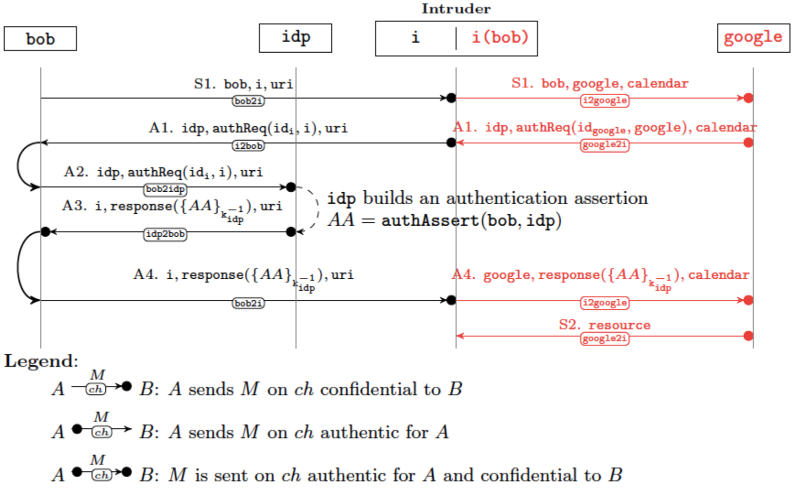
Google's SAML-based Single Sign-On for Google Applications deviates from the above protocol for a few, seemingly minor simplifications in the messages exchanged:

G1. *ID* and *SP* are not included in the authentication assertion, *i.e.* $AA = \text{AuthAssert}(C; IdP)$ instead of $\text{AuthAssert}(ID; C; IdP; SP)$;

G2. *ID*, *SP* and *IdP* are not included in the response, *i.e.* $Resp = \text{Response}(\{AA\}_{K_{IdP}^{-1}})$ instead of $\text{Response}(ID; SP; IdP; \{AA\}_{K_{IdP}^{-1}})$.

Attack Google's SSO implementation

[A. Armando, R. Carbone, L. Compagna, J. Cullar, L. Tobarra, "Formal analysis of SAML 2.0 web browser single sign-on: breaking the SAML-based single sign-on for google apps", (FMSE'08)]



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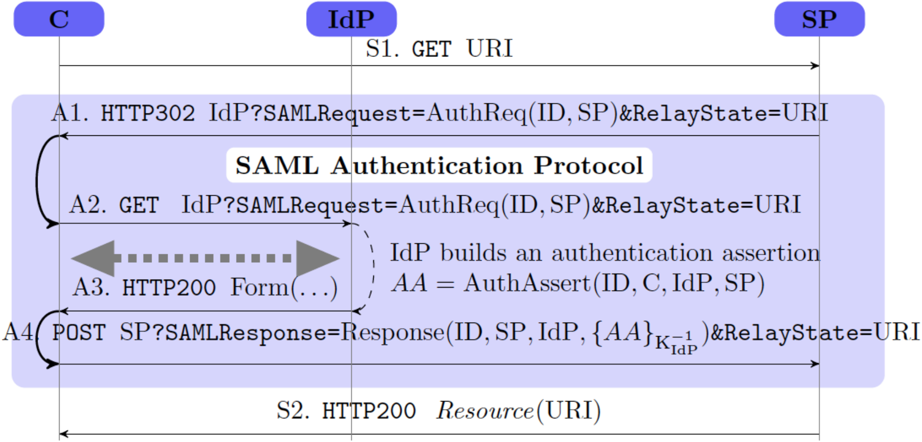
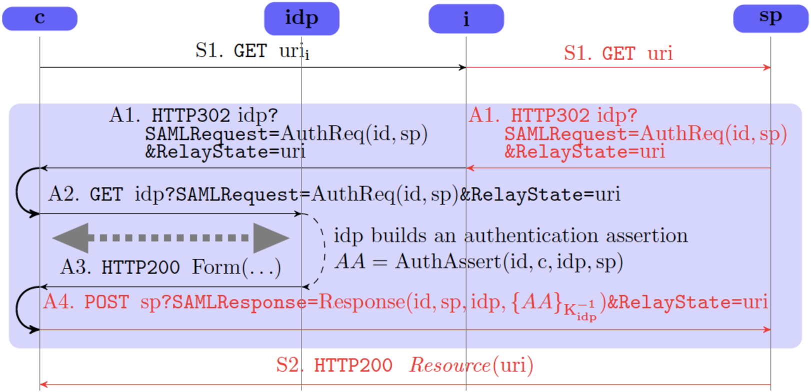


Attack SAML SSO protocol (OASIS 2012)

[A. Armando, R. Carbone, L. Compagna, J. Cullar, G. Pellegrino, A. Sorniotti, "From Multiple Credentials to Browser-Based Single Sign-On: Are We More Secure?", Chapter in Future Challenges in Security and Privacy for Academia and Industry]



⇒ XSS attack on SAML-base SSO for Google Apps