Cryptographic protocols (II)

Myrto Arapinis
School of Informatics
University of Edinburgh

February 13, 2014

Credit card payment protocol

Credit card payment

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

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 $VS = \{hash(Data)\}_{sk_B}$
- 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. $Ca \rightarrow T : Data, \{hash(Data)\}_{sk_B}$

The terminal asks for the secret pin:

2. $T \rightarrow Cu$: pin?
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

The security was initially ensured by:

- the cards were difficult to reproduce
- the protocol (!) and keys were secret

But:

- cryptographic flaw: 320-bit keys can be broken (1988),
- logical flaw: no link between the secret code and the authentication of the card,
- fake cards can be built.

⇒ "YesCard" built by Serge Humpich (France, 1998)

How does the "YesCard" work?

Logical flaw

1. $Ca \rightarrow T : Data, \{hash(Data)\}_{sk_B}$
2. $T \rightarrow Cu$: pin?
3. $Cu' \rightarrow Ca'$: 12345678
4. $Ca' \rightarrow T$: ok

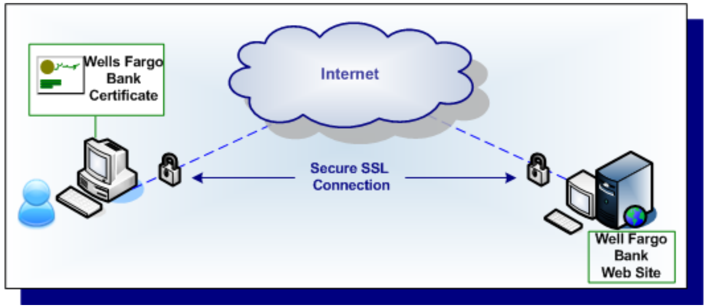
There is always someone to debit
⟶ creation of a fake card

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

The SSL/TLS protocol

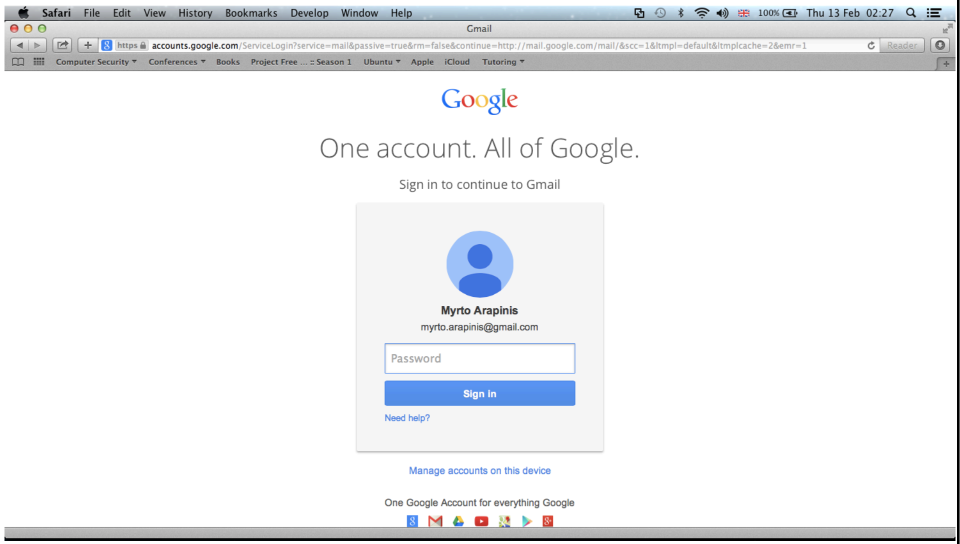
SSL/TLS protocol

Goals: Confidentiality, Integrity, Non repudiation

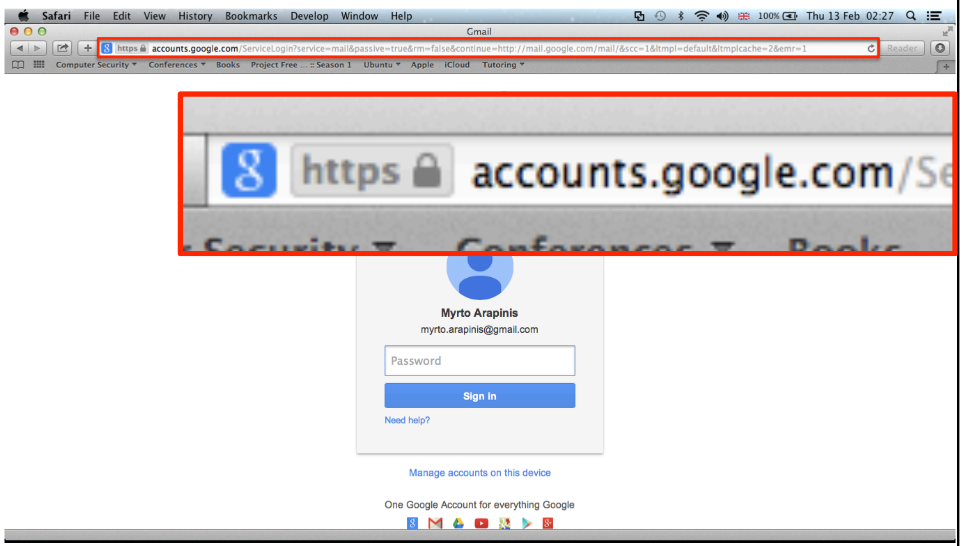


SSL/TLS use X.509 certificates and hence asymmetric cryptography to exchange a symmetric key. This session key is then used to encrypt subsequent communication. This allows for **data/message confidentiality**, and message authentication codes for **message integrity** and thus, **message authentication**.

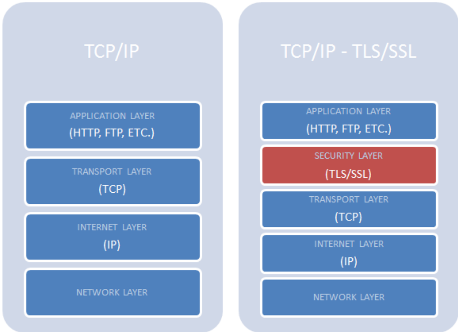
SSL/TLS protocol



SSL/TLS protocol

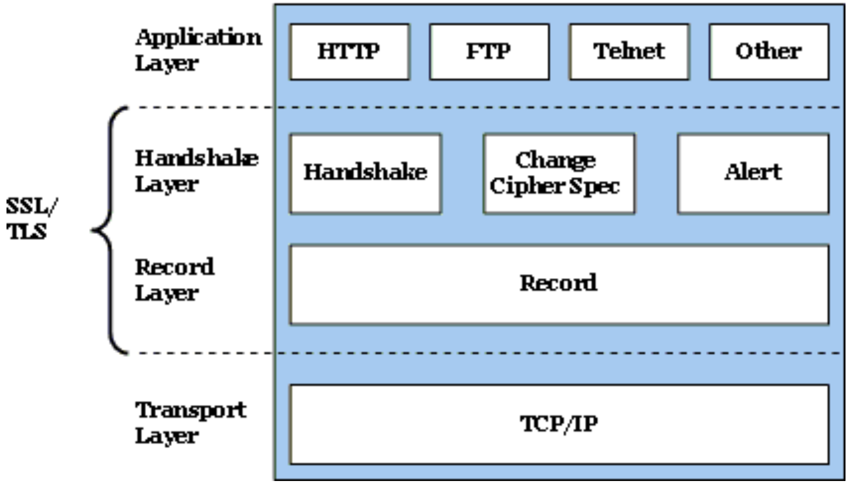


TCP/IP protocol stack



- 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

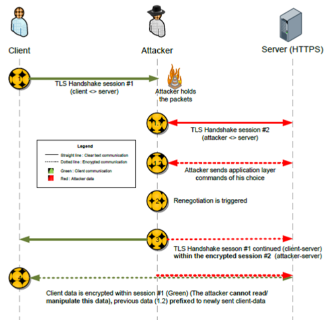
Client and server are allowed to initiate renegotiation of the session encryption in order to:

- 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

Attacker:
`GET /pizza?toppings=pepperoni;address=attacker_str HTTP/1.1`
`X-Ignore-This:(no carriage return)`

Victim:
`GET /pizza?toppings=sausage;address=victim_str HTTP/1.1`
`Cookie:victim_cookie`

Result:
`GET /pizza?toppings=pepperoni;address=attacker_str HTTP/1.1`
`X-Ignore-This:GET /pizza?toppings=sausage;address=victim_str HTTP/1.1`
Cookie:victim_cookie

⇒ **Server uses victim's account to send a pizza to attacker!**

Anil Kurmus' plaintext injection attack on HTTPS

Twitter status updates using its API by posting the new status to http://twitter.com/statuses/update.xml, as well as the user name and password

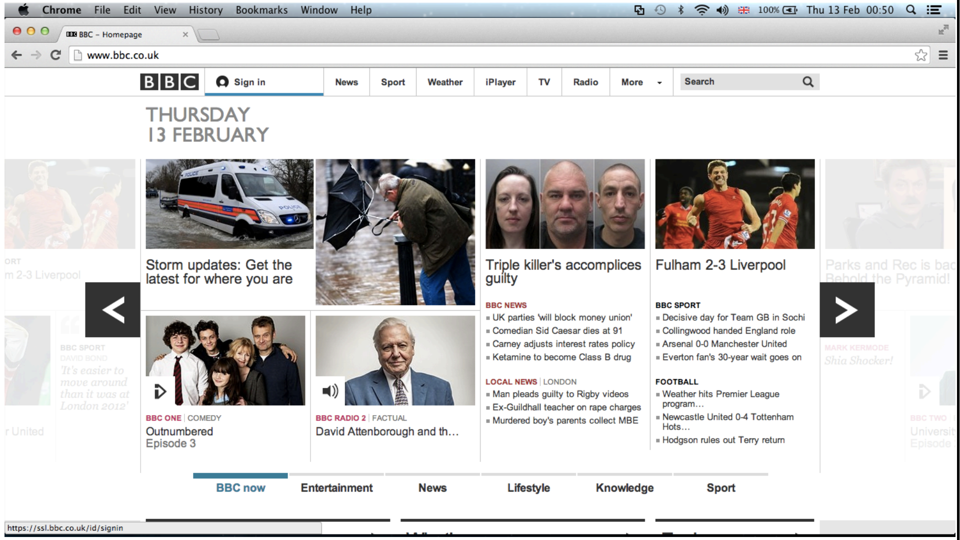
Attacker:
```
POST /statuses/update.xml HTTP/1.1
Authorization: Basic username:password
User-Agent: curl/7.19.5
Host: twitter.com
Accept:*/*
Content-Length: 140
Content-Type: application/x-www-form-urlencoded
status=
```

Victim:
```
POST /statuses/update.xml HTTP/1.1
Authorization: Basic username:password...
```

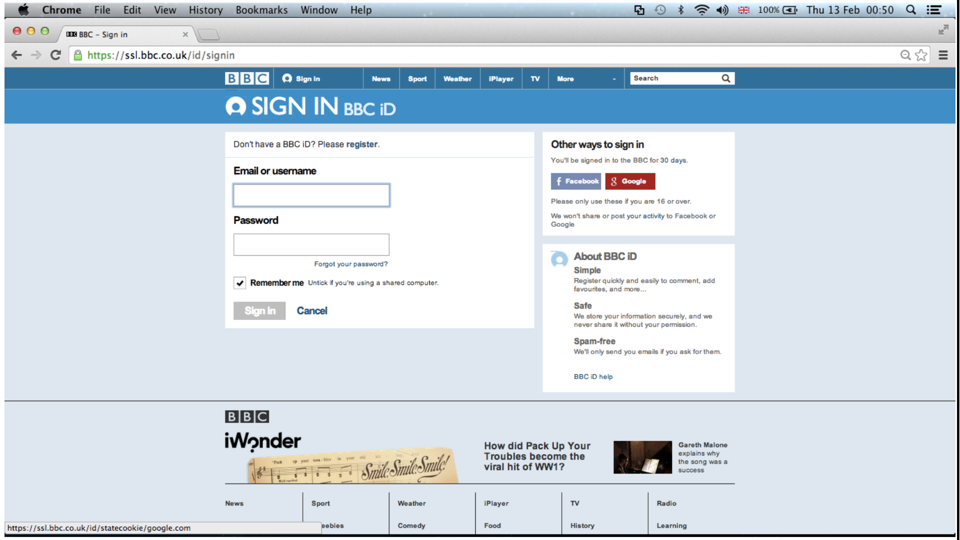
⇒ **the attacker gets the user name and password of the victim!**

The SAML Signle Sign On (SSO) protocol

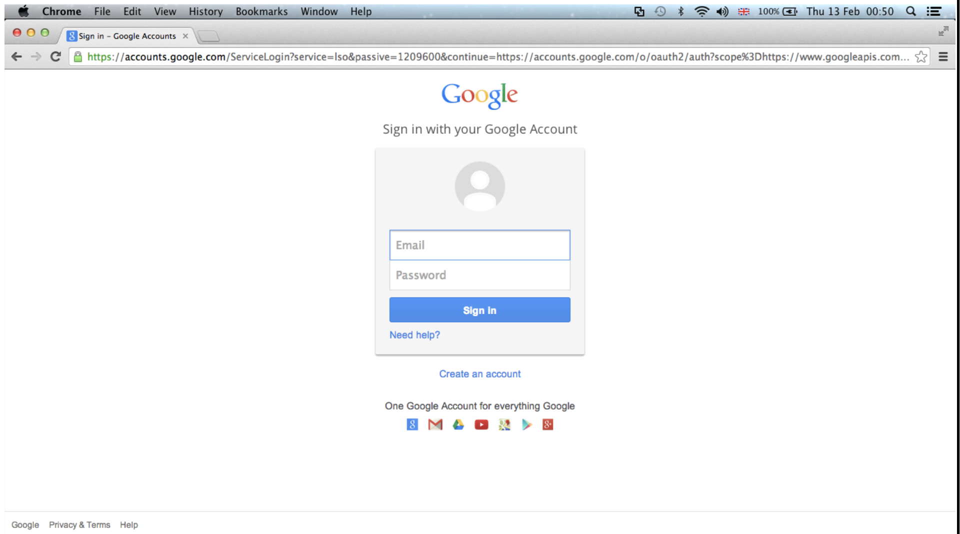
SAML SSO protocol



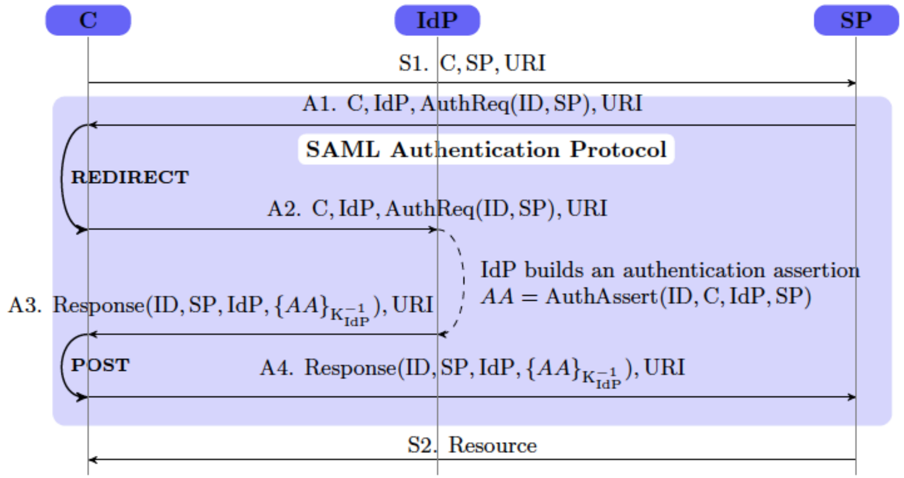
SAML SSO protocol



SAML SSO protocol



SAML SSO protocol (OASIS 2005)



Google's implementation of SSO

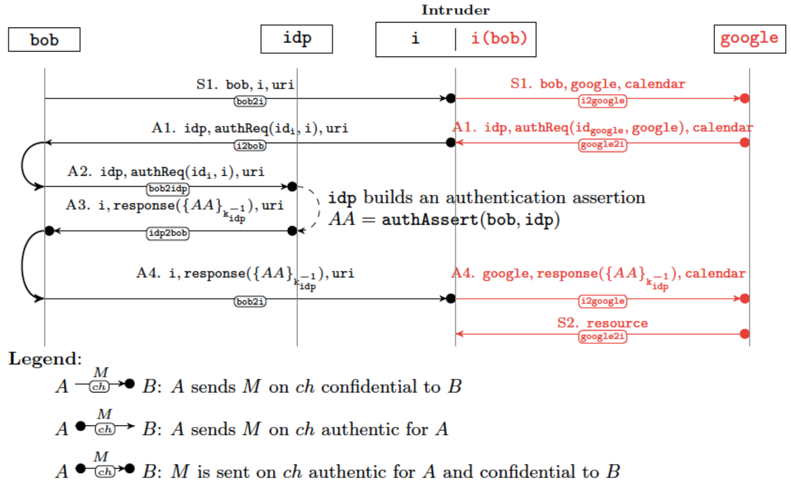
Google's SAML-based Single Sign-On for Google Applications deviates from the above protocol for a few, seemingly minor simplifications in the messages exchanged:

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

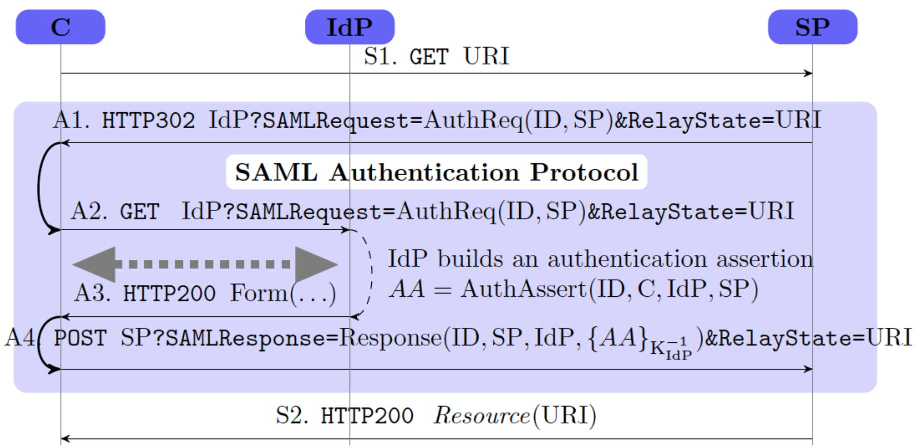
G2. *ID*, *SP* and *IdP* are not included in the response, *i.e.* $Resp = \text{Response}(\{AA\}_{K_{IdP}^{-1}})$ instead of $\text{Response}(ID; SP; IdP; \{AA\}_{K_{IdP}^{-1}})$.

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)]

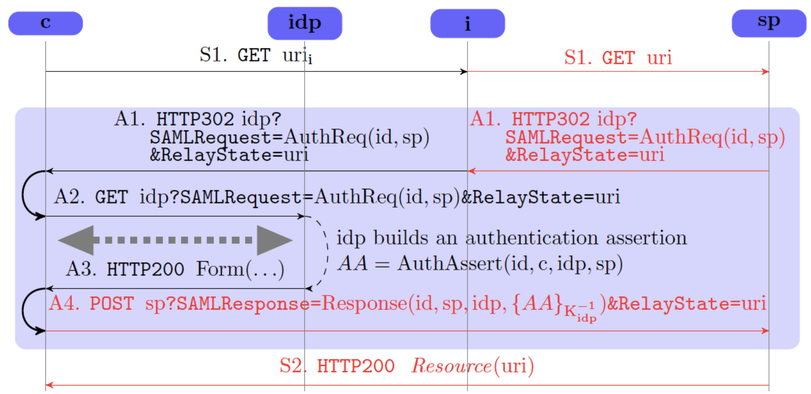


SAML SSO protocol (OASIS 2012)



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