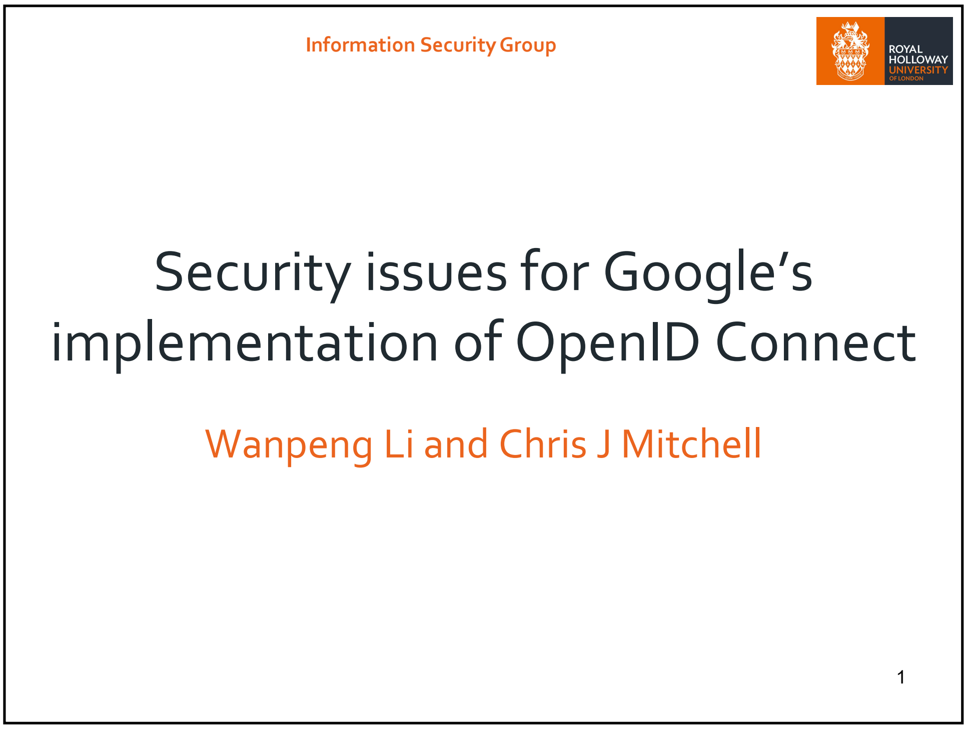
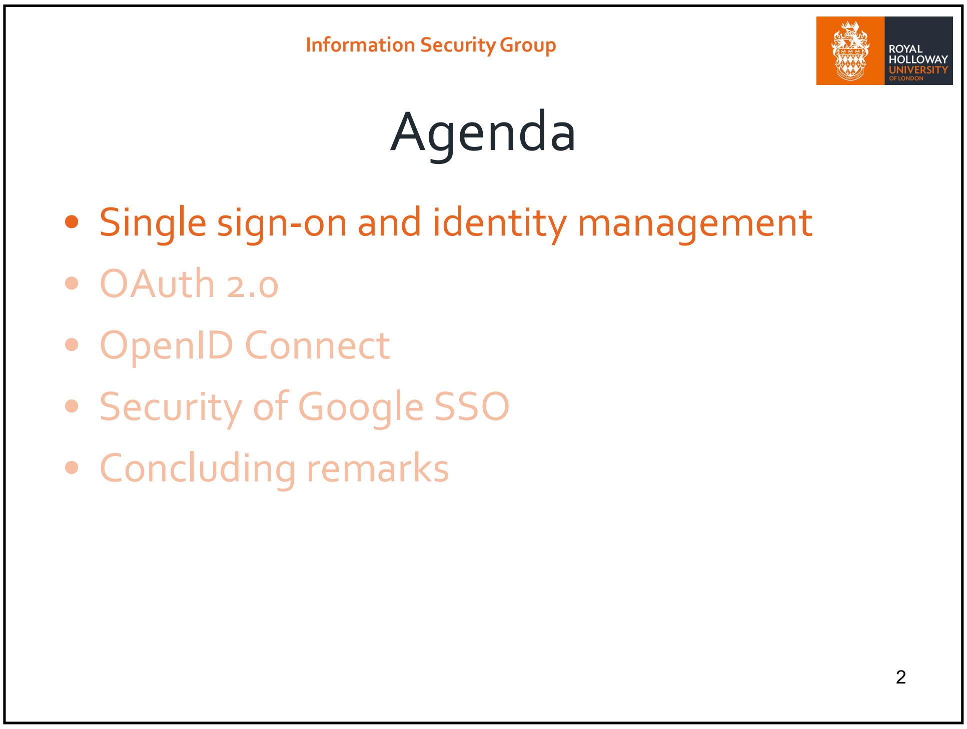


Security issues for Google's implementation of OpenID Connect

Wanpeng Li and Chris J Mitchell



Agenda

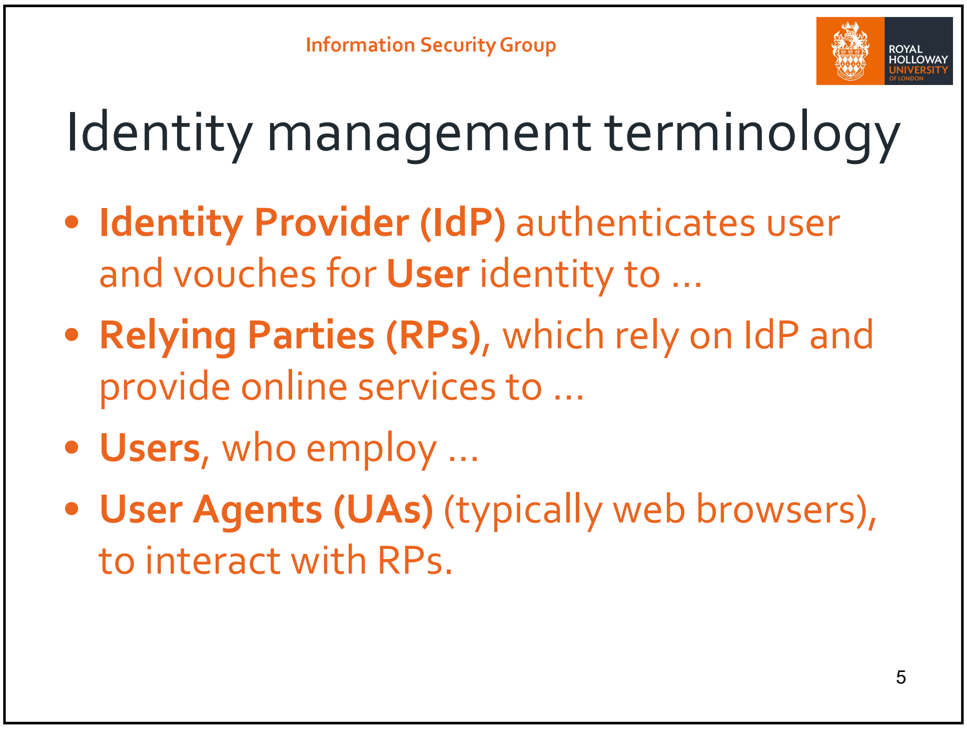
- Single sign-on and identity management
- OAuth 2.0
- OpenID Connect
- Security of Google SSO
- Concluding remarks

Single sign on (SSO)

- An Internet single sign on (SSO) system allows a user to log in to multiple web sites with just one authentication.
- Increasingly widely used, e.g. in form of
  - Facebook Connect (OAuth 2.0);
  - Google SSO service (formerly built using OpenID and now employing OpenID Connect).

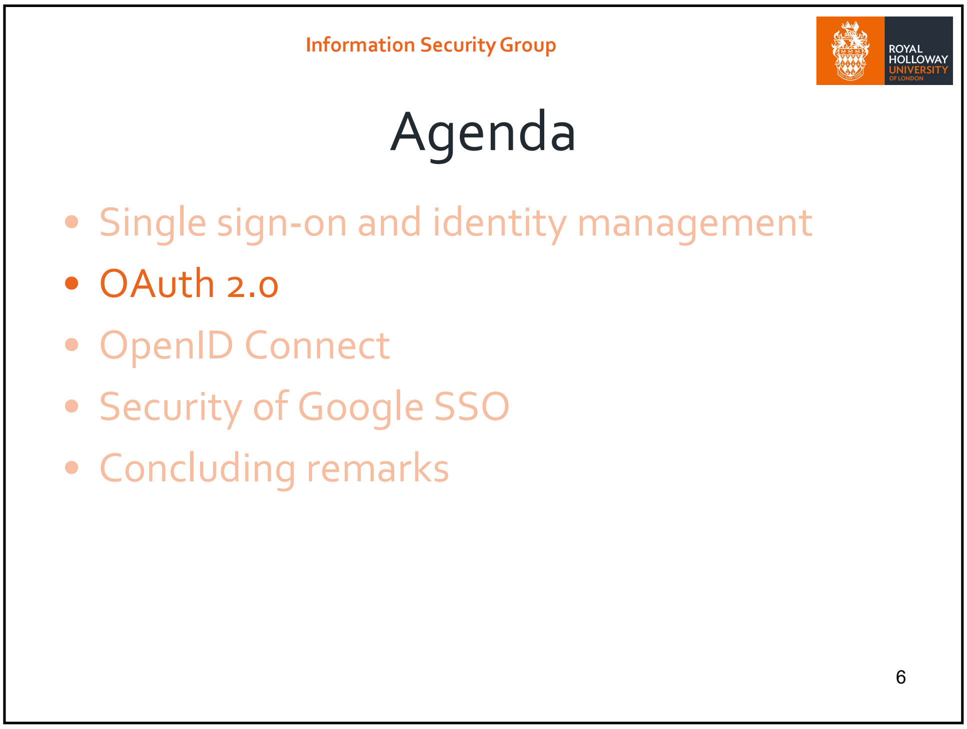
Identity management

- An SSO system is just a special case of an identity management system.
- In general, in an ID management system, one or more third parties manage aspects of a user’s identity on behalf of a user, e.g. they
  - store user attributes;
  - authenticate users on behalf of other parties.



Identity management terminology

- **Identity Provider (IdP)** authenticates user and vouches for **User** identity to …
- **Relying Parties (RPs)**, which rely on IdP and provide online services to …
- **Users**, who employ …
- **User Agents (UAs)** (typically web browsers), to interact with RPs.



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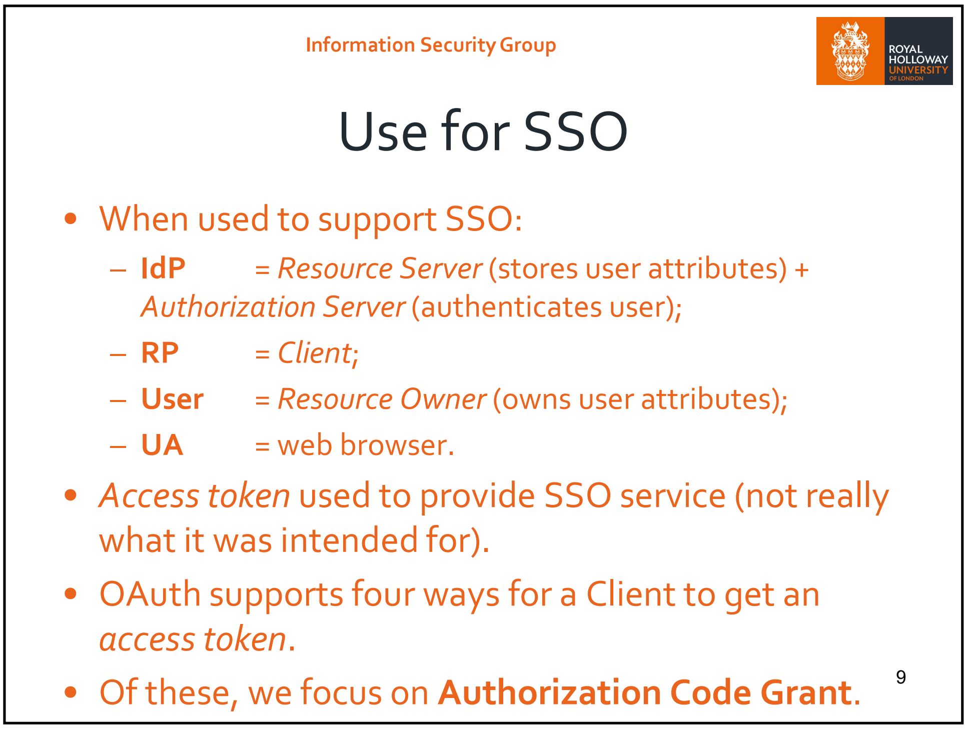
OAuth 2.0

- OAuth 2.0, published in 2012 (RFC 6819), is being widely used as the basis of SSO services, e.g. for *Facebook Connect*.
- It is also being very widely used for SSO by a range of popular IdPs in China.
- Serious practical issues with use of OAuth 2.0 by Facebook and others have been identified.

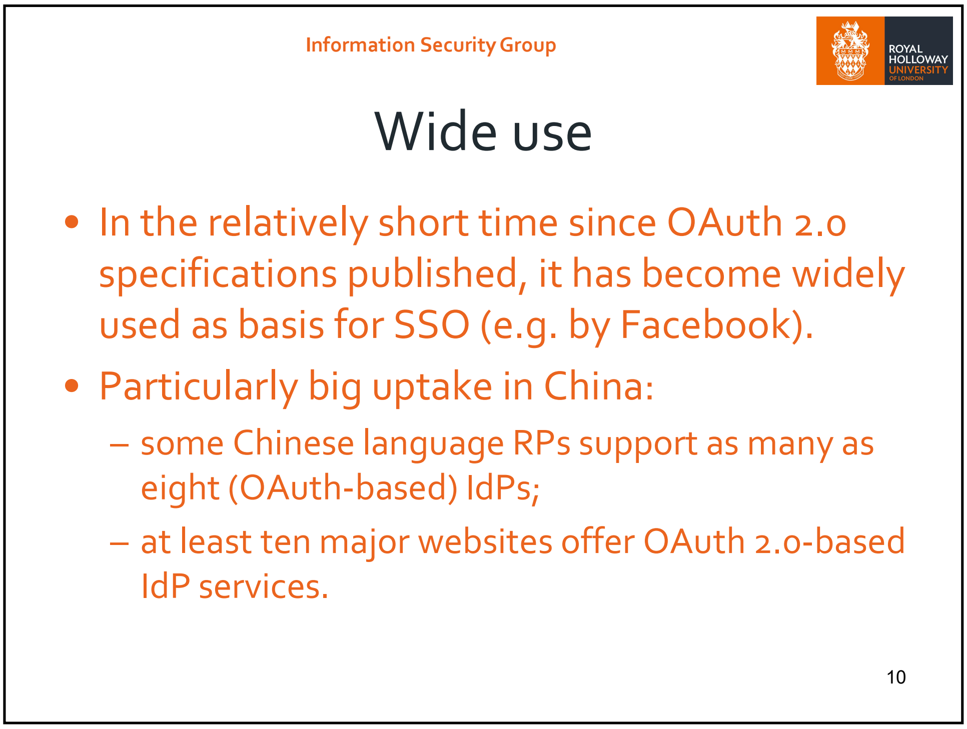
OAuth design goals

- Original goal of OAuth (1.0 & 2.0) not SSO.
- OAuth allows a *Client* application to access information (belonging to a *Resource Owner*) held by a *Resource Server*, without knowing the *Resource Owner*'s credentials.
- Also requires an *Authorization Server*, which, after authenticating the *Resource Owner*, issues an *access token* to the *Client*, which sends it to the *Resource Server* to get access.



Use for SSO

- When used to support SSO:
  - **IdP** = *Resource Server* (stores user attributes) + *Authorization Server* (authenticates user);
  - **RP** = *Client*;
  - **User** = *Resource Owner* (owns user attributes);
  - **UA** = web browser.
- *Access token* used to provide SSO service (not really what it was intended for).
- OAuth supports four ways for a Client to get an *access token*.
- Of these, we focus on **Authorization Code Grant**.



Wide use

- In the relatively short time since OAuth 2.0 specifications published, it has become widely used as basis for SSO (e.g. by Facebook).
- Particularly big uptake in China:
  - some Chinese language RPs support as many as eight (OAuth-based) IdPs;
  - at least ten major websites offer OAuth 2.0-based IdP services.

Known issues

- OAuth 2.0 has been critically examined by a number of authors.
  - Frostig & Slack (2011) found a Cross-Site Request Forgery (XSRF) attack in the *Implicit Grant* flow of OAuth 2.0.
  - Wang, Chen & Wang (2012) found a logic flaw in a range of SSO implementations.
  - Sun & Beznosov (2012) found flaws in OAuth 2.0 implementations.
  - Li & Mitchell (2014) found range of flaws in federation process for widely used Chinese language implementations.

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Building on OAuth 2.0

- OpenID Connect 1.0 is built as an *identity layer* on top of OAuth 2.0.
- Adds extra functionality aimed specifically at SSO, and hence should help to address OAuth probems.
- Adds a new type of token to OAuth 2.0, namely the *id token* [a JSON web token].
- The *id token* contains claims about authentication of end user – generated by entity known as *OpenID Provider (OP)* [=IdP].
- It is digitally signed by the OP.

Four ways to retrieve an *id token*

- OAuth (and hence OpenID Connect) supports four ways for a Client (the RP) to retrieve a token from the Authorization Server (IdP):
  - *hybrid flow* [token sent via the UA, using an RP-provided JavaScript client running on UA];
  - *client-side flow* [very similar to hybrid flow];
  - *authorization code flow* [token sent directly from authorization server (IdP) to client (RP)];
  - *pure server-side flow* [not supported by Google].

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A large study

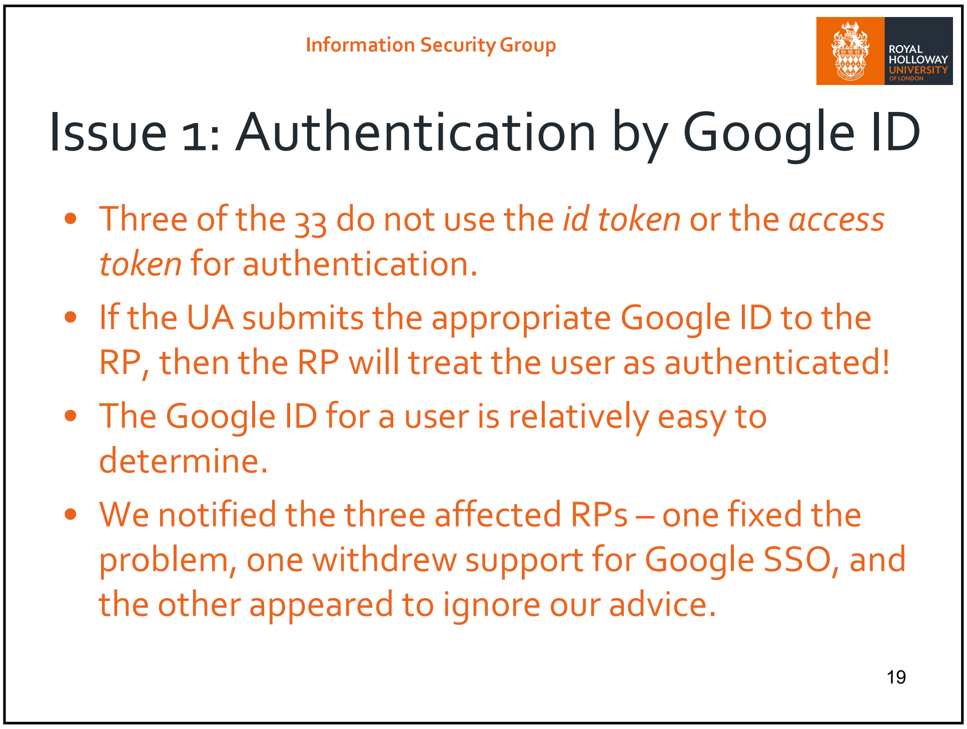
- We looked at the GTMetrix top 1000 websites providing an English language service.
- Of these, 103 support Google's SSO service based on OpenID Connect.
- We examined all 103 in detail.
- As in OAuth study, we use Fiddler to capture browser-relayed messages, and developed a Python program to analyse these messages.
- No third party accounts were hacked.

Retrieving the *id token*

- As mentioned, OpenID Connect supports four ways for a Client (the RP) to retrieve a token from the Authorization Server (IdP).
- Of the 103 websites we examined:
  - 69 use the authorization code flow;
  - 33 use the hybrid flow;
  - just one uses the client-side flow.
- Look further at the two main cases.

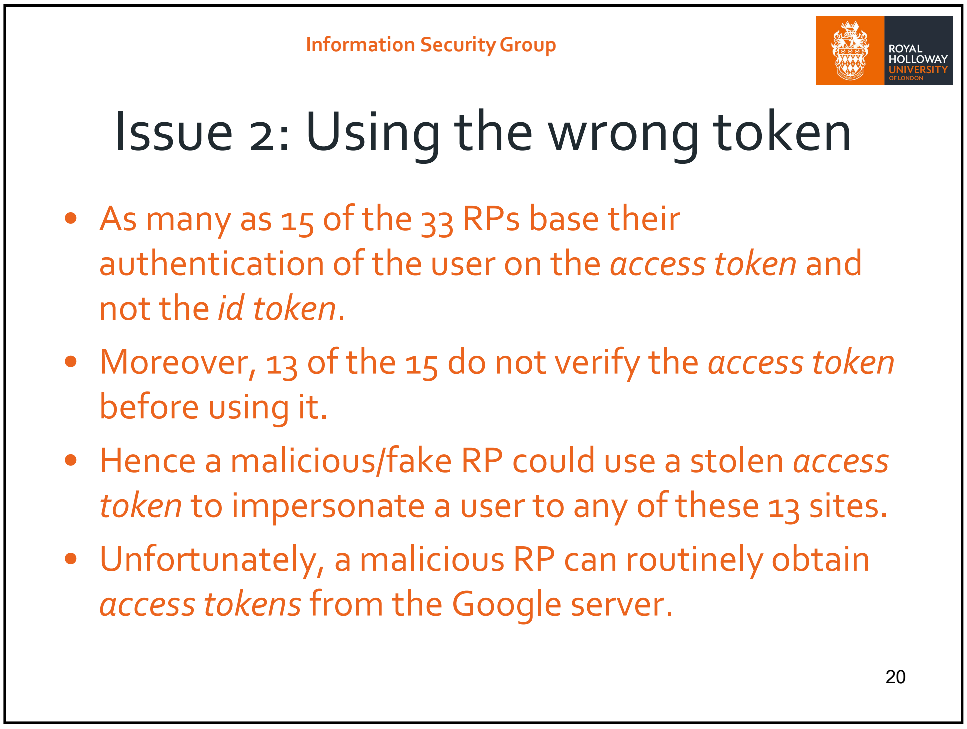
Hybrid server-side flow

- We identified a wide range of serious vulnerabilities in many of the 33 RP sites implementing this approach.
- We next summarise some of the main issues we have identified.



Issue 1: Authentication by Google ID

- Three of the 33 do not use the *id token* or the *access token* for authentication.
- If the UA submits the appropriate Google ID to the RP, then the RP will treat the user as authenticated!
- The Google ID for a user is relatively easy to determine.
- We notified the three affected RPs – one fixed the problem, one withdrew support for Google SSO, and the other appeared to ignore our advice.



Issue 2: Using the wrong token

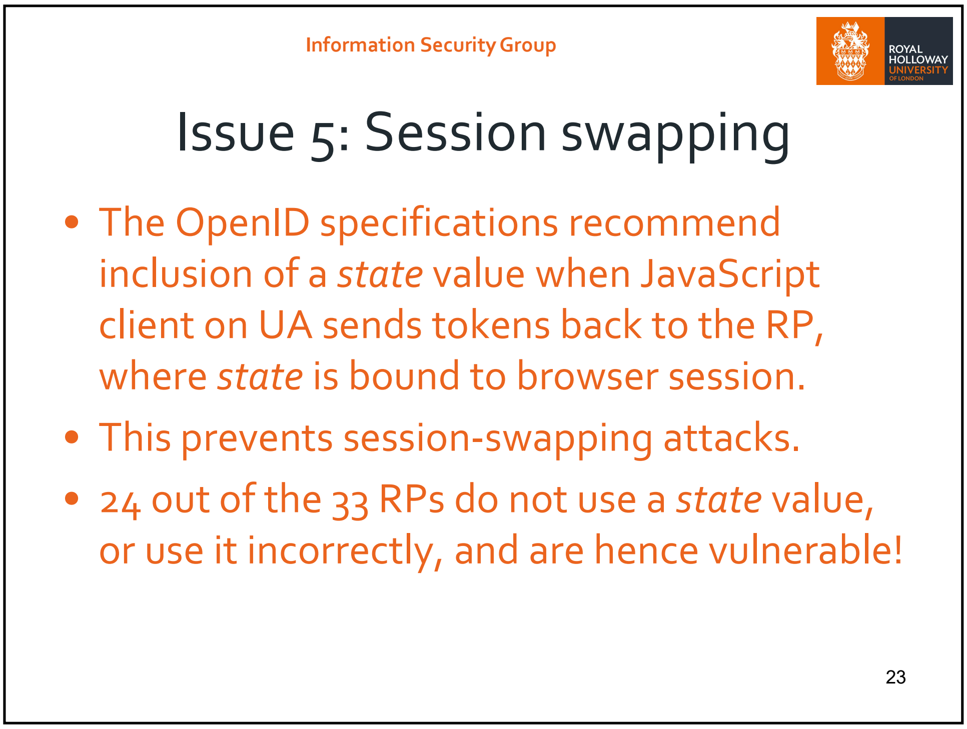
- As many as 15 of the 33 RPs base their authentication of the user on the *access token* and not the *id token*.
- Moreover, 13 of the 15 do not verify the *access token* before using it.
- Hence a malicious/fake RP could use a stolen *access token* to impersonate a user to any of these 13 sites.
- Unfortunately, a malicious RP can routinely obtain *access tokens* from the Google server.

Issue 3: Intercepting an *access token*

- Four of the 33 RPs arrange for an *access token* to be sent from the UA to the RP in cleartext.
- This contravenes the OAuth specifications.
- A passive interceptor, e.g. someone monitoring an unencrypted Wi-Fi network, could thus intercept the token.
- This has potentially serious consequences, given that some sites use the *access token* for authentication.

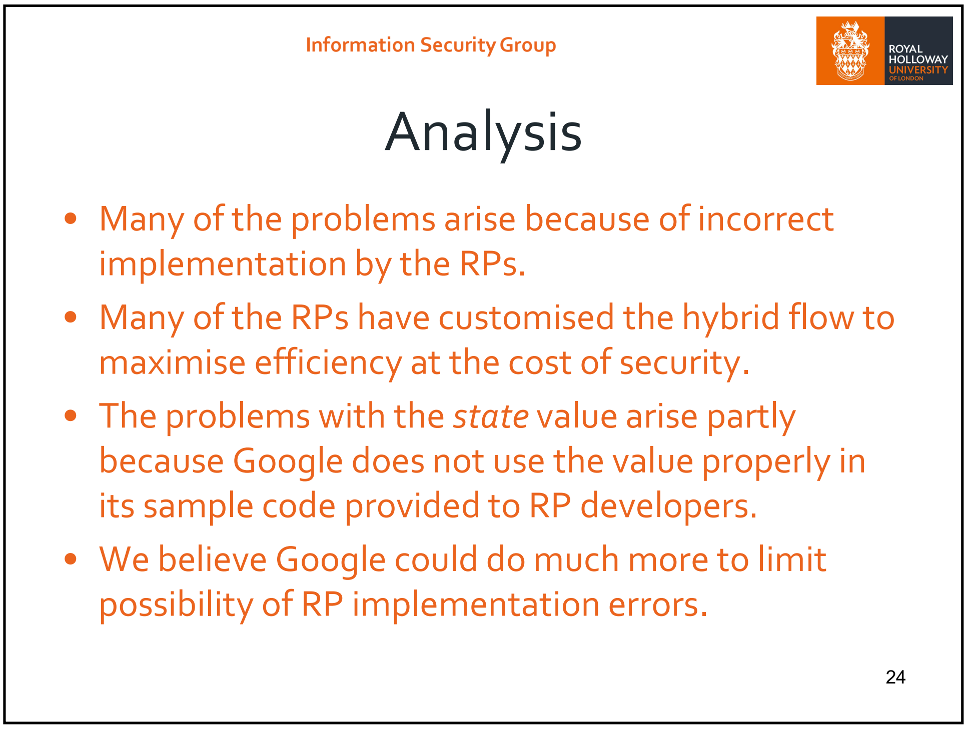
Issue 4: Privacy threats

- Intercepting an *access token* or an *id token* has potential privacy implications, since they both encode user attributes.
- As many as seven of the 33 RPs potentially leak a token (to a passive eavesdropper) through lack of SSL protection.



Issue 5: Session swapping

- The OpenID specifications recommend inclusion of a *state* value when JavaScript client on UA sends tokens back to the RP, where *state* is bound to browser session.
- This prevents session-swapping attacks.
- 24 out of the 33 RPs do not use a *state* value, or use it incorrectly, and are hence vulnerable!



Analysis

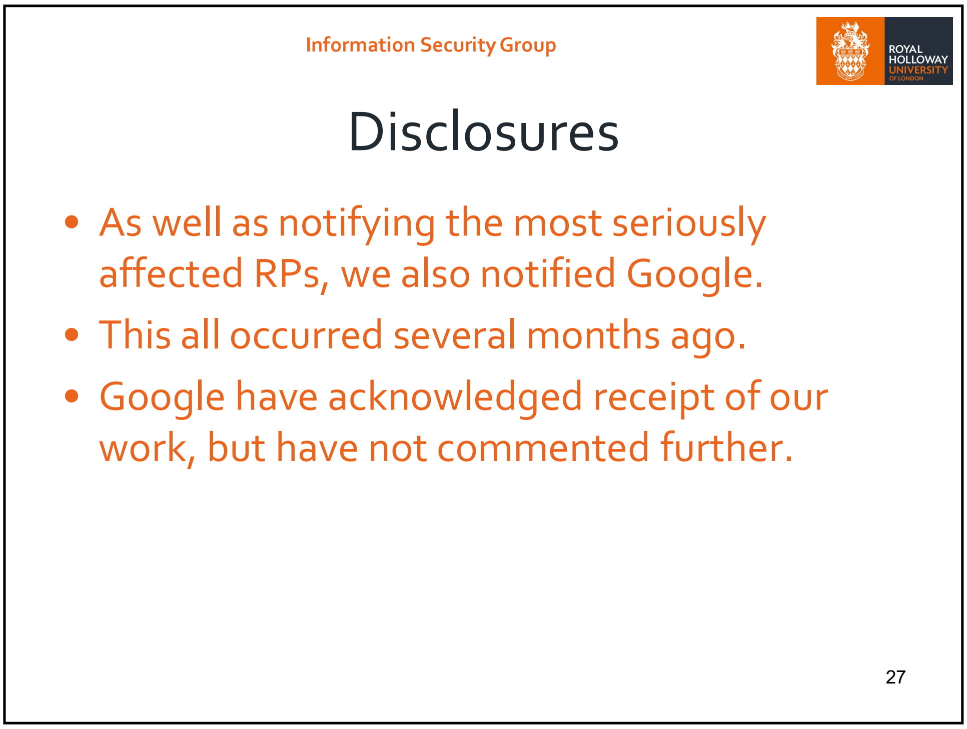
- Many of the problems arise because of incorrect implementation by the RPs.
- Many of the RPs have customised the hybrid flow to maximise efficiency at the cost of security.
- The problems with the *state* value arise partly because Google does not use the value properly in its sample code provided to RP developers.
- We believe Google could do much more to limit possibility of RP implementation errors.

Authorization Code flow

- The authorization code flow (used by 69 of 103 RPs) is inherently more secure than the hybrid flow.
- The tokens never pass through the UA, and hence are not at risk from malware running on the user machine.
- However, we still identified a range of security issues.

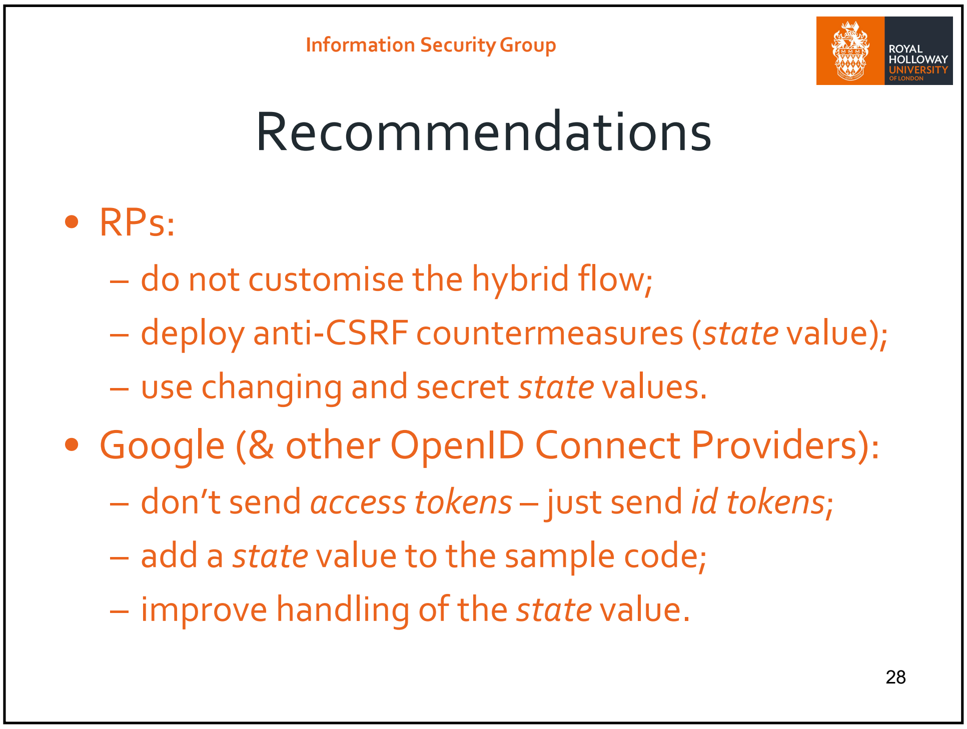
Authorization code flow issues

- Issues identified include:
  - sending an *access token* over an non-SSL protected link (4 out of 69);
  - stealing an *access token* using a common XSS vulnerability (possible for all 69);
  - sending user information unprotected across a link (11 out of 69);
  - session-swapping vulnerability (24 of 69);
  - CSRF-based forced login (24 of 69).



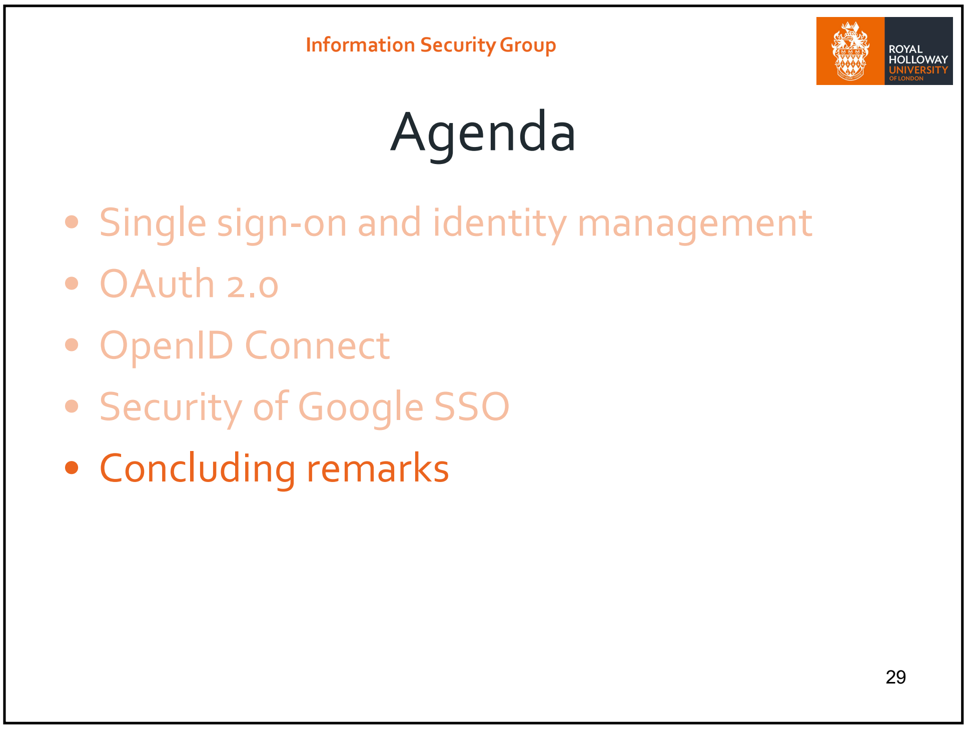
Disclosures

- As well as notifying the most seriously affected RPs, we also notified Google.
- This all occurred several months ago.
- Google have acknowledged receipt of our work, but have not commented further.



Recommendations

- RPs:
  - do not customise the hybrid flow;
  - deploy anti-CSRF countermeasures (*state* value);
  - use changing and secret *state* values.
- Google (& other OpenID Connect Providers):
  - don’t send *access tokens* – just send *id tokens*;
  - add a *state* value to the sample code;
  - improve handling of the *state* value.



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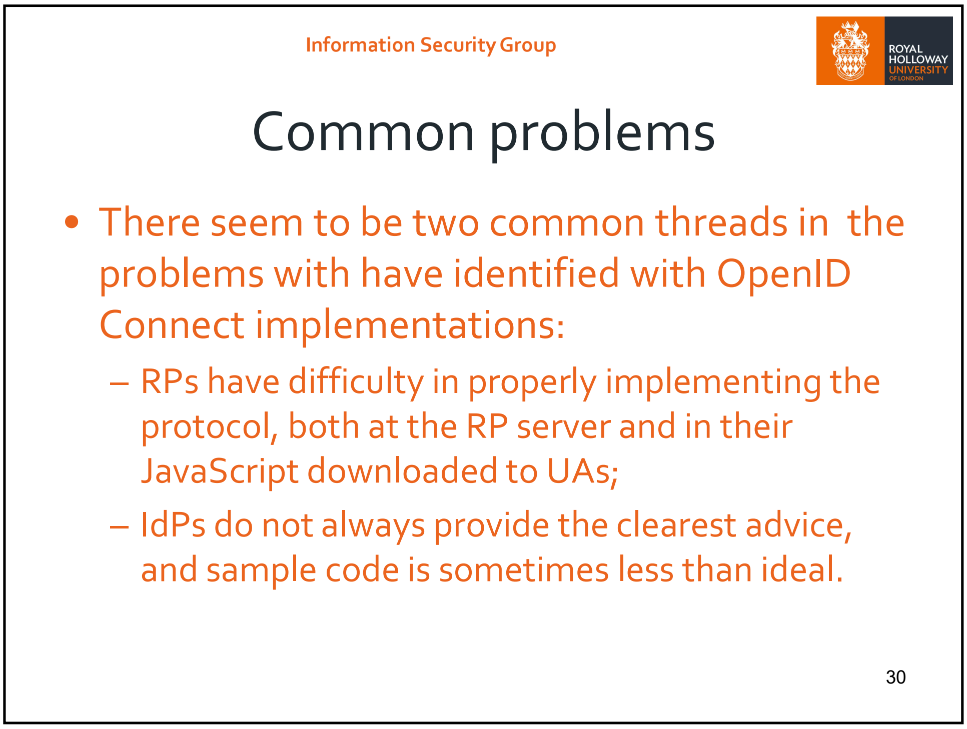
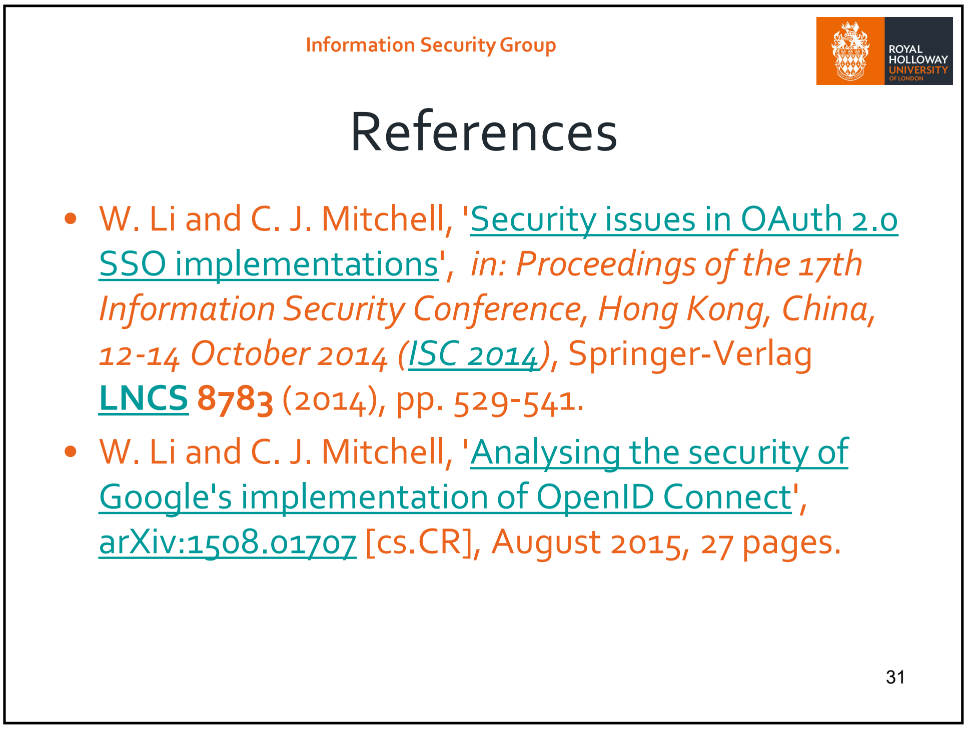


Common problems

- There seem to be two common threads in the problems with have identified with OpenID Connect implementations:
  - RPs have difficulty in properly implementing the protocol, both at the RP server and in their JavaScript downloaded to UAs;
  - IdPs do not always provide the clearest advice, and sample code is sometimes less than ideal.



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- W. Li and C. J. Mitchell, 'Analysing the security of Google's implementation of OpenID Connect', arXiv:1508.01707 [cs.CR], August 2015, 27 pages.