AuthScan: Automatic Extraction of Web Authentication Protocols from Implementations

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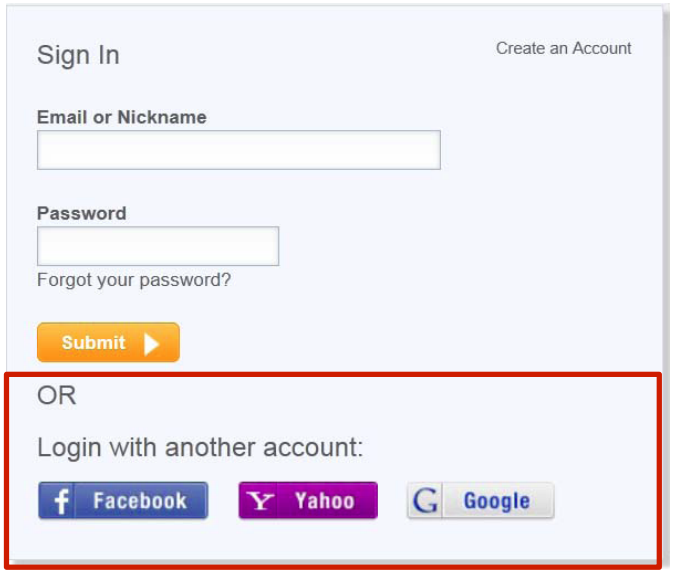
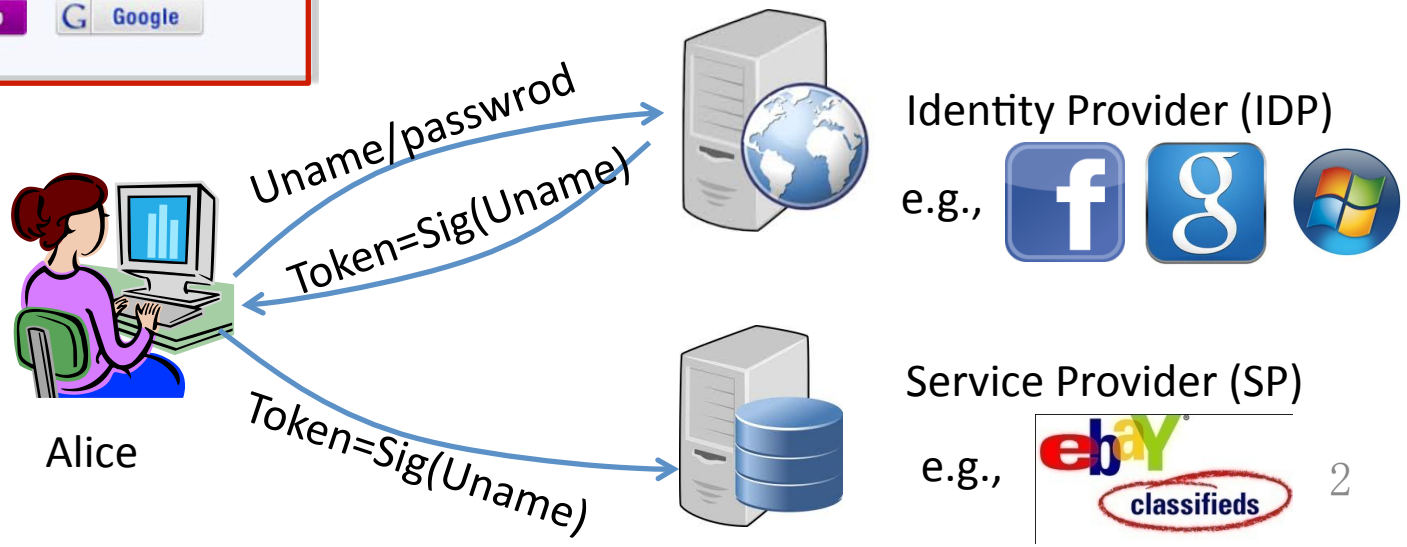
Web Authentication Schemes & Single Sign-On

- Web Authentication

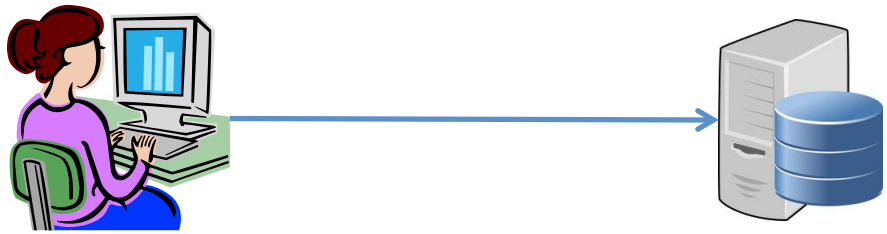


- Single Sign-On (SSO)
  - BrowserID (Mozilla)
  - Facebook Connect
    - 250+ Million users, 2,000,000 websites
  - OpenID
    - one billion users, 50,000 websites
  - …

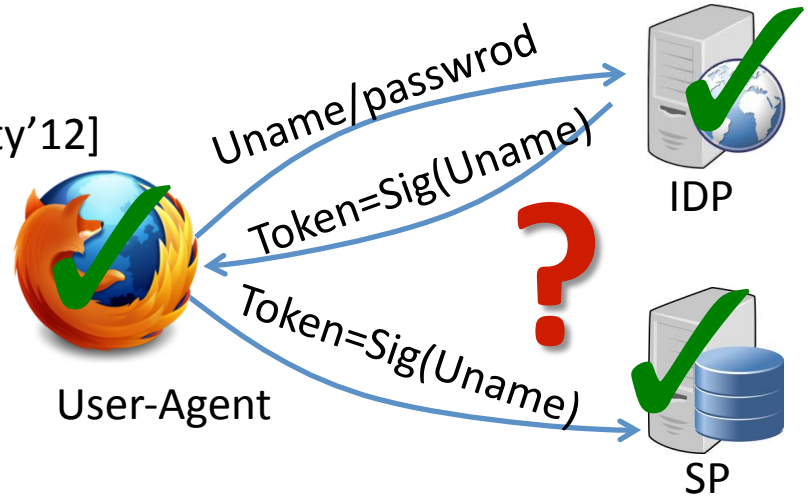


Implementations Can have Bugs!!

- Web Authentication
  - Password Guessing
  - Session/Cookie Stealing
  - …



- Harder in SSO implementations
  - Vulnerabilities [BlackHat'07, Oakland'12, CCS'12,USENIX Security'12]



Is Manual Analysis Possible?

- Manual analysis is impractical
  - Closed source
  - Numerous implementations
    - OAuth 1.0 & 2.0: **47** implementations

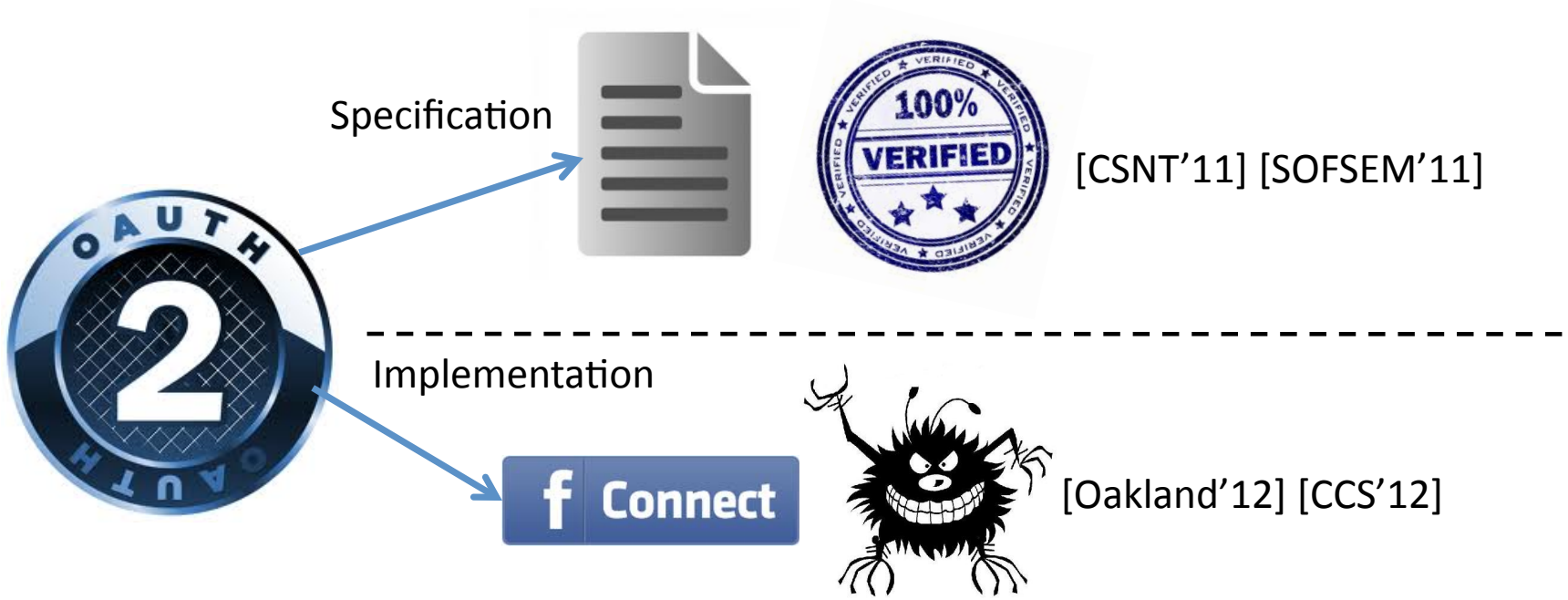
OAuth (RFC 5849 & RFC 6749)

Can't We Verify the Web Authentication?

- Previous protocol verification: **design-level** protocol **specifications**

  It is the **IMPLEMENTATION** that security relies on!!

Implementation == Specification?



Our Solution & Contributions

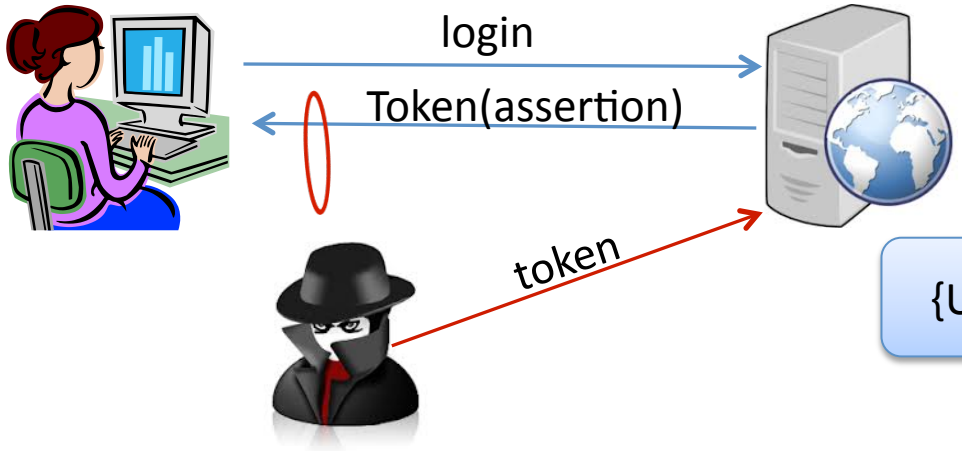
#1 **Automatically** extract protocols **from implementations**

#2 **Checking** extracted protocols **for vulnerabilities**

- **Automatic extraction techniques** to extract protocol specifications
- **AuthScan**: an end-to-end framework
- Find **7** security flaws in the **real-world** implementations

Examples #1: Freshness Problem in BrowserID Imp

- Missing Nonce
  - May lead to replay attacks



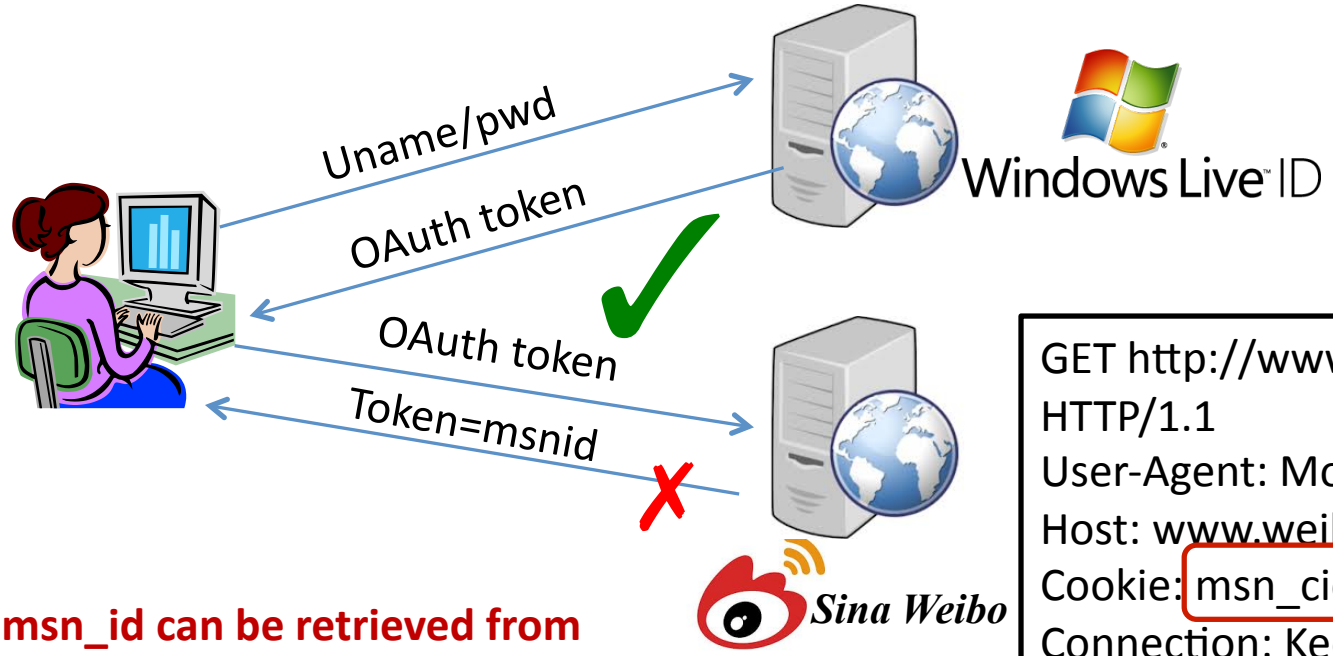
$\{USER, pubKey_{USER}, IDP\}_{prvK_{IDP}}, \{SP\}_{prvKey_{USER}}$

$\{USER, pubKey_{USER}, IDP, \mathbf{nonce}\}_{prvK_{IDP}}, \{SP\}\ prvKey_{USER}$

Example #2: Logic Flaw in Using Windows Live ID

- Using Publicly-Known Values as Tokens
  - Keep **constant** across multiple login sessions and the values are **publicly-known**
  - e.g., email, publicly-known id, hash(email), etc.

- Flaw found in credential cookies in Sina Weibo



msn_id can be retrieved from profile page on MSN space !!!

```
GET http://www.weibo.com/msn/bind.php
HTTP/1.1
User-Agent: Mozilla/5.0
Host: www.weibo.com
Cookie: msn_cid=412ee98792885346
Connection: Keep-Alive
```

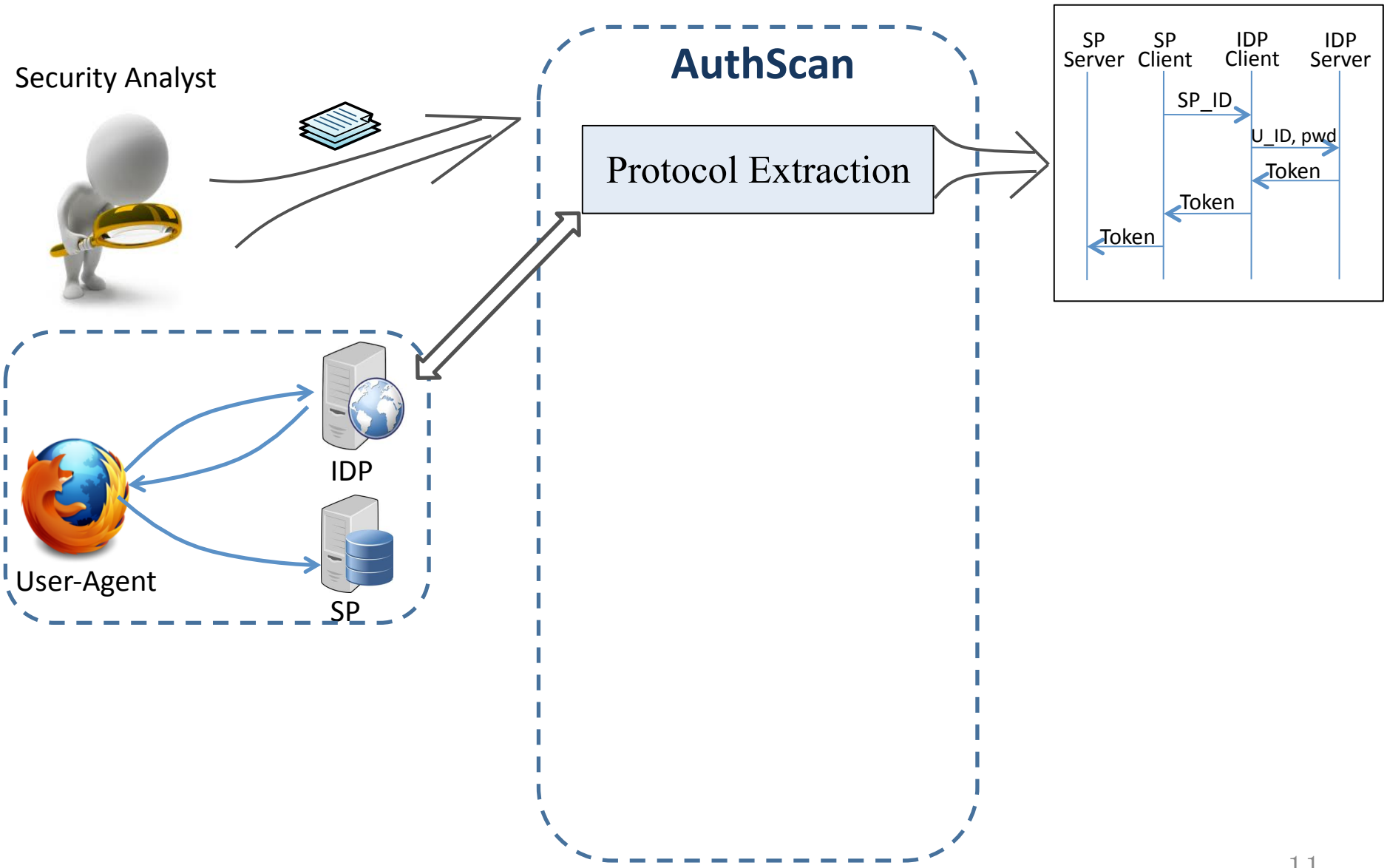
Many More Vulnerability Examples

- Guessable Token
- Unchecked Referrer
  - Leading to CSRF attack
- Secret Token Leakage
- Short-length Token

Is there a **generalized** method to detect all these vulnerabilities?

Our Approach

AuthScan: Overview

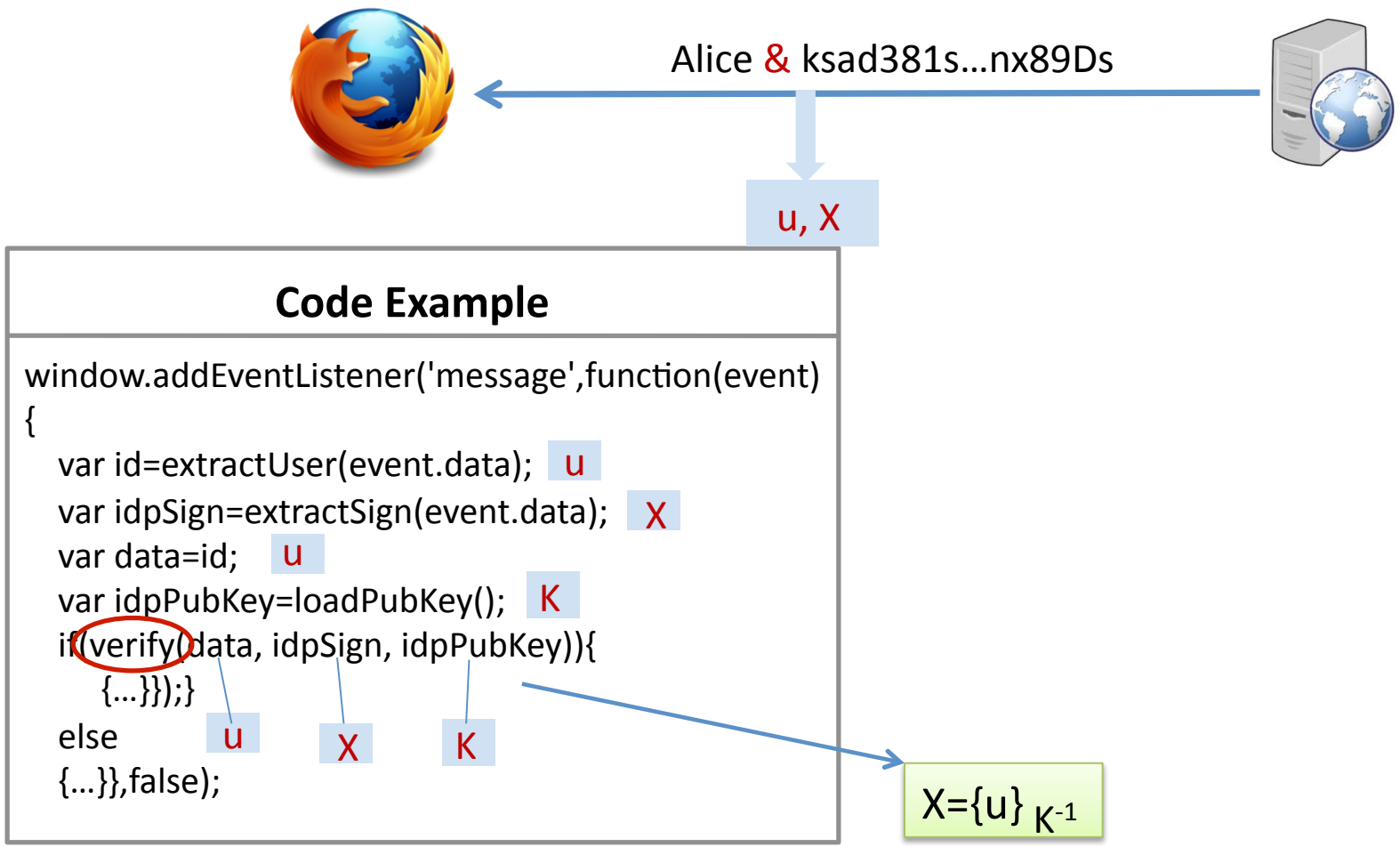


Protocol Extraction & Challenge

- Extraction: to infer protocol from these available code and messages exchanged
  - Protocol steps
  - Semantics of data element exchanged in each step
    - Signature, cipher text, nonce, etc.

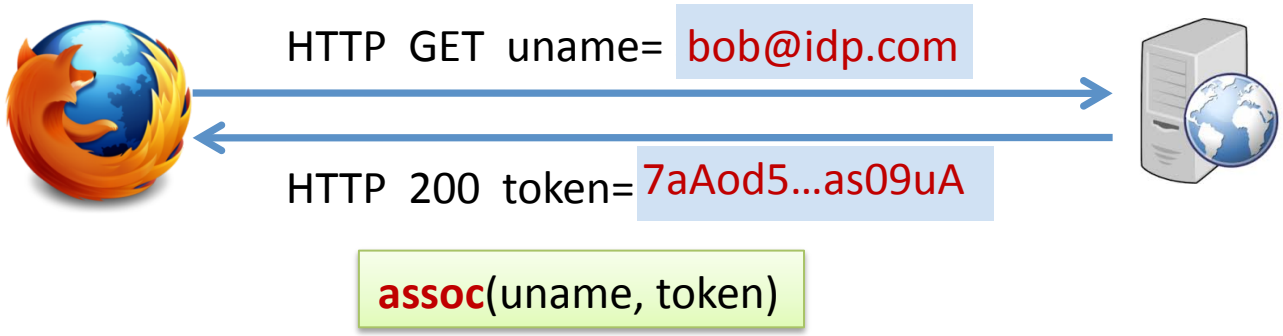
- Challenge: Partially available implementation
  - Partial code (client-side JavaScript code)
  - HTTP messages exchanged
- Insight: Hybrid Inference
  - Whitebox Program Analysis
  - Blackbox Differential Fuzzing

Whitebox Program Execution Analysis

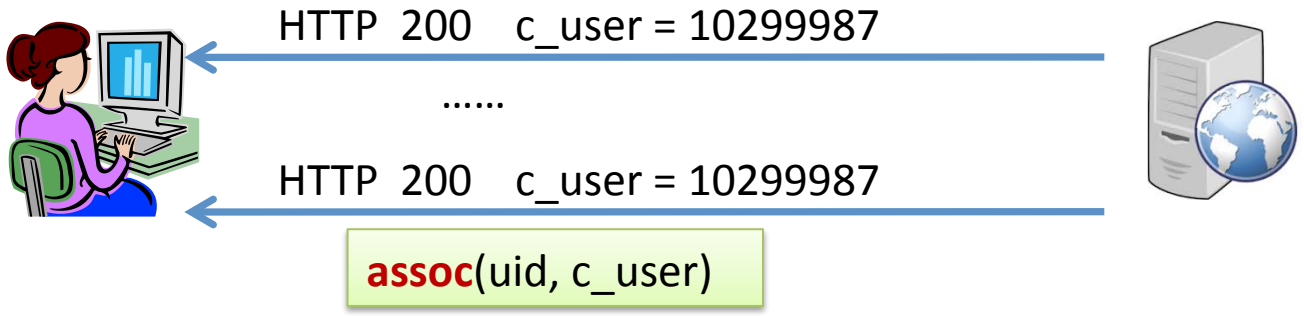


Blackbox Differential Fuzzing

- To identify the relations between HTTP data

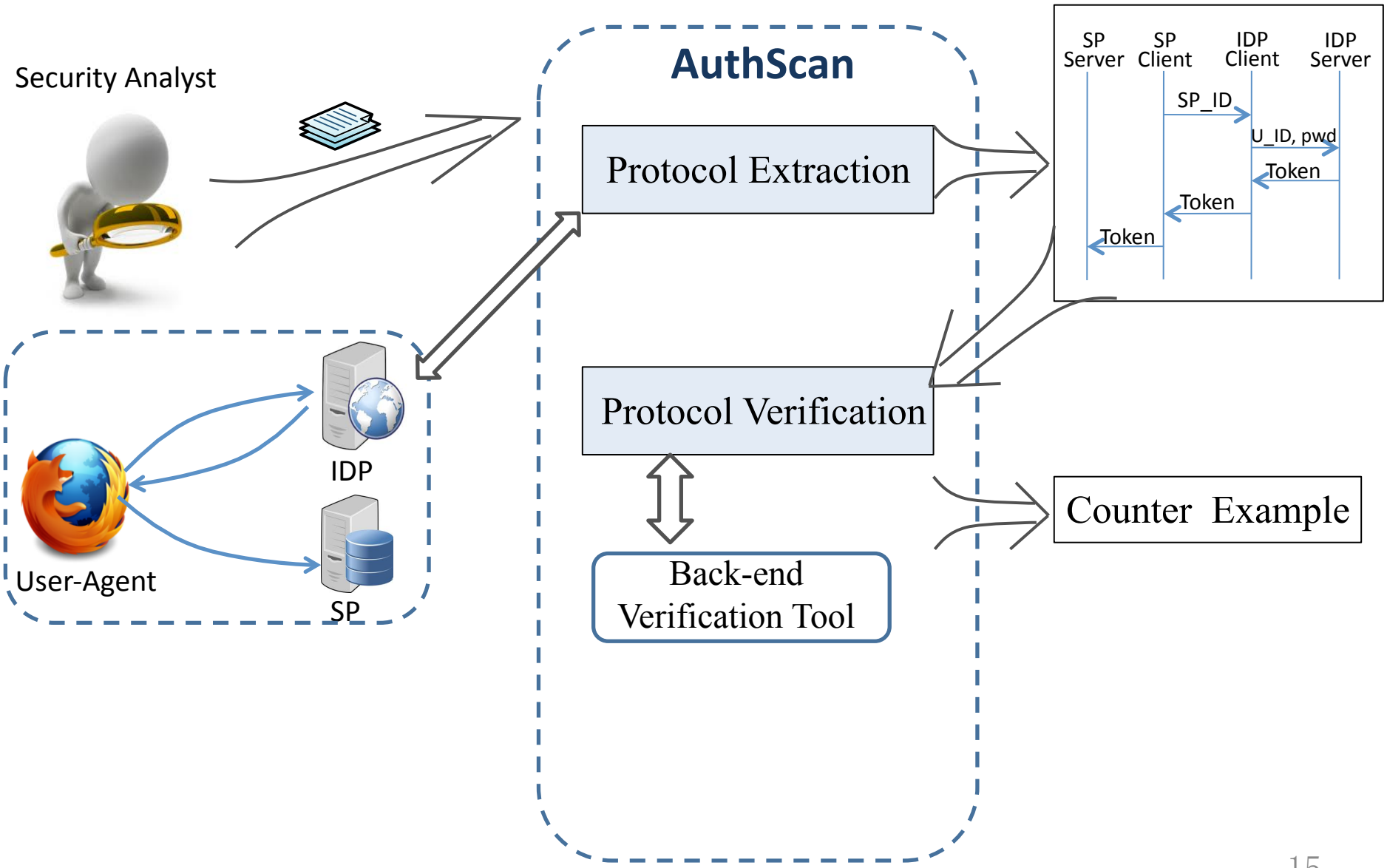


- To identify the relations between HTTP data and participants



- To eliminate the redundant messages and data
- To identity **long-lived** and **short-length** token

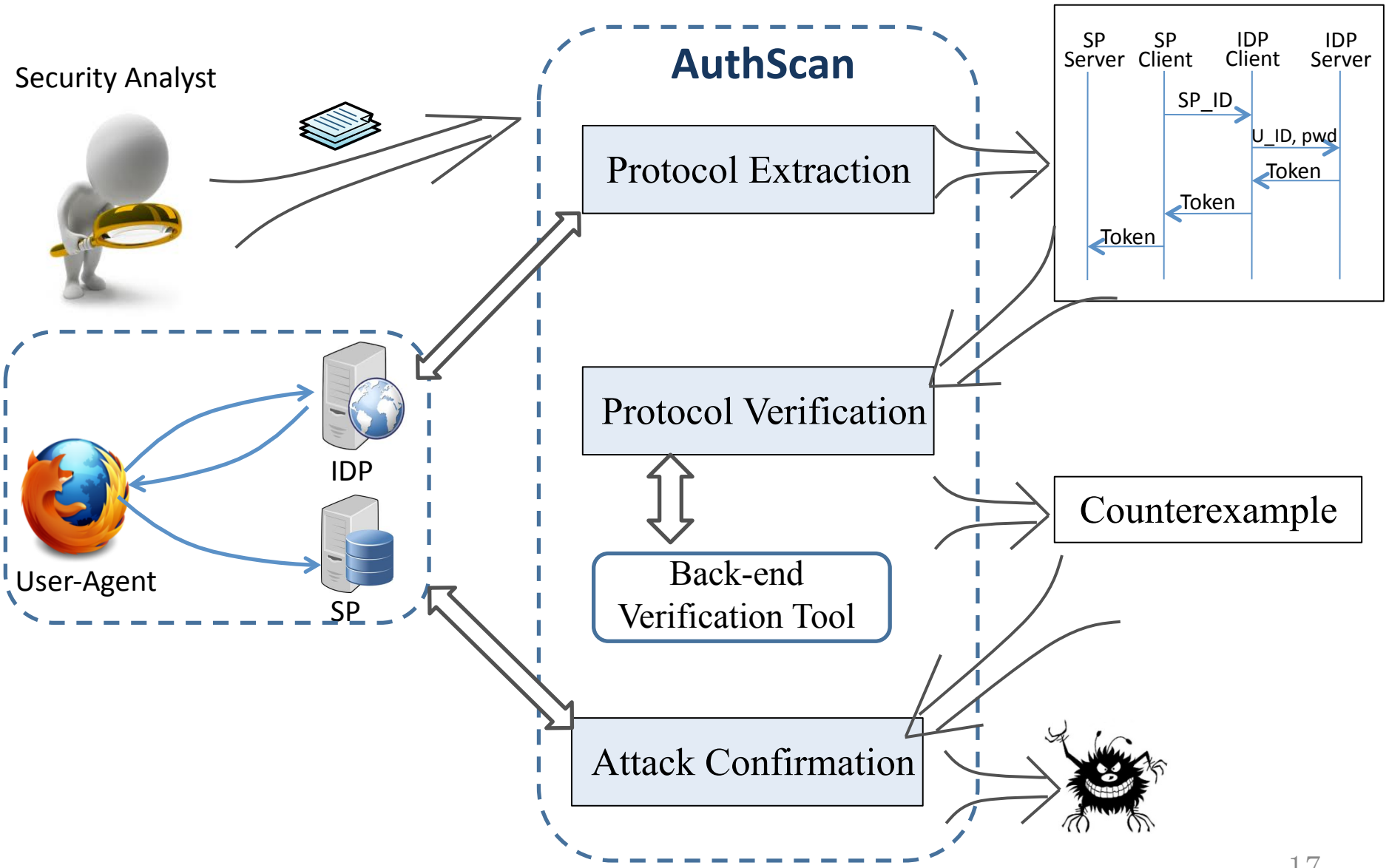
AuthScan: Overview



Attacker Models, Properties & Assumptions

- Attacker models considered in AuthScan
  - Network Attacker
  - Web Attacker
    - Same-origin policy, Referrer, postMessage
- Properties
  - Authentication
    - Correspondence [oakland' 93]
  - Secrecy
- Assumptions
  - Correct Cryptographic Algorithms
  - Knowledge of Participants
    - Each one knows the others' identifiers

AuthScan: Overview



Evaluation

AuthScan Evaluation

- Implementation
  - Implemented as a Firefox add-on
  - Uses ProVerif as the back-end
- Evaluation Subjects
  - BrowserID (three websites)
  - Facebook Connect (two websites)
  - Windows Live ID

Millions of Users are Impacted!

- Setup
  - Test harness
    - pre-registered user accounts
  - Protocol principals & public keys
  - Cryptographic functions
    - Mozilla jwcrypto used in BrowserID

Vulnerabilities Found

- 7 real-world vulnerabilities
  - 6 previously unknown

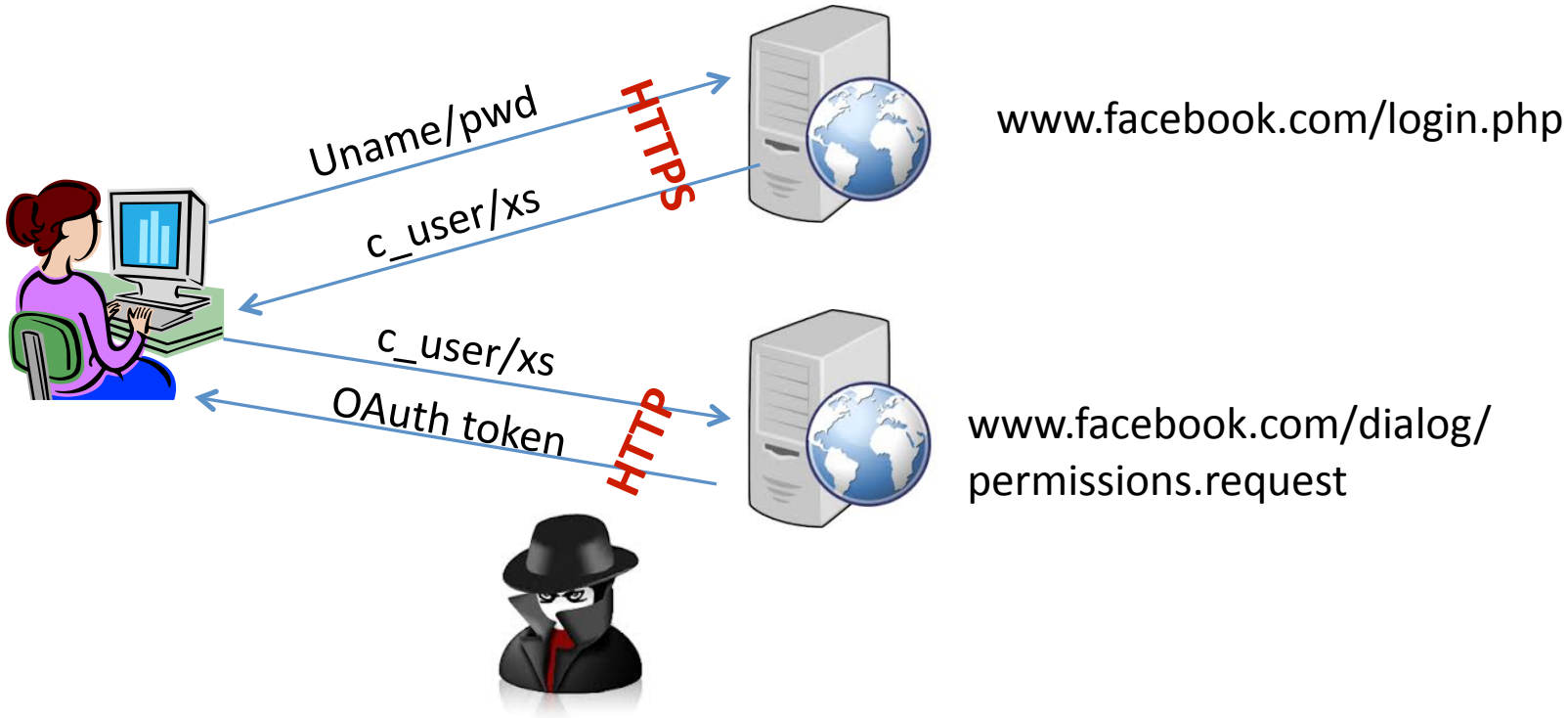
Web Sites	Deployed SSO	#Flaws*	Flaw Type
myfavoritebeer.com	BrowserID	2(T1, T2)	T1 Missing nonce in BrowserID
openphoto.me		2(T1, T2)	T2 Unchecked Referrer in SPs
developer.mozilla.org		0	(leading to CSRF attack)
ebayclassifieds.com	Facebook Connect	2(T3, T4)	T3 Secret token leak in FB connect
familybuilder.com		1(T3)	T4 Secret token leak in SP
Weibo.com	Windows Live ID	1(T5)	T5 Using Publicly-Known Values as Tokens
iyermatrimony.com	---	1(T6)	T6 Guessable Token
meetingmillionaires.com	---	1(T7)	T7 Short-Length Token

* With Overlapping

Example #3: Secret Token Leakage in FB Connect

- Secret Token Leakage
  - Secret tokens are transmitted through **unencrypted** channels

- Flaw found in secret cookie in Facebook Connect



Example #4: Guessable Token

- Guessable Token

http://www.iyermatrimony.com/login/intermediatelogin.php?
sds=QdR.j/ZJEX./A&
sdss=Tf/GpQpvtzuEs&
sde=U1ZsU01UZ3dOVE01

Keep constant

First 14 characters: keep constant

Incremented by one across accounts whose IDs are consecutive

Example #5: Short-Length Token

- Short-Length Token

http://app.icontact.com/icp/mmail-mprofile.pl?
r=36958596&l=2601&m=318326&c=752641&s=21DS

User ID

Constant among different users' sessions

Alpha-numeric string

$(10 + 26)^4$ Possible Values
Attacker: 500 "probes"/ min

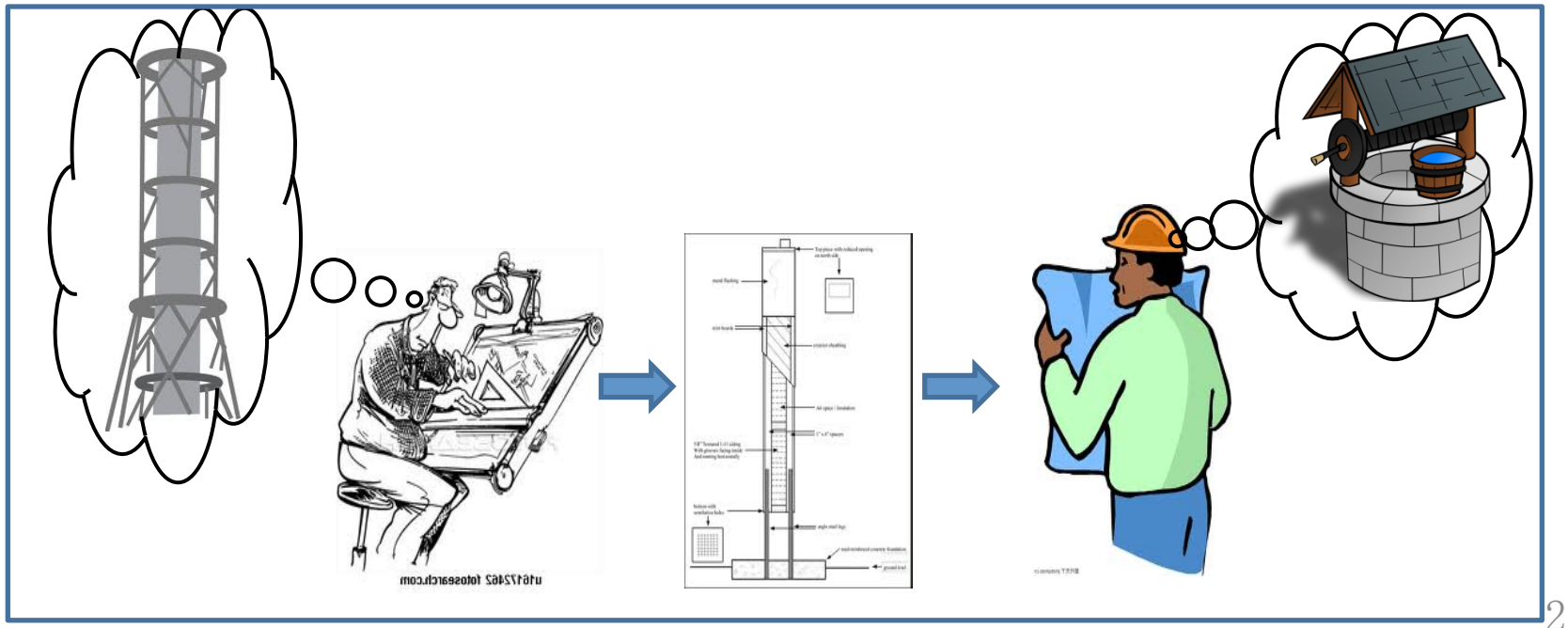
Scalability

Web Sites	Time(s) (Excluding Verification Time)	Verification Time	Fuzzing Round
myfavoritebeer.com	113	3.0	20
openphoto.me	72	3.0	22
developer.mozilla.org	96	3.0	28
ebayclassifieds.com	127	58.7	107
familybuilder.com	110	58.7	77
Weibo.com	30	0.03	78
iyermatrimony.com	5.33	0.04	51
meetingmillionaires.com	4.72	0.04	30

Conclusion & Take-away

- AuthScan: an end-to-end framework to extract web authentication protocols from their implementations
  - Hybrid inference techniques for protocol extraction
  - Found 7 vulnerabilities in real-world web-sites

- The devil is in the details!



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