Side Channel Vulnerabilities on the Web - Detection and Prevention

Sebastian Schinzel
Virtual Forge GmbH
University of Mannheim
sebastian.schinzel@virtualforge.de

OWASP
Education Project

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Agenda

- Background side channel vulnerabilities
- Side channel vulnerabilities on the Web
- Timing Side Channels
  - Detection
  - Attack
  - Prevention
- Storage Side Channels
  - Detection
  - Attack
  - Prevention
- Conclusion

Background side channel vulnerabilities

- Intrusive attacks against software systems well researched
- Vulnerabilities in real systems appear if developers don't apply countermeasures
- Besides: what can attackers still do..?
- Side channel vulnerabilities allow attackers to infer potentially sensitive information just by observing normal behavior of software system

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Side channel vulnerabilities on the Web

- Learn what a user types by observing
  - reflections of monitor picture [1]
  - inter-packet timing in encrypted SSH session [2]
- Learn about the action a user performs on a Web application by observing packet sizes in encrypted Web traffic [3]

Side channel vulnerabilities on the Web

- Learn existence of user name from
  - response time of Web application [4]
  - error messages in Web page
- Timing related
  - Learn private key of SSL server [5]
  - Learn amount of hidden images in Gallery [4]

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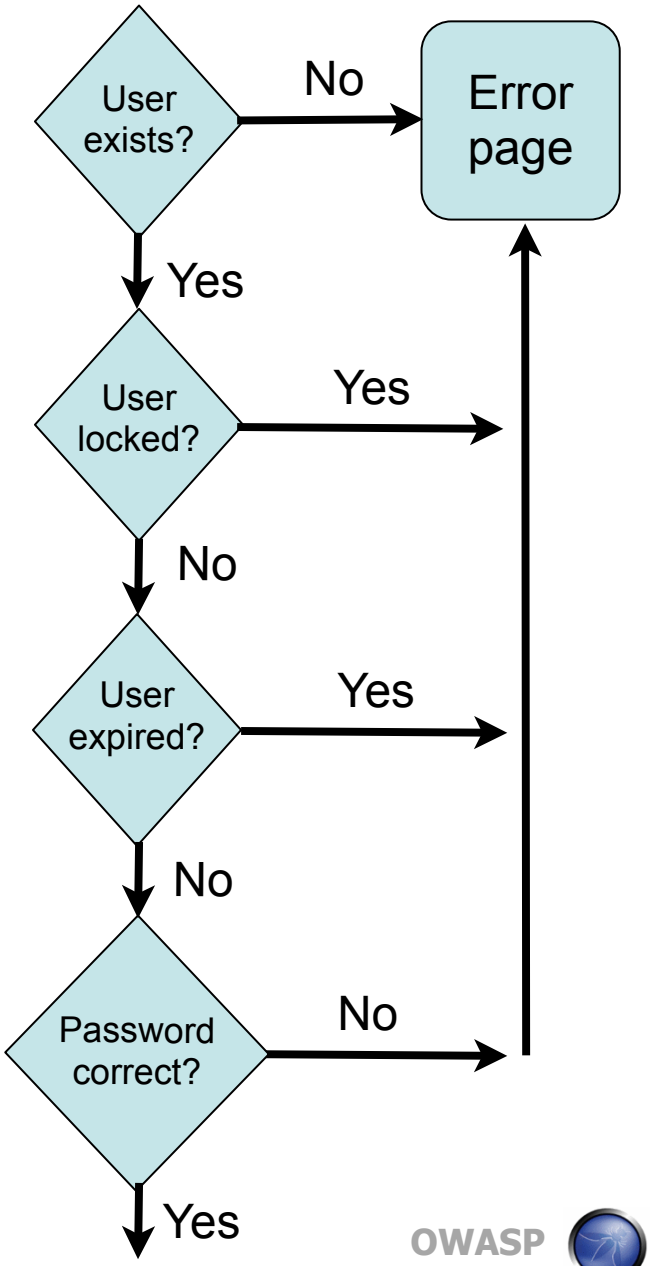
Timing Side Channels

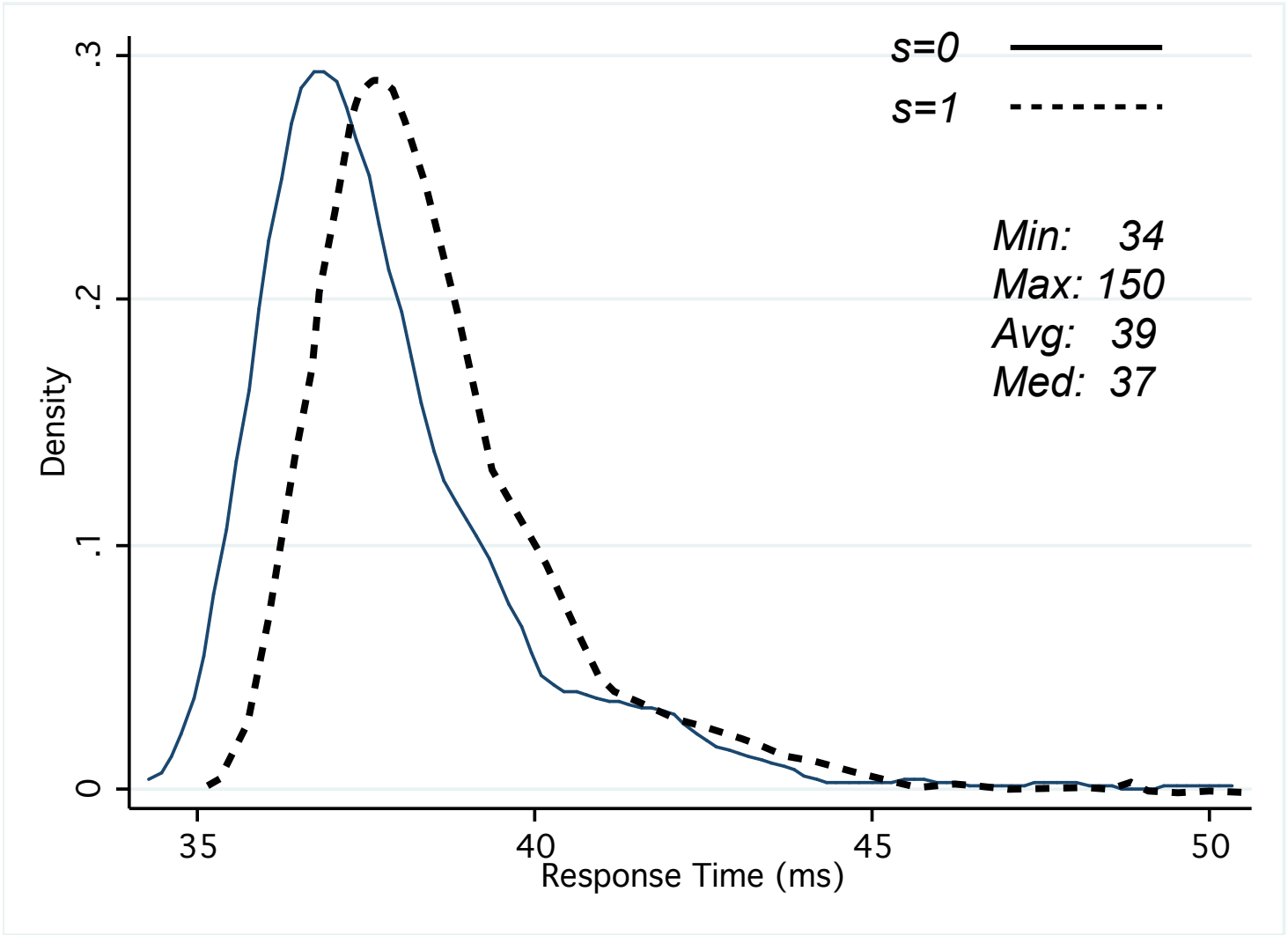
Example control flow of login form

- Different control flow depending on whether user name exists
- Control flow have different length and therefore different execution time
- Can we measure this time difference?



Timing Side Channels

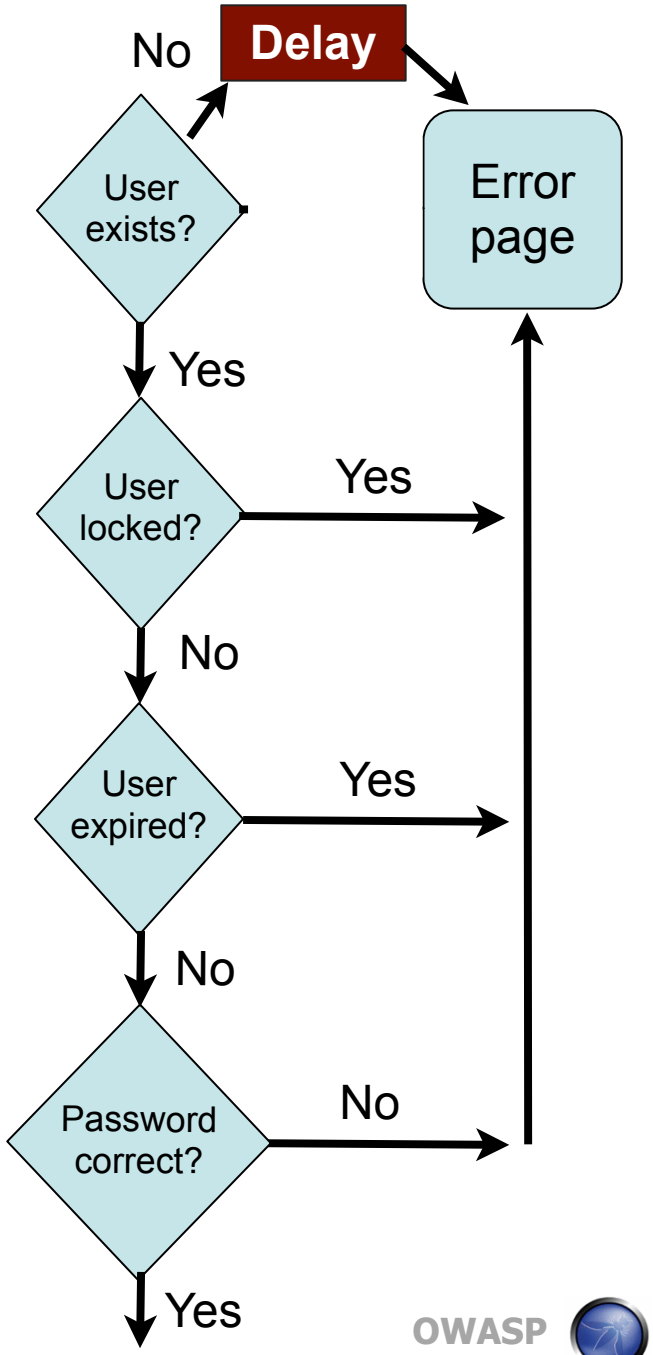
- Detection and Attack



Timing Side Channels

Preventing timing side channels (white box)

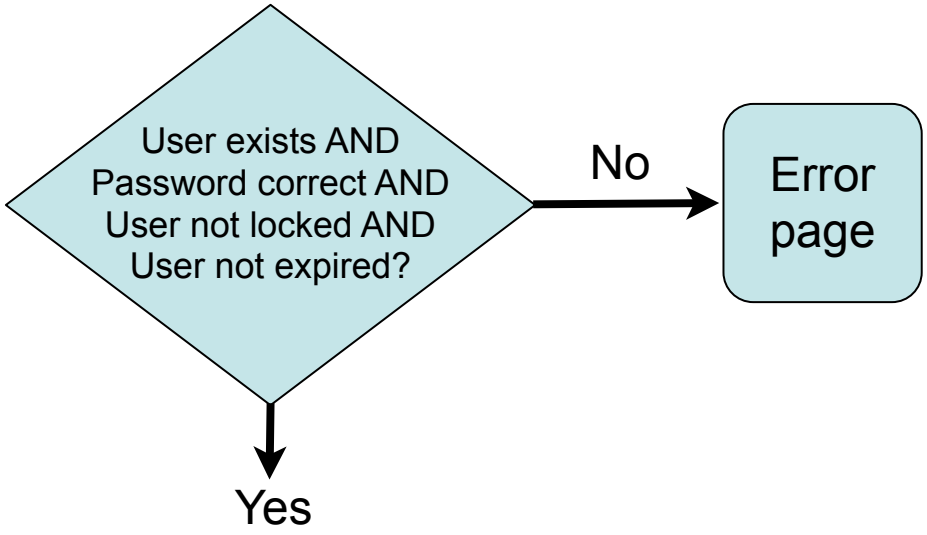
- Change control flow so that paths have same length, e.g.
  - Pad short control paths

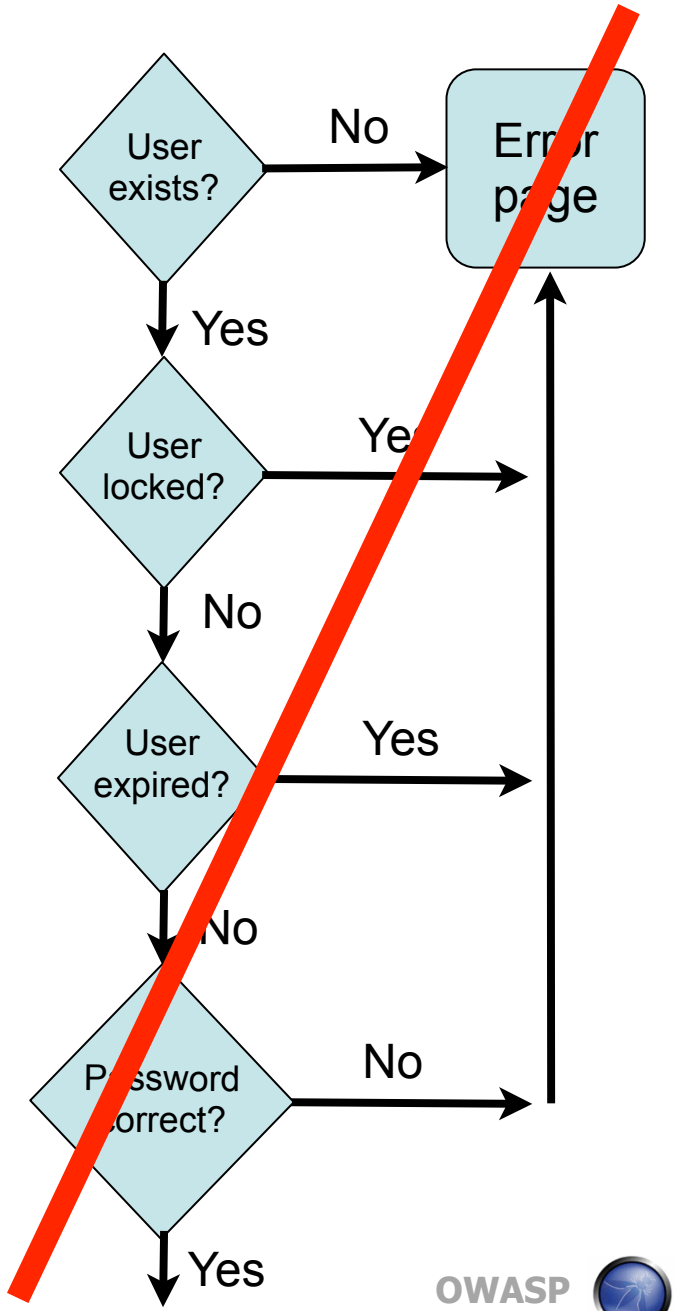


Timing Side Channels

Preventing timing side channels (white box)

- Join control paths, e.g.
  - Pack all db queries in one SQL statement





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Storage Side Channels

Example for obvious storage side channel: Error messages of login form

- "Invalid user name" → user name does not exist
- "Invalid password" → user name exists

Storage Side Channels

- **Hidden** storage side channel: Secret-dependent differences that are invisible to "normal user"
  - HTTP headers and values
  - HTML meta data
  - ...

Storage Side Channels

- Noise is a problem for measurements
  - lots of dynamic content in HTTP/HTML

```
$ diff responses/1.content responses/3.content
2c2
< Date: Tue, 22 Jun 2010 17:20:31 GMT
---
> Date: Tue, 22 Jun 2010 17:20:37 GMT
8c8
< Last-Modified: Tue, 22 Jun 2010 17:20:34 GMT
---
> Last-Modified: Tue, 22 Jun 2010 17:20:38 GMT
122c122
<          <input type="hidden" name="challenge"
value="35018d1af7184bad10944cb617677c99" />
---
>          <input type="hidden" name="challenge"
value="b50cbc351f525fcad0cb0fc97e080b29" />
```

Time dependent difference

Time dependent difference

Randomly generated difference

Storage Side Channels

- Widely used Content Management System leaks information by HTTP header ordering

Non-existent user name (s=0)	*Existing user name (s=1)*
HTTP/1.1 200 OK *Date: Mon, 25 Jan 2010 11:47:55 GMT* *Server: Apache/2.2.9 (Debian) PHP/5.2.6-1+lenny4 with Suhosin-Patch* *X-Powered-By: PHP/5.2.6-1+lenny4* *Expires:* ***Thu, 19 Nov 1981 08:52:00 GMT*** ***Last-Modified: Mon, 25 Jan 2010 11:47:55 GMT*** ***Cache-Control: no-store, no-cache, must-revalidate, post-check=0, pre-check=0*** ***Pragma: no-cache*** *Vary: Accept-Encoding* *Content-Type: text/html;charset=iso-8859-1* *Content-Length: 5472*	*HTTP/1.1 200 OK* *Date: Mon, 25 Jan 2010 11:47:45 GMT* *Server: Apache/2.2.9 (Debian) PHP/5.2.6-1+lenny4 with Suhosin-Patch* *X-Powered-By: PHP/5.2.6-1+lenny4* *Expires:* ***0*** ***Cache-Control: no-cache, must-revalidate*** ***Pragma: no-cache*** ***Last-Modified: Mon, 25 Jan 2010 11:47:45 GMT*** *Vary: Accept-Encoding* *Content-Type: text/html;charset=iso-8859-1* *Content-Length: 5472*

Storage Side Channels

- Online gallery leaks the amount of private pictures:

7 public images, 0 private image (s=0)

```
<div style='float:left'>Pictures -
 <a href='display.php?t=bycat&amp;q=4&amp;nr=7&amp;st=0&amp;upto=12&amp;p=1'>
  <span style='color:#fff'>Other</span>
 </a>
</div>
```

7 public images, 1 private image (s=1)

```
<div style='float:left'>Pictures -
 <a href='display.php?t=bycat&amp;q=4&amp;nr=8&amp;st=0&amp;upto=12&amp;p=1'>
  <span style='color:#fff'>Other</span>
 </a>
</div>
```

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Bibliography

[1]: Michael Backes and Markus Dürmuth and Dominique Unruh, Compromising Reflections-or-How to Read LCD Monitors around the Corner, IEEE Symposium on Security and Privacy, pp. 158-169, IEEE Computer Society, 2008.

[2]: D. X. Song, D. Wagner, and X. Tian, "Timing analysis of keystrokes and SSH timing attacks," in USENIX Security Symposium, 2001.

[3]: Shuo Chen and Rui Wang 0010 and XiaoFeng Wang and Kehuan Zhang, Side-Channel Leaks in Web Applications: A Reality Today, a Challenge Tomorrow, IEEE Symposium on Security and Privacy, pp. 191-206, IEEE Computer Society, 2010.

[4]: Andrew Bortz and Dan Boneh, Exposing private information by timing web applications, WWW, pp. 621-628, ACM, 2007

[5]: Felten and Schneider, Timing Attacks on Web Privacy, SIGSAC: 7th ACM Conference on Computer and Communications Security, ACM SIGSAC, 2000.

Conclusion

- Side channel vulnerabilities pose a serious threat for Web applications with high security requirements
- Side channels can appear in various ways
  - Detection is difficult
- Side channel attacks are passive
  - Attacks are feasible for a skilled attacker
- Prevention strategies may have a negative impact on system performance
  - Prevention is difficult

Thank you for your attention!

Critique, feedback, discussion?

Contact:

Sebastian Schinzel

ssc@seecurity.org