

Storing Cryptographic Keys in Persistent Browser Storage

Revised after Presentation at ICMC 2017

Please see the companion blog post at
<https://pomcor.com/blog/keys-in-browser/>

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Key storage in web clients

- Use of cryptography in web apps has been hindered by the problem of **where to store cryptographic keys** on the client side
 - Cryptographic keys can be stored today in smart cards and TPMs, and have been stored in the past in Infocards and files accessed by Java applets
 - TLS client certificates can be imported into web browsers
 - But these solutions are **not generally available today to all users of web apps**
- New web technologies may enable generally available key storage solutions
- In this talk we focus as an example on **keys in cryptographic credentials** used for authentication or identification

New web technologies

- These new web technologies are available to JavaScript (JS) code embedded in web pages through APIs:
 - Web Storage API
 - Provides “HTML5 *localStorage*”
 - IndexedDB API
 - Web Cryptography API
 - Service Worker API
 - Web Authentication API

Web Authentication API

- Based on FIDO U2F specification, taken over by the W3C
 - Will be available later this year in Chrome, Firefox, Edge
- Allows JS code to store a cryptographic credential in an “authenticator”
 - Cryptographic module in secure storage (e.g. USB dongle, TPM, Secure Element or TEE)
 - Provides a signed attestation of security
- But the cryptographic credential is an uncertified key pair
 - Only usable for two-party authentication
 - No support for credentials issued by a third party
- Very complex

Web Storage API

- Available in all browsers
- Provides persistent storage for **JS strings** as properties of the *localStorage* object
- **Data protected by the same origin policy of the browser**
- Very simple

IndexedDB API

- Available in all browsers
- Provides persistent storage of **JS objects** indexed by keys in databases managed by the *indexedDB* object
- **Data protected by the same origin policy of the browser**
- Complex asynchronous interface
 - “IndexedDB API is powerful, but may seem too complicated for simple cases” – MDN

Web cryptography API

- Available in most browsers
- Provides **RSA and ECDSA** (with NIST curves P-256, P-384 and P-512)
 - Plus ECDH, AES (including AES-GCM), HMAC, SHA (SHA-1, SHA-256, SHA-384 and SHA-512), HKDF, PBKDF2
 - Does not provide DSA
- Key pair generation produces two **CryptoKey objects** and private key can be made **non-extractable** from its CryptoKey object
 - CryptoKey object is not persistent by itself
 - It **cannot** be encoded as a string for storage in **localStorage**
 - But it **can** be stored in **indexedDB**

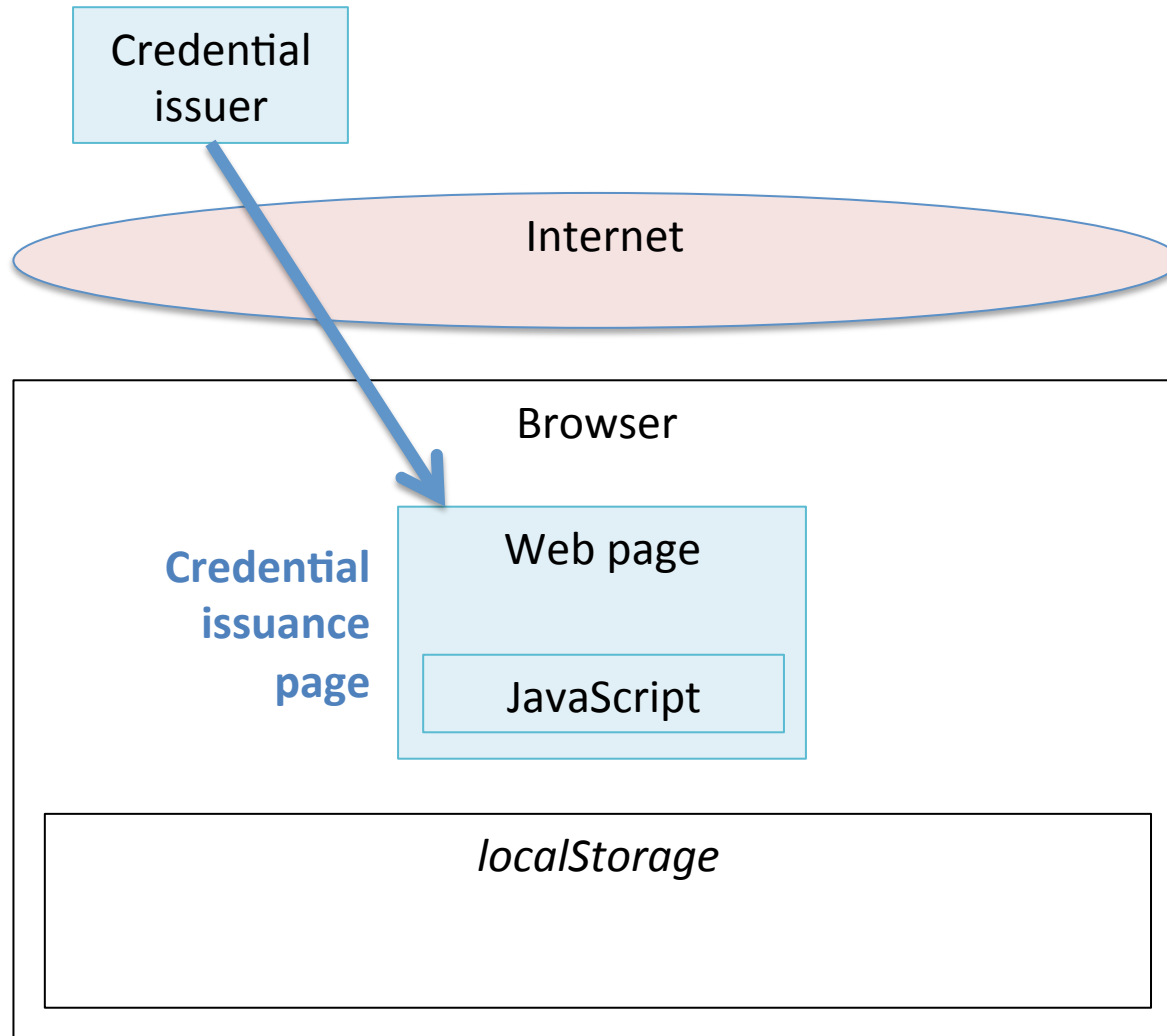
Service Worker API

- Allows the front-end of a web app to work “offline” like a native app, without accessing the back-end
- Available in Chrome, Firefox and Opera, under development in Edge, under consideration for Safari
- JS front-end registers a service worker with the browser and configures it to **intercept** certain requests to the backend and respond to them by **generating a web page** that is rendered by the browser
- The generated web page may include **JS code**, which can be used to **present a cryptographic credential**

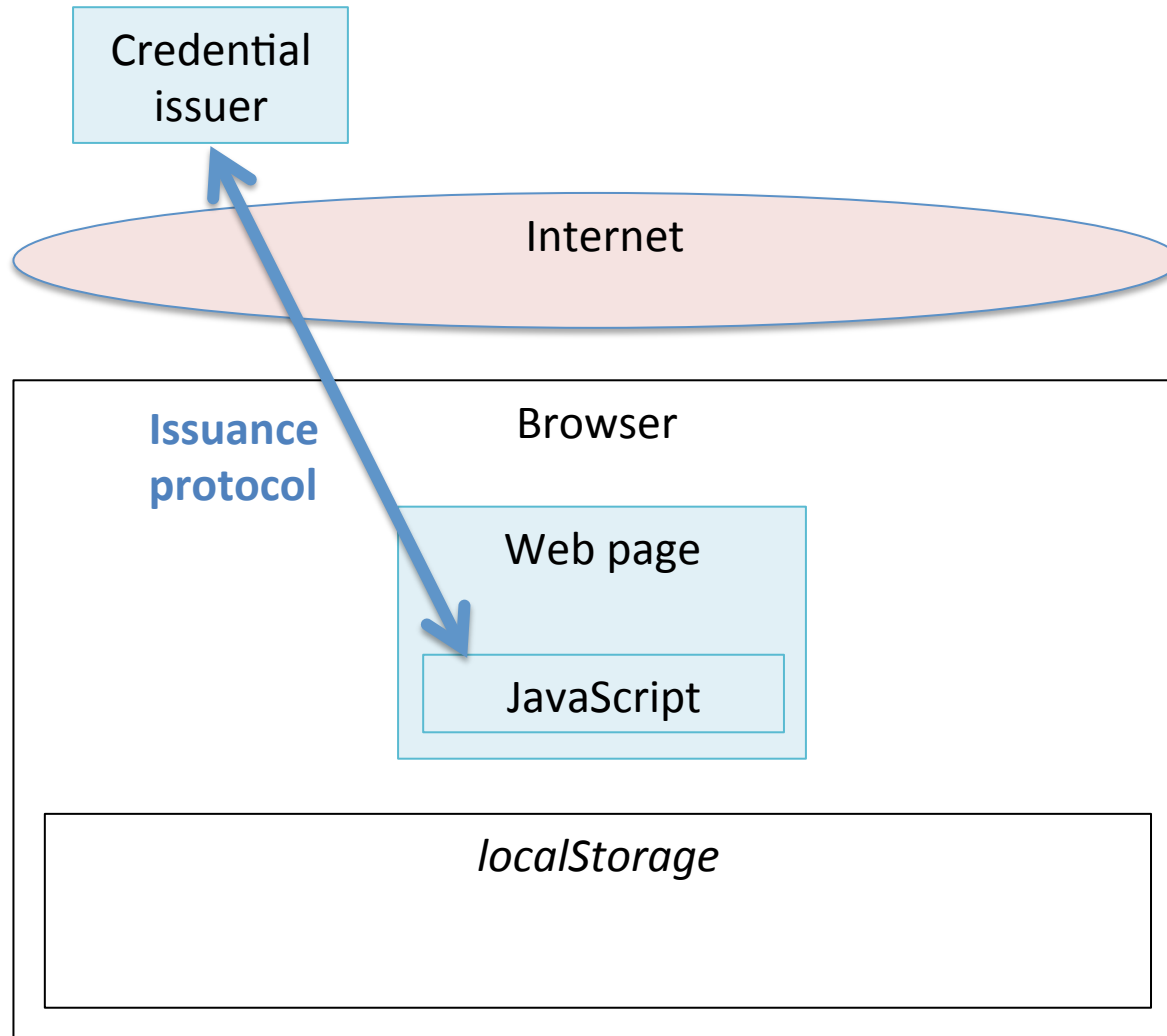
<p>Four solutions for storing cryptographic credentials in the browser</p>	<p>Using localStorage</p> <p>Any cryptographic credential (any certified key pair, anonymous credentials, rich credentials, etc.)</p>	<p>Using the IndexedDB and Web Cryptography APIs</p> <p>Credential must be RSA or ECDSA certified key pair; private key not extractable from CryptoKey object</p>
<p>No Trusted Consent Manager</p>	<p>Solution 1</p>	<p>Solution 2</p>
<p>With Trusted Consent Manager</p>	<p>Solution 3</p>	<p>Solution 4</p>

Details in slide 19

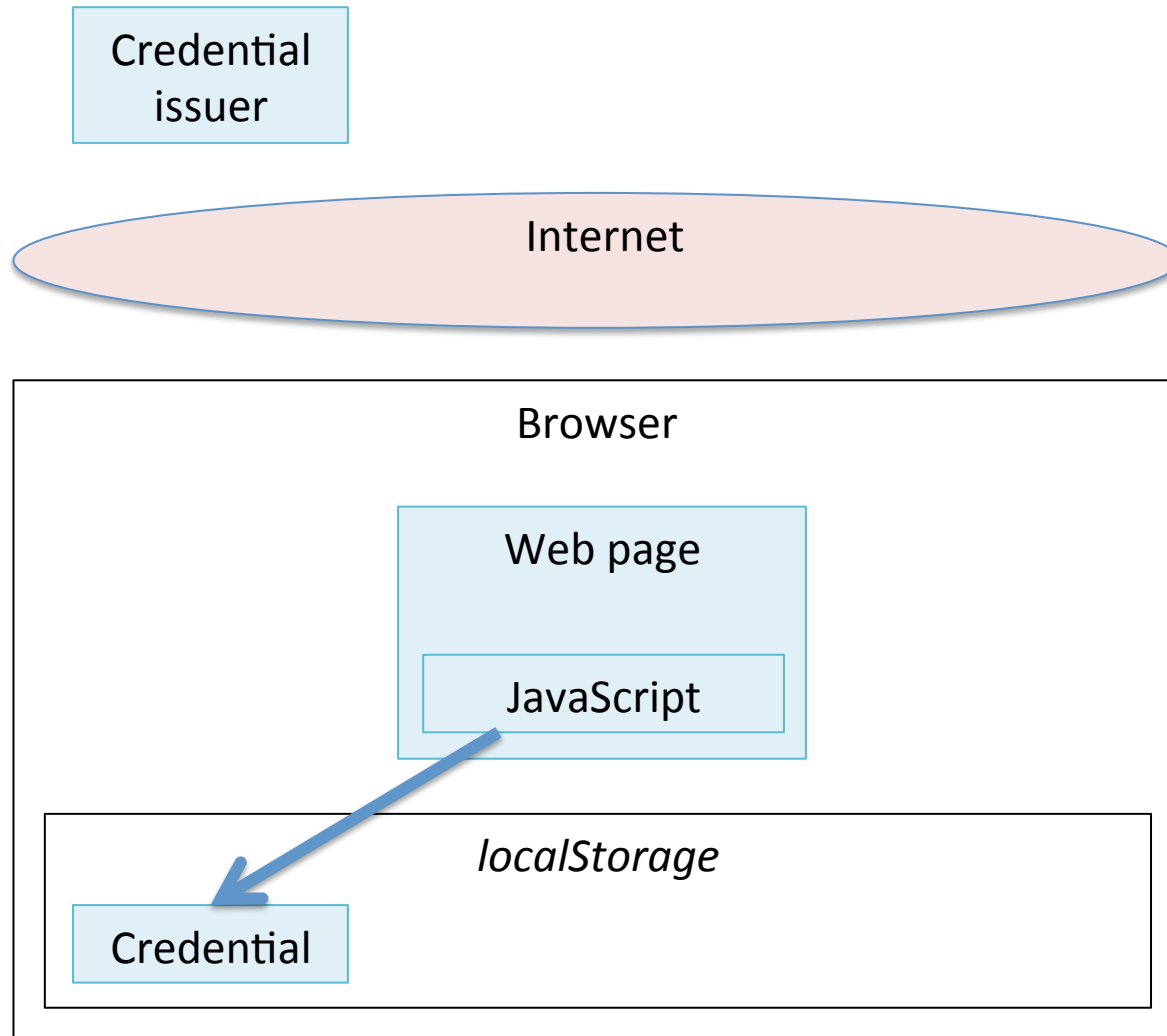
Solution 1 – Issuance



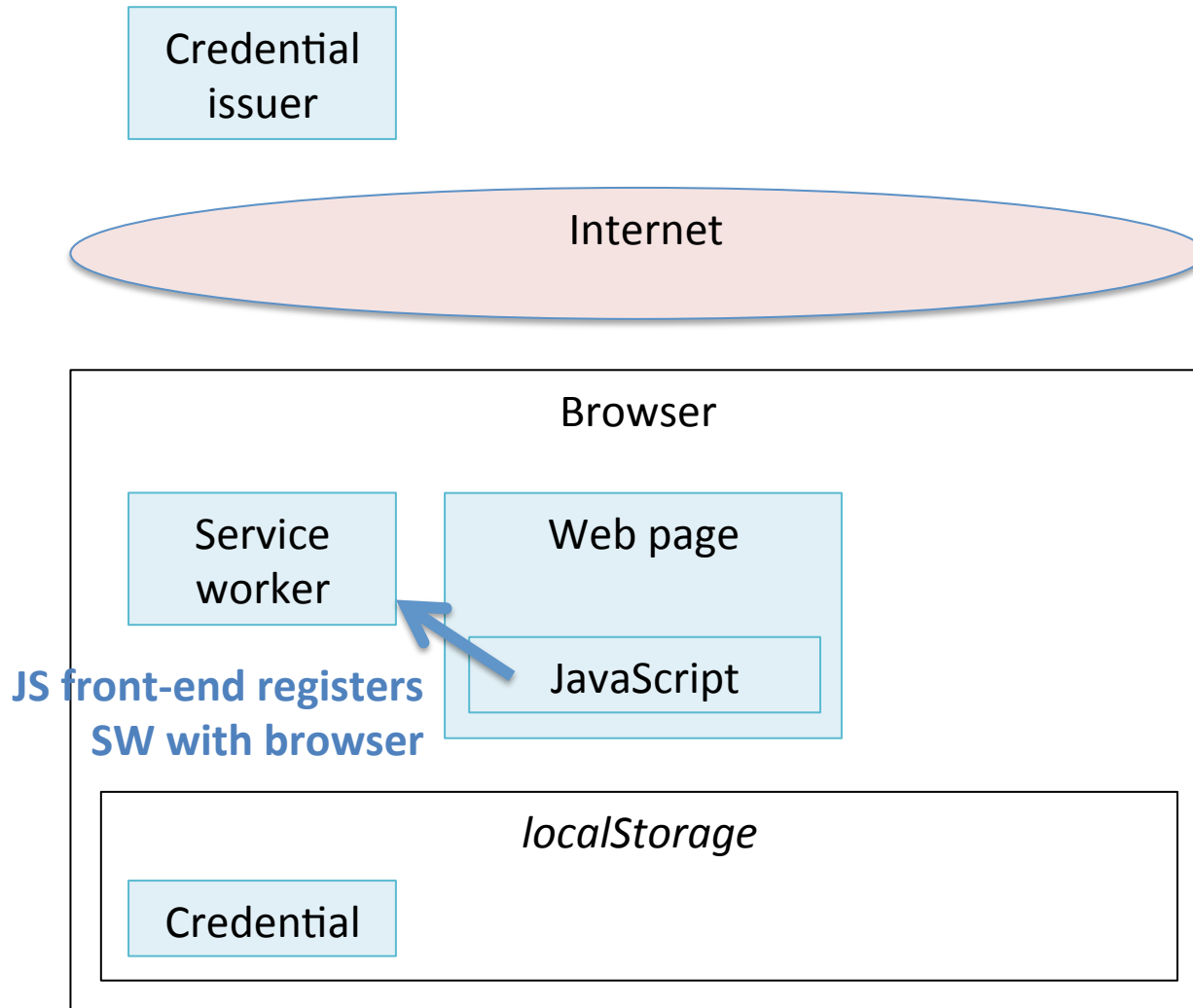
Solution 1 – Issuance



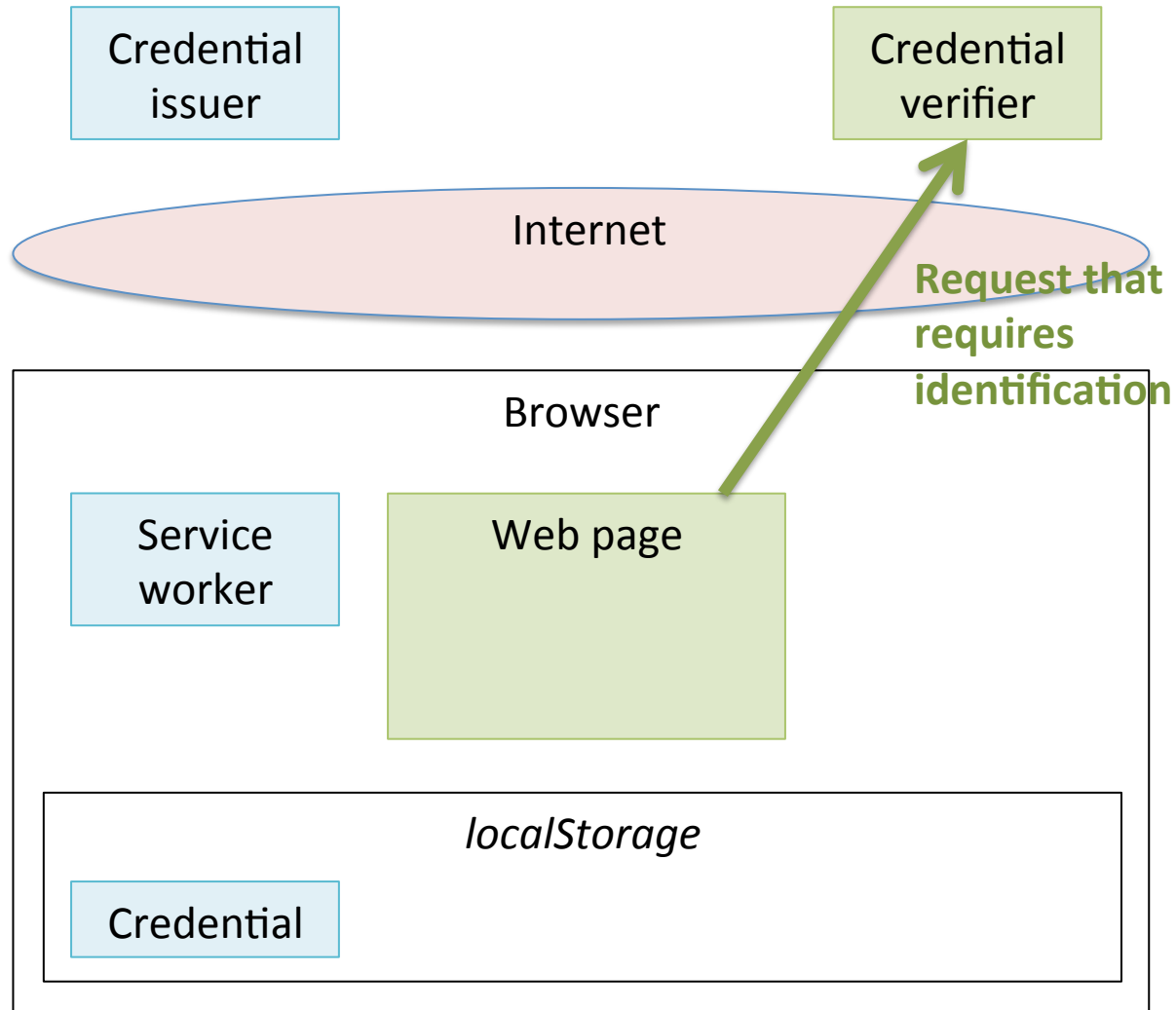
Solution 1 – Issuance



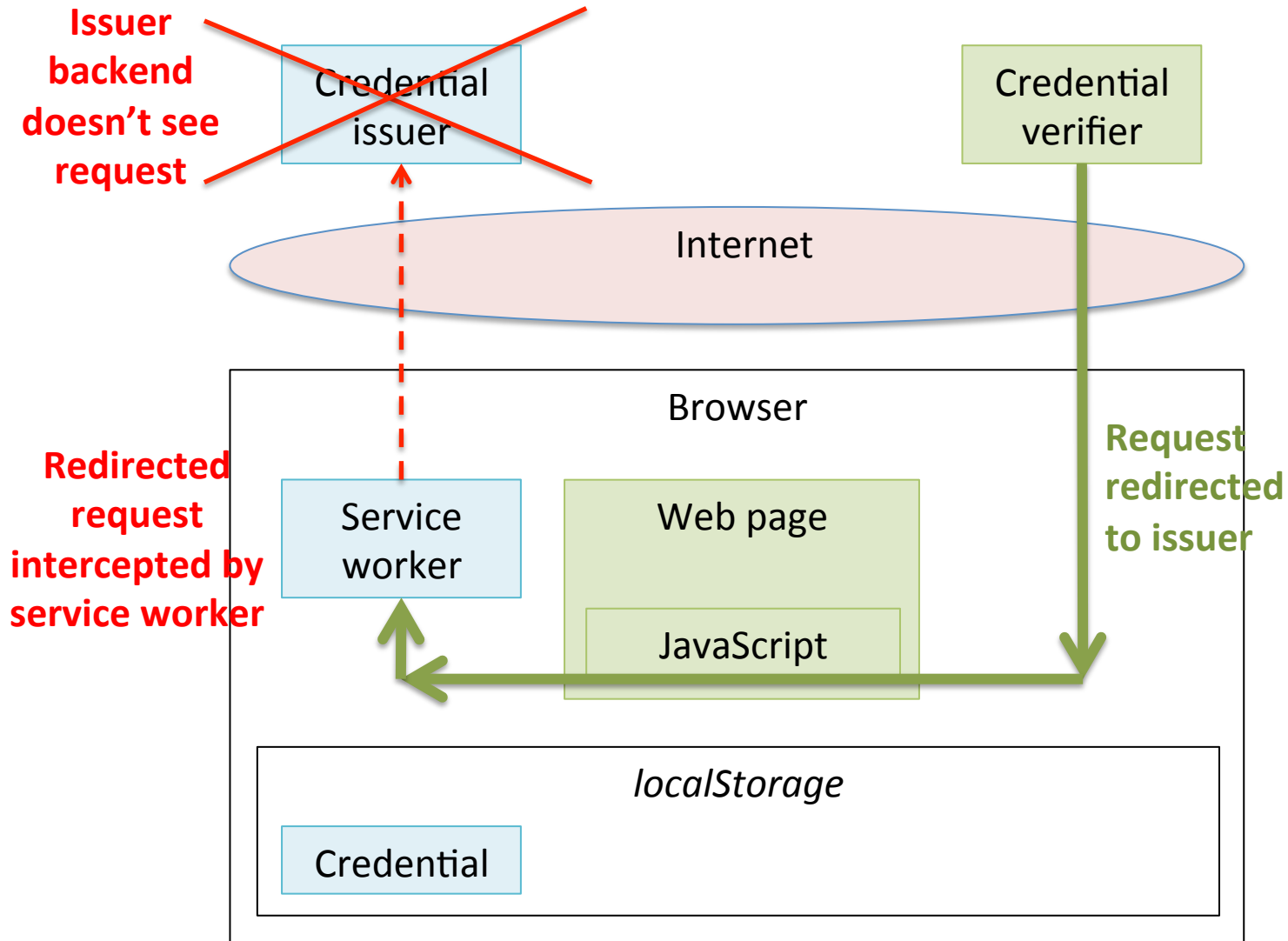
Solution 1 – Issuance



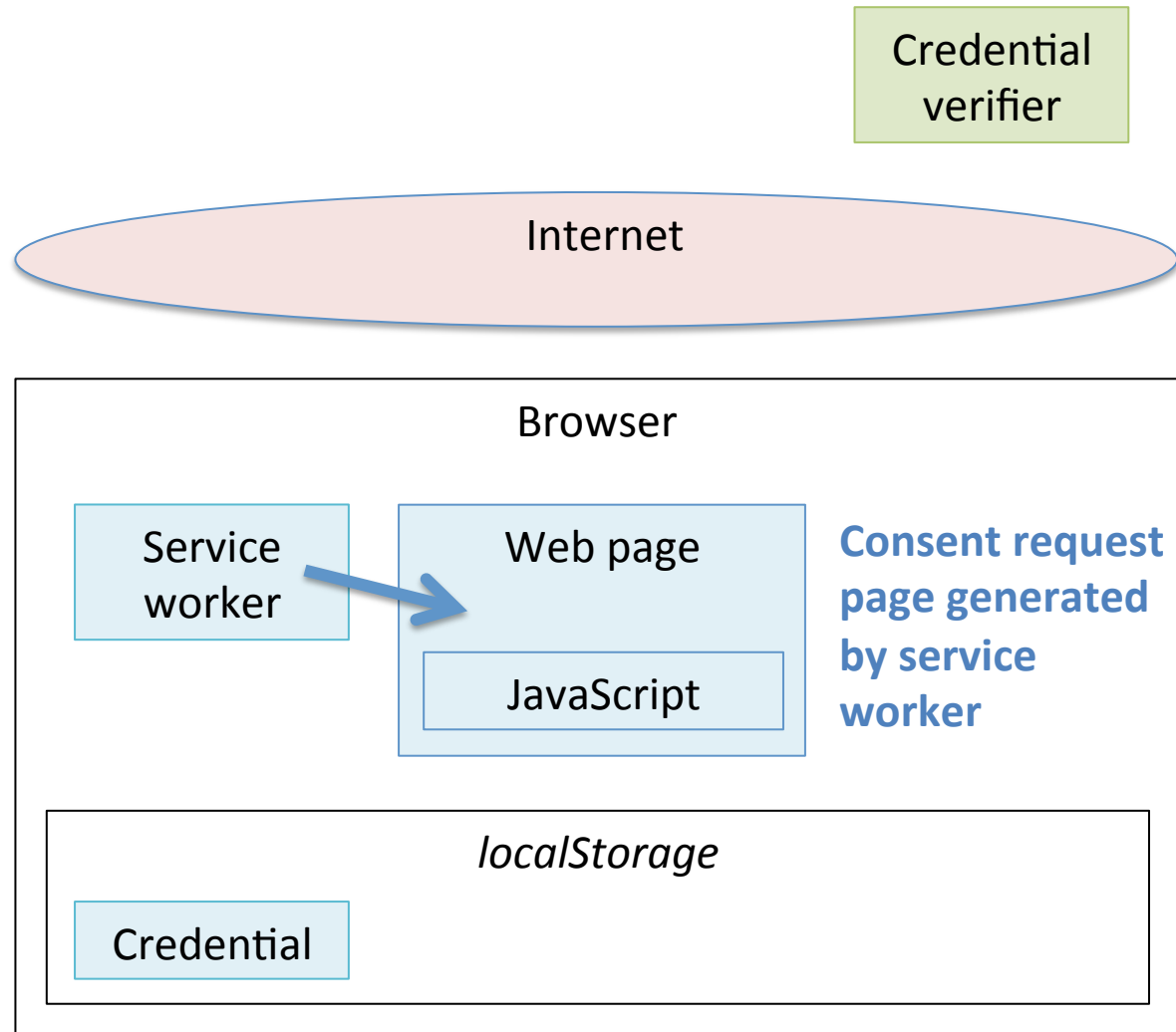
Solution 1 – Presentation



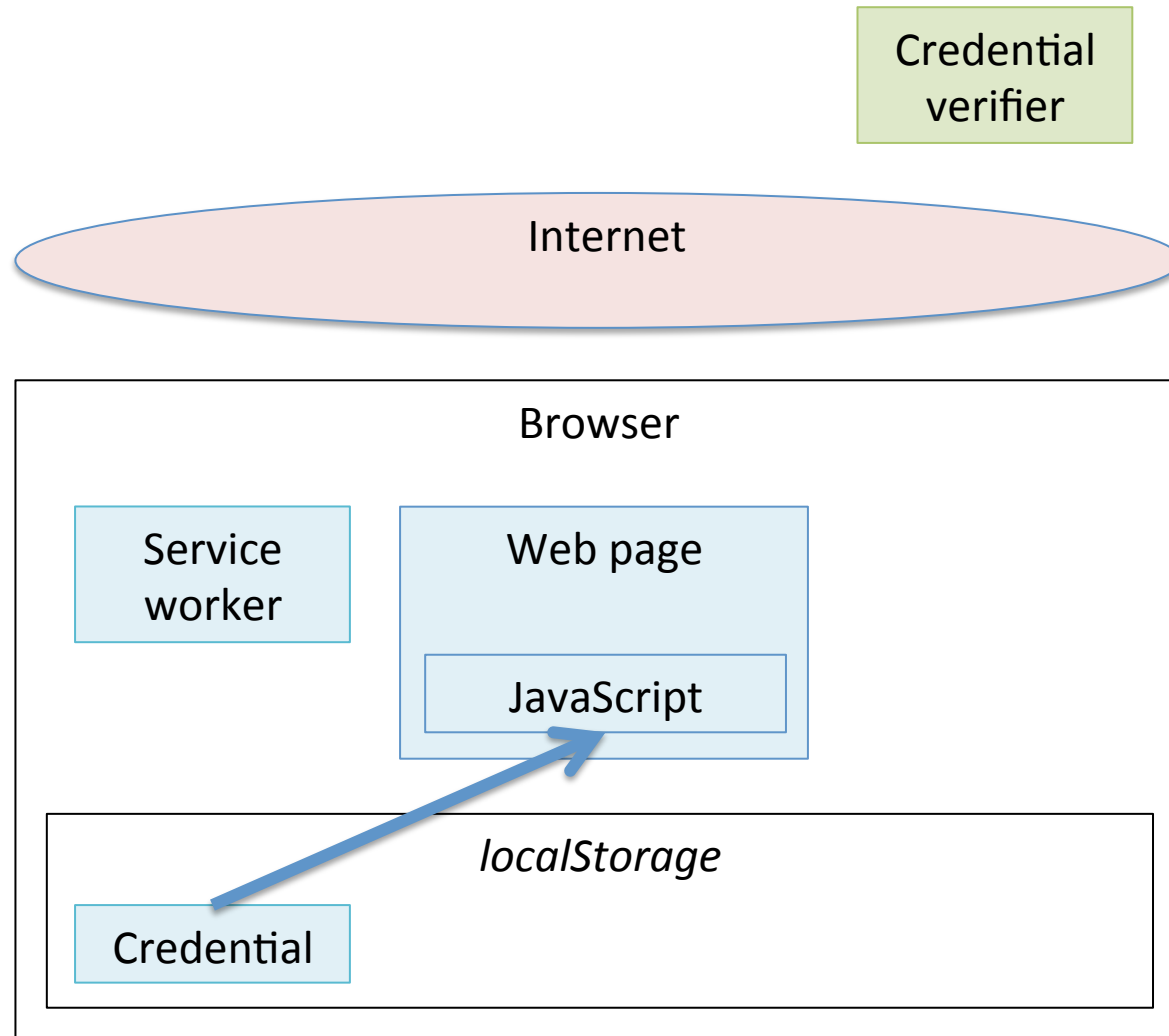
Solution 1 – Presentation



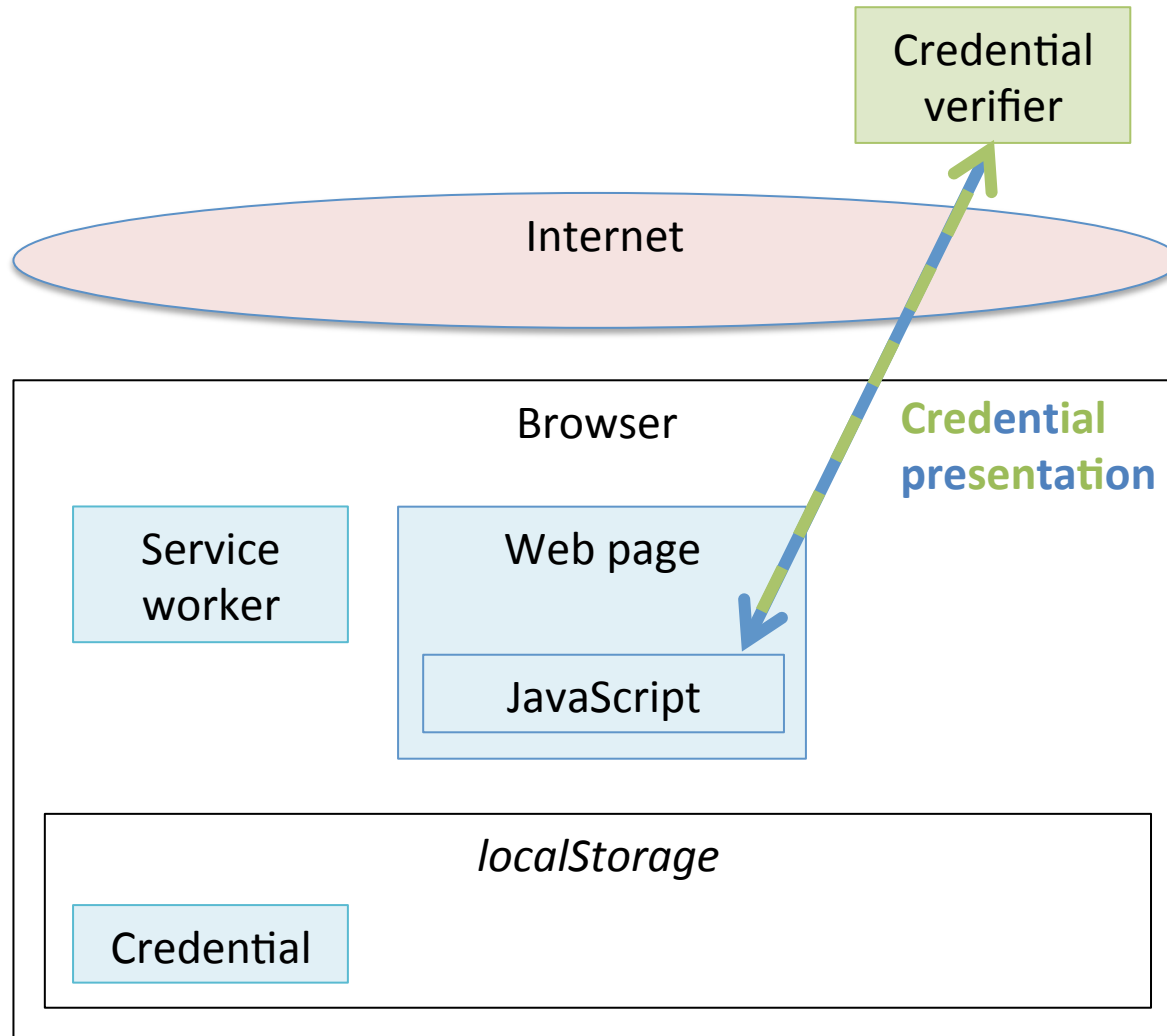
Solution 1 – Presentation



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Solution 1 – Presentation



Four solutions for storing cryptographic credentials in the browser	Using localStorage	Using the IndexedDB and Web Cryptography APIs
No Trusted Consent Manager	<p>Solution 1</p> <p>Issuer FE runs issuance protocol with issuer BE</p> <p>Issuer SW presents credential</p>	<p>Solution 2</p> <p>Issuance protocol: issuer FE generates key pair, issuer BE certifies public key. Issuer SW presents credential but cannot extract private key</p>
With Trusted Consent Manager	<p>Solution 3</p> <p>TCM FE runs issuance protocol with issuer BE</p> <p>TCM SW presents credential</p>	<p>Solution 4</p> <p>Issuance protocol: TCM FE generates key pair, issuer BE certifies public key. TCM SW presents credential but cannot extract private key</p>

TCM = Trusted Consent Manager, FE = Front-end, BE = Back-end; SW = service worker

SECURITY POSTURES	Attack by issuer at issuance	Attack from issuer after issuance	Malicious JS from other origin	Malware	Physical capture
Solution 1: LS	Capture	Capture	Secure	Capture	Capture
Solution 2: IDB/CK	Capture	Use	Secure	Capture	Capture
Solutions 3 and 4: TCM	Secure				Capture
SC/preloaded credential	Capture				Secure
SC/on-card key pair gen	Capture				Secure
SC/trusted firmware	Secure				Secure
TP HW on device	Secure				Secure
TEE	Secure	Secure	Secure	Secure	Capture

Capture/Use/Secure: refers to whether the cryptographic credential can be used by the adversary on the subject's machine, or captured for use elsewhere

JS = Javascript; IDB = *indexedDB*; CK = CryptoKey object; LS = *localStorage*; SC = Smartcard
 TCM = Trusted consent manager; TP HW = Tamper-proof hardware, e.g. TPM, Secure Element; TEE = Trusted execution environment

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Storage in browser is secure if: (i) issuer is honest and secure; (ii) no malware on subject's device; and (iii) no physical capture of subject's device

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Storage in browser not secure against malware or physical capture

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Storage-in-browser solutions have different security postures w.r.t. attack from issuer after issuance, e.g. attack by an issuer insider after issuance or introduction of an XSS vulnerability

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localStorage controlled by trusted consent manager is more secure than SC assuming no malware or physical capture, even with on-card key pair generation, if SC is provided by the issuer. Must use trusted firmware on SC to match LS controlled by TCM

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Tamper-proof hardware on device (TPM, Secure Element) or TEE are good solutions; but web applications cannot use them today

Potential applications

- Remote identity proofing, recurring authentication and privilege escalation using a cryptographic credential such as:
 - Traditional public key certificate and associated private key
 - Anonymous credential (e.g. Idemix)
 - Rich credential
- End-to-end encryption for web mail
- Cryptographically secured online payments

Thank you for your attention!

For more information:

pomcor.com

pomcor.com/blog/

Companion post: pomcor.com/blog/keys-in-browser/

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Any questions?