

Attacking and Fixing PKCS#11 Security Tokens

Matteo Bortolozzo, Matteo Centenaro

Riccardo Focardi and **Graham Steel**

Università Ca' Foscari, Venezia

and

LSV, INRIA & CNRS & ENS-Cachan

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Widely adopted in industry for authentication tokens, smartcards
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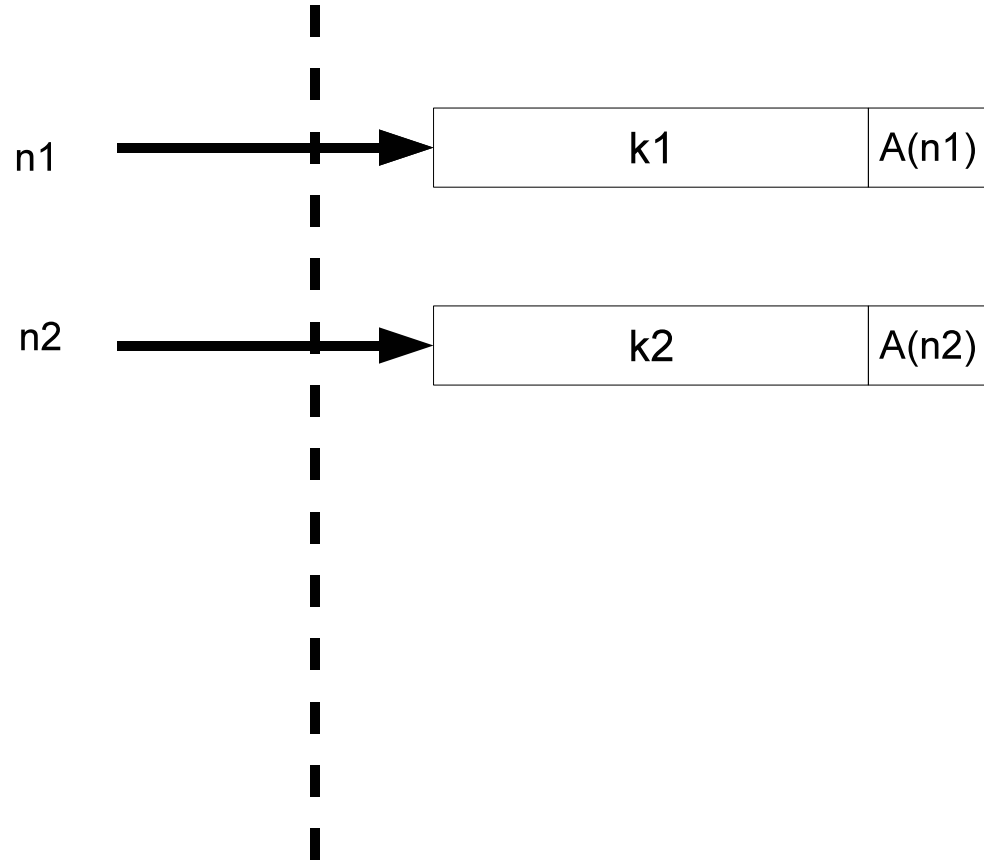
Cryptoki provides a logical view of objects on the token

Keys (etc.) stored on the device and accessed by *handles*

Attributes stored with keys to control usage

Host machine

Trusted device



PKCS #11

PKCS#11 Security

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“Rogue applications and devices may also change the commands sent to the cryptographic device to obtain services other than what the application requested [but cannot] compromise keys marked “sensitive,” since a key that is sensitive will always remain sensitive. Similarly, a key that is unextractable cannot be modified to be extractable.”

Host machine

Trusted device

n1



k1

x,s

n2



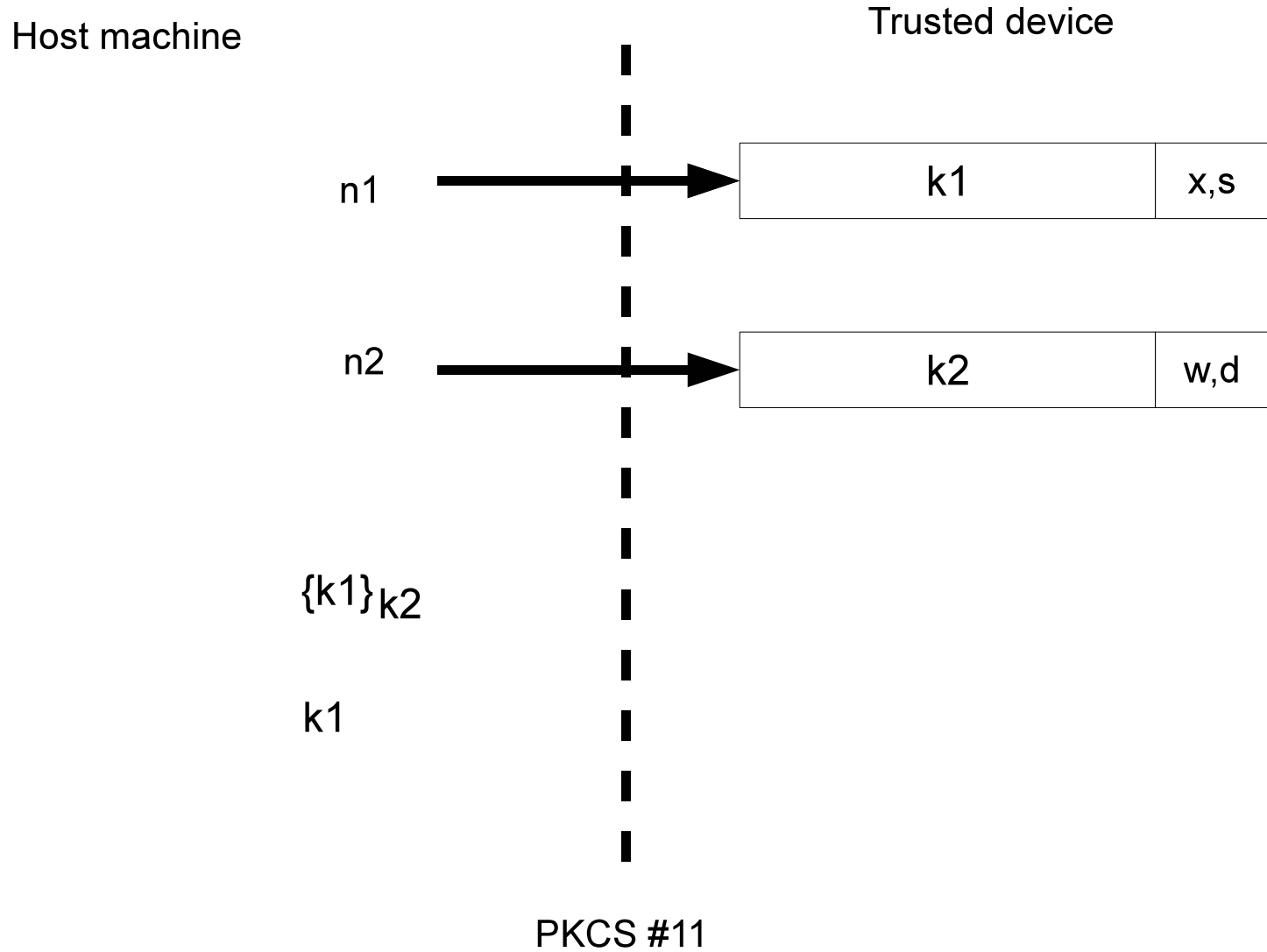
k2

w,d

$\{k1\}_{k2}$

PKCS #11

Clulow, CHES 2003



Formal Model (Delaune, Kremer, S., CSF 2008)

Abstract 'Dolev-Yao' style

$h(n1, k1)$ - a handle $n1$ for key $k1$ (h is a *private symbol*)

$a1(n1)$ - setting of attribute $a1$ for handle $n1$

Command :

$$\text{input;state} \xrightarrow{\text{new}} \text{output;state}'$$

Key Management - 1

KeyGenerate :

$\xrightarrow{\text{new } n, k}$ $h(n, k); L$

Where $L = \text{extract}(n), \neg\text{wrap}(n), \neg\text{unwrap}(n),$
 $\neg\text{encrypt}(n), \neg\text{decrypt}(n), \neg\text{sensitive}(n)$

Key Management - 2

Set_Wrap : $h(x_1, y_1); \neg \text{wrap}(x_1) \rightarrow ; \text{wrap}(x_1)$

Set_Encrypt : $h(x_1, y_1); \neg \text{encrypt}(x_1) \rightarrow ; \text{encrypt}(x_1)$

⋮

⋮

UnSet_Wrap : $h(x_1, y_1); \text{wrap}(x_1) \rightarrow ; \neg \text{wrap}(x_1)$

UnSet_Encrypt : $h(x_1, y_1); \text{encrypt}(x_1) \rightarrow ; \neg \text{encrypt}(x_1)$

⋮

⋮

Some restrictions, e.g. can't unset sensitive, can't set extract

Key Management - 3

Wrap :

$$h(x_1, y_1), h(x_2, y_2); \text{wrap}(x_1), \quad \rightarrow \quad \{y_2\}_{y_1} \\ \text{extract}(x_2)$$

Unwrap :

$$h(x_2, y_2), \{y_1\}_{y_2}; \text{unwrap}(x_2) \xrightarrow{\text{new } n_1} h(n_1, y_1); L$$

Where $L = \text{extract}(n), \neg\text{wrap}(n), \neg\text{unwrap}(n),$
 $\neg\text{encrypt}(n), \neg\text{decrypt}(n), \neg\text{sensitive}(n)$

Key Usage

Encrypt :

$$h(x_1, y_1), y_2; \text{encrypt}(x_1) \rightarrow \{y_2\}_{y_1}$$

Decrypt :

$$h(x_1, y_1), \{y_2\}_{y_1}; \text{decrypt}(x_1) \rightarrow y_2$$

Fix decrypt/wrap, (and encrypt/unwrap):

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Intruder knows: $h(n_1, k_1)$, $h(n_2, k_2)$, k_3

State: $\text{sensitive}(n_1)$, $\text{extract}(n_1)$, $\text{extract}(n_2)$

Set_wrap: $h(n_2, k_2) \rightarrow ;\text{wrap}(n_2)$

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Wrap: $h(n_1, k_1), h(n_2, k_2) \rightarrow \{k_2\}_{k_1}$

Set_unwrap: $h(n_1, k_1) \rightarrow ;\text{unwrap}(n_1)$

Unwrap: $h(n_1, k_1), \{k_2\}_{k_1} \xrightarrow{\text{new } n_3} h(n_3, k_2)$

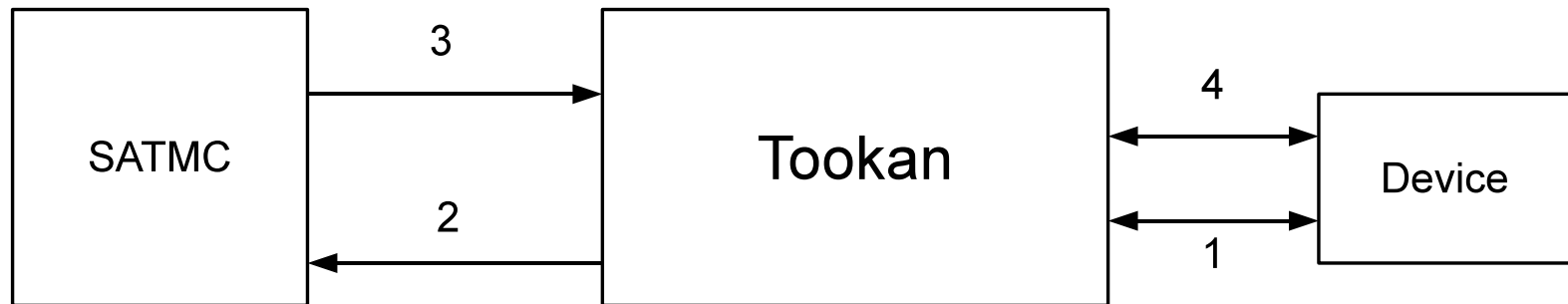
Wrap: $h(n_2, k_2), h(n_1, k_1) \rightarrow \{k_1\}_{k_2}$

Set_decrypt: $h(n_3, k_2) \rightarrow ;\text{decrypt}(n_3)$

Decrypt: $h(n_3, k_2), \{k_1\}_{k_2} \rightarrow k_1$

TOOKAN

'Tool for cryptoKi Analysis'



Templates

KeyGenerate : $\xrightarrow{\text{new } n, k}$ $h(n, k); \mathcal{A}(n, B)$ (with $B \in \mathcal{G}$)

KeyPairGenerate : $\xrightarrow{\text{new } n, s}$ $h(n, s), \text{pub}(s); \mathcal{A}(n, B)$ (with $B \in \mathcal{G}$)

Unwrap (sym/sym) :

$h(x, y_2), \{y_1\}_{y_2}; \text{unwrap}(x, \top) \xrightarrow{\text{new } n_1}$ $h(n_1, y_1); \mathcal{A}(n_1, B)$
(with $B \in \mathcal{U}$)

CreateObject : $x; \xrightarrow{\text{new } n}$ $h(n, x); \mathcal{A}(n, B)$ (with $B \in \mathcal{C}$)

Configuration Language

Functions

Attributes

Always on/off

Conflicts

Tied

Templates

Flags

(see <http://secgroup.ext.dsi.unive.it/tookan> for full description)

Abstractions for Proof (based on Fröschle & Steel WITS '09)

KeyGenerate : $\rightarrow h(n_i, k_i); \mathcal{A}(n_i, B_i)$ (with $B_i \in \mathcal{G}$)

KeyPairGenerate : $\rightarrow h(n_j, s_j), \text{pub}(s_j); \mathcal{A}(n_j, B_j)$ (with $B_j \in \mathcal{G}$)

Unwrap (sym/sym) :

$h(x, y_2), \{y_1\}_{y_2}; \text{unwrap}(x, \top) \rightarrow h(n_k, y_1); \mathcal{A}(n_k, B_k)$
(with $B_k \in \mathcal{U}$)

CreateObject : $x; \rightarrow h(n_l, x); \mathcal{A}(n_l, B_l)$ (with $B_l \in \mathcal{C}$)



Device		Supported Functionality						Attacks found				Tookan	
Brand	Model	s	as	cobj	chan	w	ws	wd	rs	ru	su		
Aladdin	eToken PRO	✓	✓	✓	✓	✓	✓	✓					wd
Athena	ASEKey	✓	✓	✓									
Bull	Trustway RCI	✓	✓	✓	✓	✓	✓	✓					wd
Eutron	Crypto Id. ITSEC		✓	✓									
Feitian	StorePass2000	✓	✓	✓	✓	✓	✓	✓	✓	✓			rs
Feitian	ePass2000	✓	✓	✓	✓	✓	✓	✓	✓	✓			rs
Feitian	ePass3003Auto	✓	✓	✓	✓	✓	✓	✓	✓	✓			rs
Gemalto	SEG		✓		✓								
MXI	Stealth MXP Bio	✓	✓		✓								
RSA	SecurID 800	✓	✓	✓	✓				✓	✓	✓		rs
SafeNet	iKey 2032	✓	✓	✓		✓							
Sata	DKey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		rs
ACS	ACOS5	✓	✓	✓	✓								
Athena	ASE Smartcard	✓	✓	✓									
Gemalto	Cyberflex V2	✓	✓	✓		✓	✓	✓					wd
Gemalto	SafeSite V1		✓		✓								
Gemalto	SafeSite V2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		rs
Siemens	CardOS V4.3 B	✓	✓	✓		✓				✓			ru

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All 7 received notification at least 5 months before publication.

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Gemalto responded to Cyberflex vulnerability, but not to SafeSite, and not to request to publish their response.

Minimal response from anyone else (e.g. requests to know who else is vulnerable)

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Available to download from

<http://secgroup.ext.dsi.unive.it/cryptokix>

Conclusions

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More details in the paper or online:

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