Synthesising Secure APIs

(to appear at ESORICS'09)

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and

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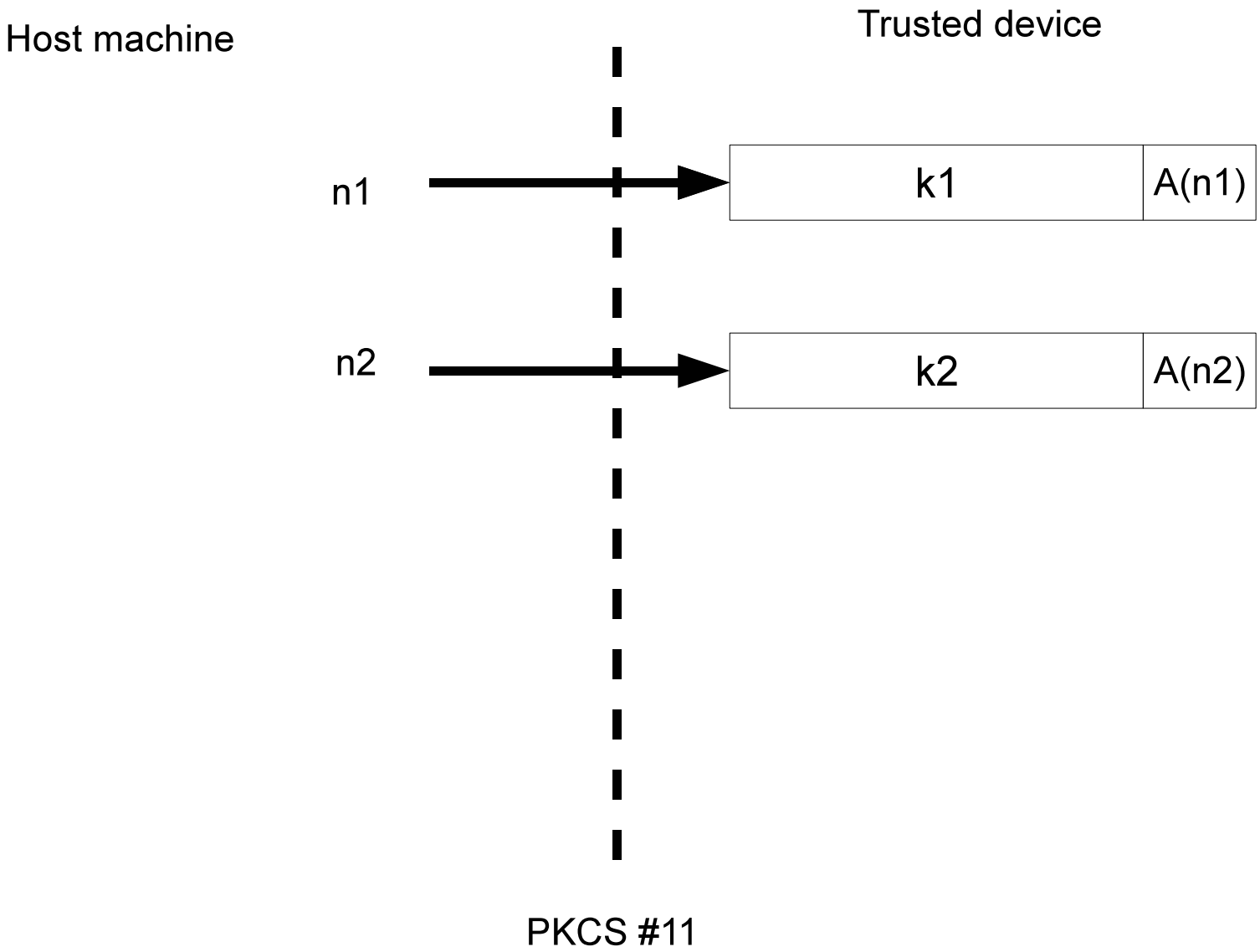
Host machine

Trusted device

Security API


Host machine
Trusted device
n1
k1
A(n1)
n2
k2
A(n2)
PKCS #11

Security Policy

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e.g. from PKCS#11 (1 page in 407 page standard)

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We note that none of the attacks just described can compromise keys marked “sensitive,” since a key that is sensitive will always remain sensitive.”

Key Separation Attack (Clulow, 2003)

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

State: $\mathsf{wrap}(n_2)$, $\mathsf{decrypt}(n_2)$, $\mathsf{sensitive}(n_1)$, $\mathsf{extract}(n_1)$

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

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

Many variations of this attack exist, not easy to fix (see Delaune, Kremer & Steel CSF'08)

Protocols

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Idea:

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Design generic API that can be instantiated to any protocol

Prove properties for the generic API that hold no matter what protocol is implemented

Generic API: Concepts

Handles for objects stored on device

Static security types for objects on device:

0 Public data (exists outside device)

1 Secret on device, not usable as key

2 Short term (session) key

3 Long term (key transport) key

Agent identifiers

Generic API: Generate Commands

$$\overset{N,K}{\Rightarrow} K_a(h_a^g(N,K,i,S)) \quad i \geq 1 \qquad \textbf{(Secure Generate)}$$

$$\overset{N,K}{\Rightarrow} K_a(K), K_a(h_a^g(N,K,0,\emptyset)) \qquad \textbf{(Public Generate)}$$

where $N \in$ VarNonce, and $K \in$ VarNonce if $i = 1$, $K \in$ VarKey if $i = 2$.

Generic API: Encrypt

$$K_a(h_a^{\alpha}(X,K,i_0,S_0)),K_a(x_1),\ldots,K_a(x_k),$$
$$K_a(h_a^{\alpha_1}(X_{n_1},y_1,i_1,S_1)),\ldots,K_a(h_a^{\alpha_l}(X_{n_l},y_l,i_l,S_l))$$
$$\Rightarrow K_a(\{x_1,0,\ldots,x_k,0,y_1,i_1,S_1,\ldots,y_l,i_l,S_l\}_K) \quad \textbf{(Encrypt)}$$

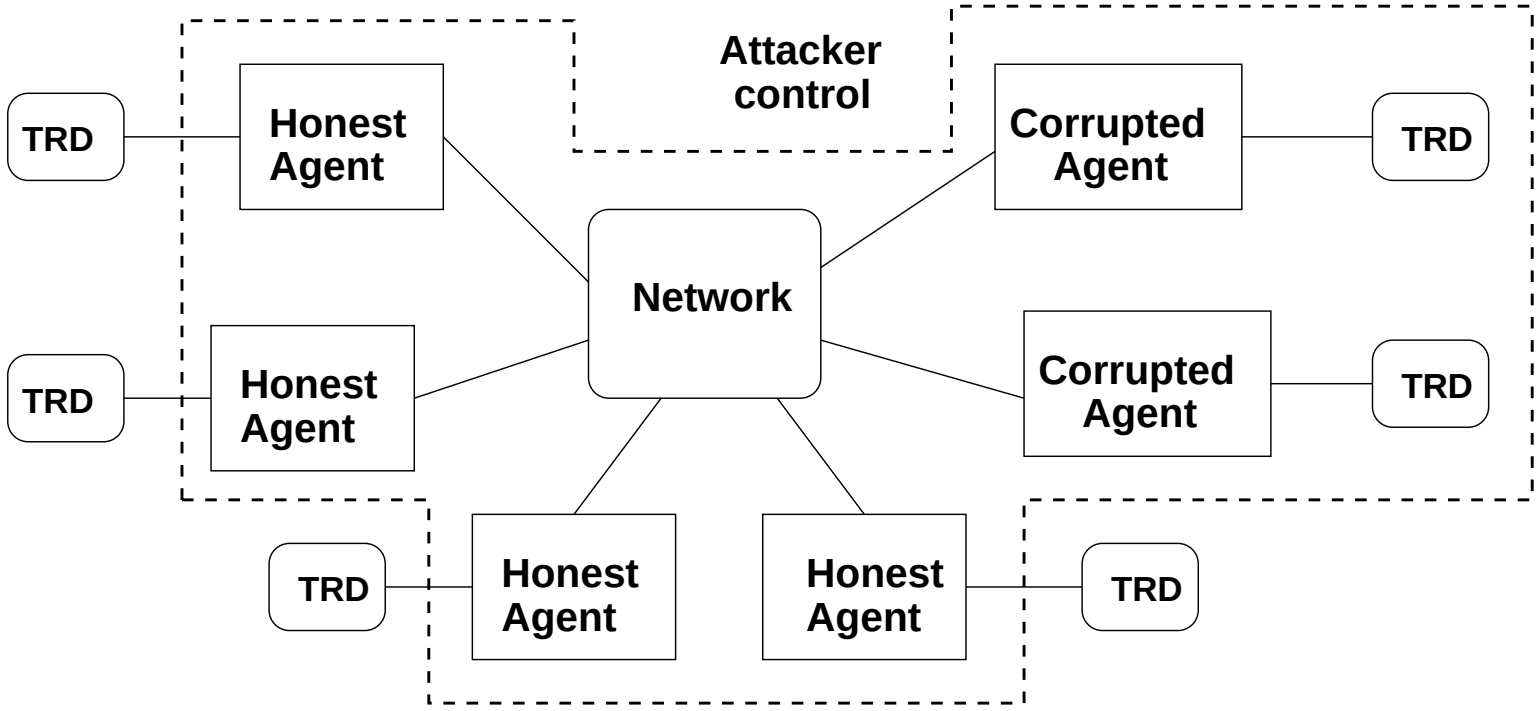
Require $i_0 > i_j$ (keys only encrypt data of strictly lower security level) and $S_0 \subseteq S_j$

Generic API: Decrypt

$$K_a(h_a^{\alpha}(X,K,i_0,S_0)), K_a(\{x_1,0,\ldots,x_k,0,y_1,i_1,S_1,\ldots,y_l,i_l,S_l\}_K),$$
$$K_a(h_a^{g}(X_1,x_1,0,\emptyset)),\ldots,K_a(h_a^{g}(X_s,x_s,0,\emptyset)),$$
$$K_a(h_a^{g}(Y_1,y_1,i_1,S_1)),\ldots,K_a(h_a^{g}(Y_l,y_l,i_l,S_l))$$
$$\stackrel{N_{r+1},\ldots,N_l}{\Rightarrow} K_a(x_{s+1})\ldots,K_a(x_k),$$
$$K_a(h^r(N_{r+1},y_{r+1},i_{r+1},S_{r+1}))\ldots,K_a(N_l,y_l,i_l,S_l) \quad \textbf{(Decrypt/Test)}$$

provided $i_0 > i_j$ (keys only encrypt data of strictly lower security level) and that $S_0 \subseteq S_j$

Properties: Scenario



Property 1 : Secrecy Invariant

"Secret data of honest users should not be known to the intruder."

i.e. data values k for which there are handles of the form $h_a^{\alpha}(n,k,i,S)$, where S is a subset of honest users, are unknown to the intruder.

$$\forall a \in \mathsf{Agent}, \forall x,y \in \mathsf{msg}, \forall i \in \{1,2,3\}, \forall \alpha \in \{r,g\}, \forall S \subseteq H$$
$$\mathcal{S} \vdash h_a^{\alpha}(x,y,i,S) \Rightarrow \mathcal{S} \nvdash y \text{ and } y \in \mathsf{Key} \cup \mathsf{Nonce} \quad \textbf{(Sec)}$$

Property 2 : Secrecy After Compromise

Intruder learns some session keys

Honest users erase old handles

API enforces tests - no session keys accepted without a test

Sec is still preserved

Implementing Protocols

Protocol (section in Clark-Jacob)	API	API^r
Needham-Schroeder SK (6.3.1)	+	-
NSSK amended version (6.3.4)	+	+
Otway-Rees (6.3.3)	+	+
Yahalom (6.3.6)	+	-
Carlsen (6.3.7)	+	+
Woo-Lam Mutual Auth (6.3.11)	+	+

http://www.lsv.ens-cachan.fr/~steel/genericapi/

Related Work

Cachin and Tandran, to appear at CSF ’09

- Cryptographic model
- Only one token
- Multiple user profiles on token
- Highly restrictive (un)wrapping commands

Further Work

- Cryptographic soundness
- Long-term key update
- PKI (asymmetric crypto, certificates,. . .)
- Timestamps

PUB

3rd Analysis of Security APIs workshop (ASA-3)

Long Island, New York, July 10-11 2009

(satellite of IEEE CSF)

http://www.lsv.ens-cachan.fr/~steel/asa3