Modeling the ISO 9798–2.4 Authentication Protocol

Britta Hale Colin Boyd

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Outline

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1. ISO 9798–2.4

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2. Analysis Issues

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2. Analysis Issues
3. Results

ISO 9798–2.4

$$B \rightarrow A : R_B || Text_1$$

$$A \rightarrow B : Text_3 || \mathcal{E}_K(R_A || R_B || I_B || Text_2)$$

$$B \rightarrow A : Text_5 || \mathcal{E}_K(R_B || R_A || Text_4)$$

ISO 9798–2 Mechanism 4 Mutual Authentication Protocol

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ISO 9798–2.4

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- R_i are random nonces

ISO 9798–2.4

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ISO 9798–2.4

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$$B \to A : R_B || Text_1$$

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Past Work

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Past Work

Basin, Cremers, Meier (2012) ISO 9798–2.4 analysis using Scyther

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Unconsidered:

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Unconsidered:

- Selection and properties of the encipherment function
- A, B agree on the data exchanged
- Messages are received in expected order, with data integrity

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Goals

- Encipherment function

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- Encipherment function
- Address optional text fields

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Goals

- Encipherment function
- Address optional text fields
- Computationally prove the security of ISO 9798–2.4

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The Encipherment Function

- Standard properties:
  Integrity and Manipulation Detection

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  What is authenticated encryption?

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  What is authenticated encryption?
  - Confidentiality

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  - EAX (CTR mode for encryption, OMAC for authentication)
  - Encrypt-then-MAC (EtM)

The Encipherment Function

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  What is authenticated encryption?
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  - Offset Codebook Mode (OCB)
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  - EAX (CTR mode for encryption, OMAC for authentication)
  - Encrypt-then-MAC (EtM)
  - Galois Counter Mode (GCM)

The Encipherment Function

- Standard properties:
  Integrity and Manipulation Detection

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The Encipherment Function

- Standard properties:
  Integrity and Manipulation Detection

- Selection for analysis: MAC
  $\mathrm{MAC}_K(M) = (M, \mathit{Tag})$

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Optional Text Fields

B		A
Symmetric K		Symmetric K
Random R_B		Random R_A
	$\xrightarrow{R_B}$	
	$\xleftarrow{\mathrm{MAC}_K(R_A, R_B, I_B)}$	
	$\xrightarrow{\mathrm{MAC}_K(R_B, R_A)}$	

ISO 9798–2.4 Protocol Core with $\mathrm{MAC}_K(M) = (M, \mathit{Tag})$

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Optional Text Fields

B		A
Symmetric K Random R_B		Symmetric K Random R_A
	$R_B \| \| Text_1$ $\longrightarrow$	
	$\longleftarrow$ $Text_3 \| \| \mathrm{MAC}_K(R_A, R_B, I_B, Text_2)$	
	$Text_5 \| \| \mathrm{MAC}_K(R_B, R_A, Text_4)$ $\longrightarrow$	

ISO 9798–2.4 Protocol with $\mathrm{MAC}_K(M) = (M, \textit{Tag})$ and Text Fields

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No security guarantee on text fields content selection

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Optional Text Fields

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Rogaway and Stegers Framework (2009)

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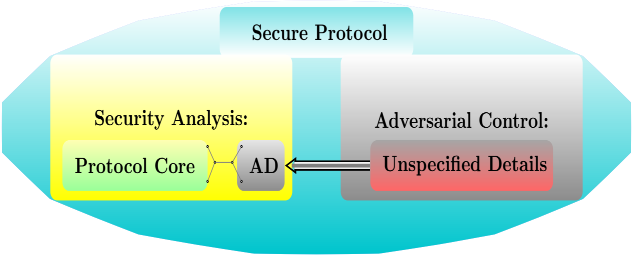

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Which text fields are Associated Data?

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Which text fields are Associated Data?

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$Text_2$: Authenticated

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	$R_B \| Text_1$ $\longrightarrow$	
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Which text fields are Associated Data?

$Text_1, Text_3, Text_5$: Unauthenticated

$Text_2$: Authenticated

$Text_4$: Authenticated, but no confirmation message received.

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Which text fields are Associated Data?

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Proof of Security

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- Use $\mathcal{E}_K(m) = \mathrm{MAC}_K(m)$ (SUF-CMA)

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Proof of Security

- Use $\mathcal{E}_K(m) = \mathrm{MAC}_K(m)$ (SUF-CMA)
- Associated data: $Text_2$

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Proof of Security

- Use $\mathcal{E}_K(m) = \mathrm{MAC}_K(m)$ (SUF-CMA)
- Associated data: $Text_2$
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Bellare–Rogaway Mutual Authentication Model

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Bellare–Rogaway Mutual Authentication Model

1. Matching conversations ⇒ acceptance.

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Bellare–Rogaway Mutual Authentication Model

1. Matching conversations $\Rightarrow$ acceptance.
2. Acceptance $\Rightarrow$ matching conversations.

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Proof of Security

- Use $\mathcal{E}_K(m) = \mathrm{MAC}_K(m)$ (SUF-CMA)
- Associated data: $Text_2$
- Authenticated but unassociated data: $Text_4$

Bellare–Rogaway Mutual Authentication Model with RS Framework

1. Matching conversations $\Rightarrow$ acceptance.
2. Acceptance $\Rightarrow$ matching conversations.
3. Matching Conversations $\Rightarrow$ Matching Associated Data.

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Results:

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Results:

$$\mathbf{Adv}^{\mathsf{MA}}(\mathcal{A}) \leq 2p^2 S \cdot \mathbf{Adv}_{\Pi}^{\mathrm{MAC}}(F) + q^2/2^{k+1}$$

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Results:

$$\mathbf{Adv}^{\mathsf{MA}}(\mathcal{A}) \leq 2p^2S \cdot \mathbf{Adv}_{\Pi}^{\mathrm{MAC}}(F) + q^2/2^{k+1}$$

If $\mathcal{A}$ runs in time t and asks q queries, then F runs in time $t_F \approx t$ and asks $q_F = q$ queries.

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Number of principals: p
Number of sessions: S
Number of allowed adversary queries: q

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Security parameter: 1^k

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Results with Authenticated Encryption:

Consider: $\mathrm{MAC}_K(M) = (M, \mathsf{AE}(K, M))$

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Results with Authenticated Encryption:

Consider: $\mathrm{MAC}_K(M) = (M, \mathsf{AE}(K, M))$

SUF-AE:

$$\mathbf{Adv}^{\mathsf{SUF\text{-}CMA}}_{\mathrm{MAC}}(E) \leq \mathbf{Adv}^{\mathsf{SUF\text{-}AE}}_{(\mathcal{K},\mathcal{E},\mathcal{D})}(F)$$

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Adversarial advantage with associated data considered:

$$\mathbf{Adv}^{\mathsf{MA\text{-}AE}}_{\Pi}(\mathcal{A}) \leq (2p^2S + n) \cdot \mathbf{Adv}^{\mathsf{SUF\text{-}AE}}_{(\mathcal{K},\mathcal{E},\mathcal{D})}(F) + q^2/2^{k+1}$$

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Results with Authenticated Encryption:

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Strongly unforgeable authenticated encryption (SUF-AE) algorithm

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Results with Authenticated Encryption:

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$$\mathbf{Adv}_{\mathrm{MAC}}^{\text{SUF-CMA}}(E) \leq \mathbf{Adv}_{(\mathcal{K},\mathcal{E},\mathcal{D})}^{\text{SUF-AE}}(F)$$

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Strongly unforgeable authenticated encryption (SUF-AE) algorithm
Number of allowed queries for MA-AE adversary $\mathcal{A}$: n

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Strongly unforgeable authenticated encryption (SUF-AE) algorithm
Number of allowed queries for MA-AE adversary $\mathcal{A}$: n
Number of allowed queries for MA-MAC adversary: q

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Results with Authenticated Encryption:

Consider: $\mathrm{MAC}_K(M) = (M, \mathsf{AE}(K, M))$

SUF-AE:

$$\mathbf{Adv}^{\text{SUF-CMA}}_{\mathrm{MAC}}(E) \leq \mathbf{Adv}^{\text{SUF-AE}}_{(\mathcal{K},\mathcal{E},\mathcal{D})}(F)$$

Adversarial advantage with associated data considered:

$$\mathbf{Adv}^{\text{MA-AE}}_{\Pi}(\mathcal{A}) \leq (2p^2 S + n) \cdot \mathbf{Adv}^{\text{SUF-AE}}_{(\mathcal{K},\mathcal{E},\mathcal{D})}(F) + q^2/2^{k+1}$$

Strongly unforgeable authenticated encryption (SUF-AE) algorithm
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Questions?