On the security of one RFID authentication protocol

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КРИПТОНИТ

Outline

1. Introduction
2. Adversarial model
3. Security reduction

Introduction

Security of RFID systems

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The following security requirement are addressed:

1. **Party authentication** (unilateral/mutual);
2. Confidentiality (of the additional data);
3. Integrity (of the additional data);

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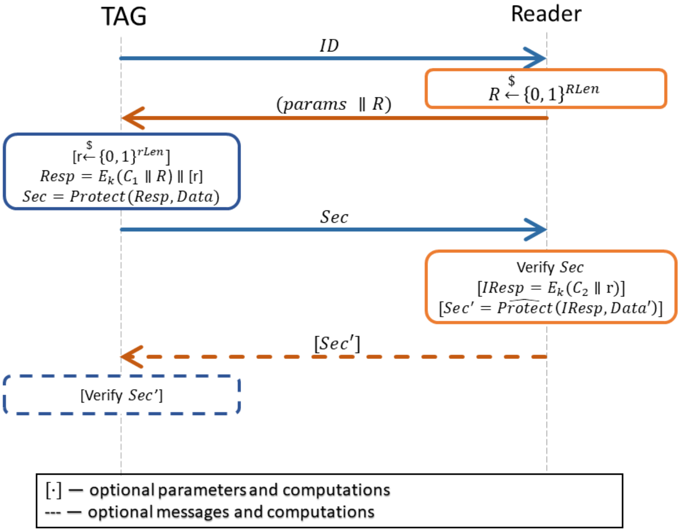
2. Implementing simplest RFID protocols on passive tags without autonomous power sources.
3. Protected WORM (write once, read many) memory to store shared secret keys.
4. Relatively small gate area; in particular, symmetric-cryptography based protocols are preferable.

RFID authentication protocol



Adversarial model

Authentication protocol with optional data transfer

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- Authentication algorithm $\mathbf{Auth}$; input: participant's $state_A$ and a message m to be processed; returns an updated state $state'_A$ and response m'.

AUTH^+ model

Interface: oracles $CreateTag$, $StartReaderSession$, $StartTagSession$, $Send$, $Result$, $SetMessage^b$, $Test^b$:

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- check the result of the session using $Result$ query;
- send messages to protocol participants using $Send$ query; messages are transmitted within some fixed session π to the session holder (the Reader is able to participate in parallel sessions, but for Tags all sessions are strictly sequential, and the adversary is able to send message only in the current session for the Tag);

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- set additional data to be authenticated and/or encrypted using $SetMessage^b$ query; the bit b controls which of the data messages (M_0, M_1) will be processed; in case of AE-sessions it is possible that $M_0 \neq M_1$ (this oracle formalizes the inability of adversary to break the confidentiality of the transmitted data);

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- test sessions using $Test^b$ query; if the adversary is able to authenticate without the help of Tag (or Reader), or to forge MAC-value, then it is possible to construct a session π for which there would be no matched session π', i.e., it can be tested using $Test^b(\pi)$ query; the answer helps to guess the bit b.

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Hence, bit b controls the following properties: confidentiality, secure participant authentication, data integrity within the session, integrity “at the session level”.

More on $Test^b$ oracle

$Test^b(\pi)$

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if $(b = 0)$ **then**

  return 0

else

  $t_1 \leftarrow Correctness(\pi)$

  $t_2 \leftarrow \mathrm{NOT}(Match(\pi, Sessions))$

  return $(t_1 \& t_2)$

fi

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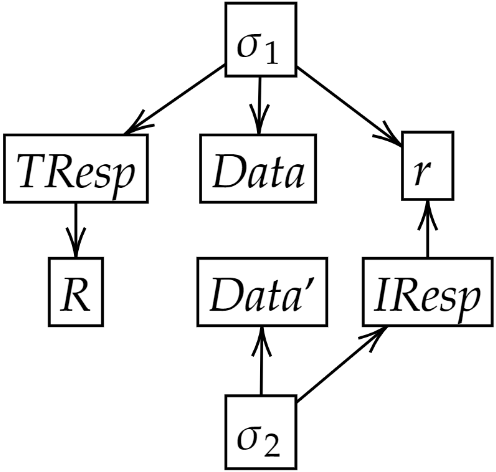
  - hence, $Data$ and $Data'$ are **implicitly binded**...
- i.e. if the Reader authentication is correct on the Tag's side, then it is guaranteed that $Data'$ is an answer not only to the Tag's challenge r, but also to the $Data$ message.

MAM-mode with integrity check



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- *Match* and *Correctness* filters out “trivial” attacks that shall not be considered as security violations;
- e.g., if the adversary relays all the messages...
- or interrupts the delivery of the last message in the session.

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Success measure:

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Main aim: estimate the maximal advantage $\mathrm{Adv}_{\Pi}^{\mathrm{auth}^+}(\mathcal{A})$; the maximum is taken over the adversarial class with the restrictions on computational complexity of $\mathcal{A}$ and the number of queries (as well as other query characteristics that depend on the the particular application of RFID technology).

Security reduction

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- Each sub-model can be studied separately.

Estimating the adversarial advantage

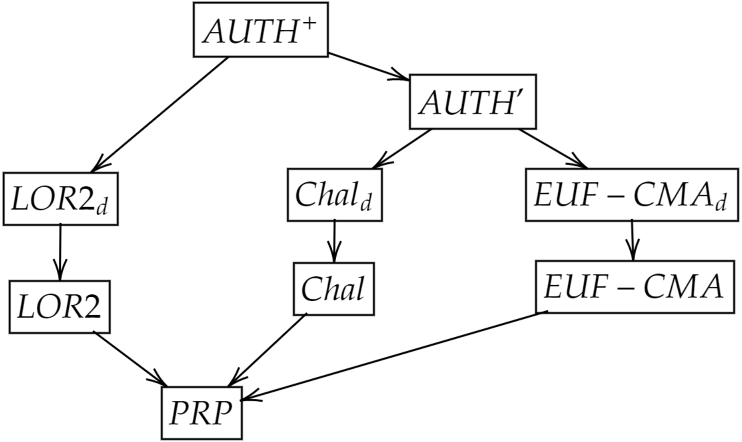

Figure 2: Schematic representation of the proof

Estimating the adversarial advantage

Theorem
The following inequality holds:

$$\mathsf{Adv}_{\Pi}^{\mathrm{AUTH}^+}(t, d, \mathcal{P}, \mathcal{Q}, \mathcal{R}, \Theta, \mathcal{M}, \mathcal{N}, \Phi, \Psi, \widehat{\mathcal{Q}}, \widehat{\mathcal{M}}, \widehat{\Phi}) \leq$$

$$\leq \sum_{i=1}^{d} \mathsf{Adv}^{LOR2}\Big(t + T, q_i, \mu_i, \phi_i, \hat{q}_i, \widehat{\mu}_i, \widehat{\phi}_i\Big) +$$

$$+2 \cdot \sum_{i=1}^{d} \mathsf{Adv}^{\text{EUF-CMA}}\Big(t + T, r_i + q_i + \hat{q}_i, \max\left(\mu_i + 2, \widehat{\mu}_i + 2, \nu_i + 1\right),$$

$$\phi_i + 2 \cdot q_i + \widehat{\phi}_i + 2 \cdot \hat{q}_i + \psi_i + r_i, \theta_i\Big) +$$

$$+2 \cdot \sum_{i=1}^{d} \Big(\mathsf{Adv}^{\mathrm{PRP}}(t + T, p_i + \theta_i) + \frac{\theta_i \cdot (p_i + \theta_i)}{2^{Rlen}} + \frac{\theta_i |Consts|}{|\mathrm{Dom}| - p_i - \theta_i + 1}\Big).$$

Example: simplifying assumptions

Let the following assumptions be true:

- The best estimate for «Magma» block cipher (in)security in sPRP-model is $\frac{q \cdot t}{2^{256}}$;
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$$\mathsf{Adv}_{\Pi}^{\mathrm{AUTH}^+}(t, d, \mathcal{P}, \mathcal{Q}, \mathcal{R}, \Theta, \mathcal{M}, \mathcal{N}, \Phi, \Psi, \widehat{\mathcal{Q}}, \widehat{\mathcal{M}}, \widehat{\Phi}) \leq$$

$$\leq \frac{6d\phi^2}{2^{64} - \phi} + \left(\frac{dp^2}{2^{58}} + \frac{9dp}{2^{63} - p}\right) +$$

$$+dp \cdot \mathsf{Adv}^{\mathrm{EUF\text{-}CMA}}(3p, \mu + 2, 3\phi + 5p) + + \frac{d \cdot (t + T + 2\phi) \cdot (p + \phi)}{2^{255}}.$$

Thank you for your attention!

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