Witness-Functions versus Interpretation-Functions for Secrecy in Cryptographic Protocols: What to Choose?

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Abstract—Proving that a cryptographic protocol is correct for secrecy is a hard task. One of the strongest strategies to reach this goal is to show that it is increasing, which means that the security level of every single atomic message exchanged in the protocol, safely evaluated, never deceases. Recently, two families of functions have been proposed to measure the security level of atomic messages. The first one is the family of interpretation-functions. The second is the family of witness-functions. In this paper, we show that the witness-functions are more efficient than interpretation-functions. We give a detailed analysis of an ad-hoc protocol on which the witness-functions succeed in proving its correctness for secrecy while the interpretation-functions fail to do so.

Index Terms—Cryptographic protocols, interpretation-functions, secrecy, verification, witness-functions.

I. INTRODUCTION

A cryptographic protocol is an encrypted communication between at least two agents. This messages’ exchange is governed by a set of rules dictated by the protocol. The purpose of designing protocols using cryptography is to ensure the security of this communication, since it is always supposed to be executed in a hostile environment. In such insecure network, cryptography offers a robust set of techniques which counteract malicious intents and protect legitimate users. However, relying only on cryptography to achieve security goals is essential, it is insufficient. The most prominent example of this is the Needham-Schroeder protocol that had been deemed to be a secure protocol until it was paralyzed by a man-in-the-middle attack seventeen years after its first utilization. Hence, the need for analytical methods of cryptographic protocols’ verification is widely accepted. Several methods have been developed and varied models for their verification have been proposed as well. Although promising efforts, the obtained results remains mixed, and this is plausible since that proving the correctness of cryptographic protocols is generally an undecidable problem \[1\]–\[3\]. In this paper, we focus on two recent static methods, namely, the interpretation-functions and witness-functions. Both transform the correctness problem (regarding the secrecy property) into a problem of protocol growth. They emit sufficient conditions on the metrics, that measure the security level of each atomic message exchanged in the protocol, and on the protocol itself, to deduce that it is an increasing protocol and consequently could be declared correct. Here, we show that the witness-functions are more efficient than the interpretation-functions in proving secrecy in cryptographic protocols. The analysis takes place in a role-based specification \[4\]. We firstly extract the roles of each agent in the protocol. Then from these roles, we define the generalized roles according to the knowledge of each agent, while unknown messages are substituted by variables. In both analyses, we adopt the Dolev and Yao \[5\] conditions. We suppose that the intruder has the total control over the network: intercepting, blocking, forging and redirecting messages, anything except decrypting the message without possessing the decryption key. All the notations used in this paper are given in \[6\]. We refer the reader to carefully take note of them before further reading.

II. PAPER ORGANIZATION

This paper is organized as follows:

1) In Section\[\textsuperscript{III}\] we remind an important result: increasing protocols are correct for secrecy. We exhibit few conditions that must be satisfied by the functions used to evaluate the level of security of atomic messages;

2) In Section\[\textsuperscript{V}\] we present the interpretation-functions \[7\]–\[10\], their way of evaluating atomic messages and their way of treating variables;

3) In Section\[\textsuperscript{V}\] we present the witness-functions \[6\], \[11\]–\[17\], their way of evaluating atomic messages and their way of treating variables. We highlight their lower bounds and upper bounds and their usage of derivation to reduce variable impact;

4) In Section\[\textsuperscript{VI}\] we analyze an ad-hoc protocol by both interpretation-functions and witness-functions. We show that it could be proven correct by the witness-functions but not by the interpretation-functions. In Section we explain why that has happened and we explain why witness-functions are more precise than interpretation-functions;

5) In Section\[\textsuperscript{X}\] we conclude and we introduce to the future avenues of our research.
III. Correctness of Increasing Protocols

We remind here a crucial result: “A protocol is correct for secrecy when we analyze it with a safe function and we show that it is increasing”.

A. Safe Functions

Definition 1: (Well-Formed Function)
\[
F(\alpha, \{\alpha\}) = \bot
\]
\[
F(\alpha, M_1 \cup M_2) = F(\alpha, M_1) \sqcap F(\alpha, M_2)
\]
\[
F(\alpha, M) = \top, \text{ if } \alpha \notin A(M)
\]

Definition 2: (Full-invariant-by-intruder Function)
\[M \vdash_c m \Rightarrow (F(\alpha, m) \sqsubseteq F(\alpha, M)) \lor (K(I)^\gamma \sqsubseteq \nu \alpha^\gamma).
\]

A function \(F\) is safe iff it is well-formed and full-invariant-by-intruder.

Definition 3: (\(F\)-Increasing Protocol) A protocol \(p\) is \(F\)-
increasing iff: \(\forall R.r, F(\alpha, r^+ \sigma) \sqsubseteq \nu \alpha^\gamma \sqcap F(\alpha, R^- \sigma)\)

Theorem 1: (Secrecy of Increasing Protocols) If \(F\) is a safe function and \(p\) is an \(F\)-increasing protocol then \(p\) is correct for secrecy.

IV. Interpretation-Functions

Houmani et al. defined two functions called interpretation-functions: DEK and DEKAN. These functions safely evaluate the level of security of any atomic message. They operate on any message either it contains variables or it is a ground term. The variables are treated the same way as the ground atoms. The function DEK selects the direct encryption key of an atomic message \(\alpha\), that returns the identity of agents that know the reverse form of that key from the context. The function DEKAN returns in addition to the identity of agents that know the reverse form of the direct key in the context, all the neighbors of \(\alpha\) encrypted with that key. For example, we have:

- \(\text{DEK}(\alpha, \{\alpha.C.X\}_k) = \gamma k_{ab}^{-1} = \{A, B\}\)
- \(\text{DEKAN}(\alpha, \{\alpha.C.X\}_k) = \{C\} \cup \{X\} \cup \{A, B\} = \{C, X, A, B\}\)

Where \(X\) is a variable. The notation \(X\) refers to the set of agent identities in \(X\) after being substituted, which is only known at runtime. Please notice that the function DEKAN is not variable free (i.e. \(X\) is among the returned values). Now that we have these two functions, it is possible to evaluate the security level of any atom in any message. Hence, we can compare the level of security levels on sent messages with those in received messages and check whether a protocol is increasing or not. Theorem establishes its correctness if it is shown increasing.

V. Witness-Functions

The witness-functions have been proposed by Fattahi et al in [6], [11], [16], [17]. First, we define six functions \(F_K^{\gamma}, F_K^{\gamma}, F_K^{\gamma}, F_K^{\gamma}, F_K^{\gamma}, F_K^{\gamma}\) and we prove that they are safe functions. For lack of space, we will focus on the function \(F_K^{\gamma}\) only and we refer to it as \(F\). This function \(F\) operates on ground terms only and does not deal with variables. To rank the security level of an atom \(\alpha\) in a message \(m\), this function selects the reverse key of the innermost protective key, and returns the identity of agents that are allowed to know this key in the context, in addition to all the neighbor identities of \(\alpha\) in \(m\) encrypted with this key. The innermost protective key is not necessarily the direct key but the most internal encryption key that has a security level superior that the security level of \(\alpha\) given in the context. This function is not very useful in practice because a static analysis should take in consideration variables. To deal with variables, we use the derivative form of \(F\) instead of \(F\).

Definition 4: (Derivative Function)
\[
F'(\alpha, m^\sigma) = F(\alpha, \partial[\alpha]m^\sigma) = \begin{cases} F(\alpha, \partial m), & \text{if } \alpha \in A(\partial m), \\ F(X, \partial[X]m), & \text{if } \alpha \notin A(\partial m) \text{ and } \alpha = X\sigma, \forall \sigma \end{cases}
\]

Since \(F'(\alpha, m^\sigma)\) does not depend on substitution (i.e the run \(\sigma\)), we denote it simply by \(F'(\alpha, m)\). Although the derivative function \(F'\) eliminates the effect of variables, it is not yet good enough to analyze protocols. For example, for a valid trace \(m = \{\alpha.A.B\}_{k_{cd}}\) having two sources \(m_1 = \{\alpha.A.X\}_{k_{cd}}\) and \(m_2 = \{\alpha.Y.B\}_{k_{cd}}\) (\(X\) and \(Y\) are variables), it may return two different images (two security levels). For instance,

- \(F'(\alpha, \alpha.A.X)_{k_{cd}} = F(\alpha, \alpha.A.X)_{k_{cd}} = F(\alpha, \alpha.A)_{k_{cd}} = \{A, C, D\}\)
- \(F'(\alpha, \alpha.Y.B)_{k_{cd}} = F(\alpha, \alpha.Y.B)_{k_{cd}} = F(\alpha, \alpha.Y)_{k_{cd}} = \{B, C, D\}\)

For that, we define the witness-function. A witness function takes \(F\) and the protocol \(p\) as parameters, then looks for all the sources of a ground term \(m^\sigma\) in the finite set \(\mathcal{M}^\sigma_p\), then applies \(F'\) to all of them, and finally returns the minimum.

This minimum is obviously unique.

Definition 5: [Witness-Function]
\[
\mathcal{W}_{p,F}(\alpha, m^\sigma) = \bigcap_{(m', \sigma') \in \mathcal{M}^\sigma_p \sqcap \Gamma(m'^\sigma = m^\sigma)} F'(\alpha, m'^\sigma)
\]

Using a witness-function roughly is not realistic since we cannot predict all the valid traces \(m^\sigma\) and their sources in the protocol statically. For that, we bind witness-function into two bounds that do not depend on substitution (i.e on \(\sigma\)). The upper bound is \(F'(\alpha, m)\) and returns the smallest set of principal identities for any \(\alpha\) in \(m\) whereas the lower bound, which is \(\bigcap_{(m', \sigma') \in \mathcal{M}^\sigma_p \sqcap \Gamma(m'^\sigma = m^\sigma)} F'(\alpha, m'^\sigma)\), returns the largest set of identities from all the possible sources of \(m\) in the protocol (the messages that are unifiable with \(m\)). Considering these facts and Theorem the theorem of secrecy decision with a witness-function becomes as follows.

Theorem 2: [Decision for Secrecy]
\(p\) is correct with respect to secrecy if: \(\forall R.r, \forall \alpha \in A(r^+), \text{ we have:}\)
\[
\bigcap_{(m', \sigma') \in \mathcal{M}^\sigma_p \sqcap \Gamma(m'^\sigma = m^\sigma)} F'(\alpha, m'^\sigma) \sqsubseteq \nu \alpha^\gamma \sqcap F'(\alpha, R^-)
\]

This theorem is the one used to prove that a protocol is increasing or not. Its correctness for secrecy follows. Please
The aim of our analysis is to show that 
the interpretation-functions fail, whereas a wit- 
ness-function, we rather mean an analysis using the two bounds of 
generalized roles.

Let us have a context of verification such that:

1) Receiving step: \(DEK\)

\[
B, A, S, Y, r, s, k_a, \{A.N_a, S, B\}_{k_a}\)

The renamed variables in \(\tilde{\mathcal{N}}_p^G\) are denoted by 
\(X_2, Y_3, Z_4, Z_5, Y_5, T_6, T_7\):

A. Analysis of the Generalized Roles of \(A\)

According to the generalized role of \(A\), an agent \(A\) may take part in some session \(S^i\) in which he receives nothing (i.e. \(c\)) and sends the message \(\{A.N_a, S.B\}_{k_a}\). This is described by the following rule:

\[
S^i: \quad \epsilon \quad \{A.N_a, S.B\}_{k_a}
\]

-Analysis of the messages exchanged in \(S^i\):

1- For \(N_a^i\):

a- Receiving step: \(R^{-}_S, \epsilon\) (when receiving, we use the upper bound)

\[
F'(N_a^i, R^{-}_S) = F(N_a^i, 0) = F(N_a^i, \epsilon) = T
\]

\(b-\) Sending step: \(r^+_S, \{A.N_a, S.B\}_{k_a}\) (when sending, we use the lower bound)

Since \(\{A.N_a, S.B\}_{k_a}\) is a ground term (no variable in), then we have: \(\mathcal{T}_{p,F}(N_a^i, \{A.N_a, S.B\}_{k_a}) = F(N_a^i, \{A.N_a, S.B\}_{k_a})\)

Since \(F = F^{\text{left}}_{\mathcal{H}_{\max}}\), we have:

\[
F(N_a^i, \{A.N_a, S.B\}_{k_a}) = k_a^{-1} \cup \{A, S, B\}\)
\[ \Upsilon_{p,F}(N^i_a, \{A.N^i_a.S.B\}_{k_a}) = \{A, S, B\} \] (2)

2. Conformity with Theorem 2

From (1) and (2) and since \( N^{i+1}_a = \{A, B, S\} \) in the context, we have:

\[ \Upsilon_{p,F}(N^i_a, r^+_S) = r^+_a N^{i+1}_a \cap F'(N^i_a, R^+_S) \] (3)

Then, the generalized role of \( A \) respects Theorem 2 (I)

B. Analysis of the generalized roles of \( B \)

According to the generalized role of \( B \), an agent \( B \) participates in a session \( S^f \) in which he receives the message \( \{B.A.S.Y\}_{k_b}.\{A.B.S.Z\}_{k_b} \) and sends the message \( \{B.Z.A.Y.S\}_{k_a} \). This is described by the following rule:

\[ S^f : \{B.A.S.Y\}_{k_b}.\{A.B.S.Z\}_{k_b} \rightarrow \{B.Z.A.Y.S\}_{k_a} \]

1. \( \forall Z \):

a. Receiving step: \( R^-_{S^f} = \{B.A.S.Y\}_{k_b}.\{A.B.S.Z\}_{k_b} \) (when receiving, we use the upper bound)

\[ F'(Y, R^-_{S^f}) = F'(Y, \{B.A.S.Y\}_{k_b}.\{A.B.S.Z\}_{k_b}) \]
\[ F(Y, \partial Y)\{B.A.S.Y\}_{k_b}.\{A.B.S.Z\}_{k_b} \]
\[ F(Y, \{B.A.S.Y\}_{k_b} \cap F(Y, \{A.B.S.Z\}_{k_b}) \]
\[ r_{k_a} \rightarrow \{B.A.S.Z\}_{k_b} \]
\[ \{A, B, S\} \]

b. Sending step: \( r^+_S = \{B.Z.A.Y.S\}_{k_a} \) (when sending, we use the lower bound)

\[ \forall Z.\{m', \sigma'\} \in \hat{M}^\ast_p \cap \Gamma|m' \sigma' = r^+_S \sigma' \]
\[ \forall Z.\{m', \sigma'\} \in \hat{M}^\ast_p \cap \Gamma|m' \sigma' = \{B.Z.A.Y.S\}_{k_a} \sigma' \]
\[ \{\{B_5, Z_5, A_5, Y_5, S_5\}_{K_A, \sigma'_1}\} \] such that:
\[ \sigma'_1 = \{B_5 \rightarrow B, Z_5 \rightarrow Z, A_5 \rightarrow A, Y_5 \rightarrow Y, S_5 \rightarrow S, K_A, \rightarrow k_a\} \]
\[ \Upsilon_{p,F}(Z, \{B.Z.A.Y.S\}_{k_a}) \]
\[ = \{\text{Definition of the lower bound of the witness-function}\} \]
\[ F'(Z, \{B_5.Z_5.A_5.Y_5.S_5\}_{K_A, \sigma'_1}) \]
\[ = \{\text{Setting the static neighborhood}\} \]
\[ F'(Z, \{B_5.Z_5.A_5.Y_5.S_5\}_{k_a, \sigma'_1}) \]
\[ = \{\text{Definition} 4\} \]
\[ F(Z_5, \partial[Z_5]\{B.Z_5.A.Y.S\}_{k_a}) \]
\[ = \{\text{Derivation}\} \]
\[ F(Y_5, \partial[Y_5]\{B.Z_5.A.Y.S\}_{k_a}) \]
\[ = \{\text{Since} F = F^1_{MAX}\} \]
\[ \uparrow_{k_a} \rightarrow \{B, A, S\} = \{A, B, S\} \]
Then, we have:

$$\mathcal{T}_{p,F}(Y, \{B.Z.A.Y.S\}_{k_a}) = \{A, B\}$$  \hspace{1cm} (7)

3- Conformity with Theorem 2

From (4) and (5), we have:

$$\mathcal{T}_{p,F}(Z, r^+_S) \supseteq \neg Z^\gamma \cap F'(Z, R^-_S)$$  \hspace{1cm} (8)

From (6) and (7), we have:

$$\mathcal{T}_{p,F}(Y, r^+_S) \supseteq \neg Y^\gamma \cap F'(Y, R^-_S)$$  \hspace{1cm} (9)

From (8) and (9), we have: the generalized role of B respects Theorem 2 (II)

C. Analysis of the generalized roles of S

According to the generalized role of B, an agent B participates in a session $S^i$ in which he receives the message $\{A.T.S.B\}_{k_b}$ and sends the message $\{B.A.S.T\}_{k_i}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b}$. This is described by the following rule:

$$S^i : \{A.T.S.B\}_{k_b} \rightarrow \{B.A.S.T\}_{k_b}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b}$$

1- $\forall T$:

a- Receiving step: $R^-_S = \{A.T.S.B\}_{k_b}$ (when receiving, we use the upper bound)

$$F'(T, \{A.T.S.B\}_{k_b}) = F(T, \partial[T]\{A.T.S.B\}_{k_b})$$
$$= F(T, \{A.T.S.B\}_{k_b})$$
$$= \neg k_b^{-1} \cap \{A, S, B\}$$
$$= \{A, B, S\}$$  \hspace{1cm} (10)

b- Sending step: $r^+_S = \{B.A.S.T\}_{k_b}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b}$ (when sending, we use the lower bound). We have:

$$\mathcal{T}_{p,F}(T, r^+_S) \supseteq \neg T^\gamma \cap F'(T, R^-_S)$$

$$\mathcal{T}_{p,F}(T, r^+_S) = \mathcal{T}_{p,F}(T, \{B.A.S.T\}_{k_b}) \supseteq \neg T^\gamma \cap F'(T, R^-_S)$$

$$= \mathcal{T}_{p,F}(T, \{B.A.S.T\}_{k_b})$$

$$= \mathcal{T}_{p,F}(T, \{A.B.S\{S.sec\}_{k_a}\}_{k_b})$$

$$= \mathcal{T}_{p,F}(T, \{A.B.S\{S.sec\}_{k_a}\}_{k_b})$$

$$= \mathcal{T}_{p,F}(T, \{A.B.S\{S.sec\}_{k_a}\}_{k_b})$$

$$\forall T, \{(m', \sigma') \in \hat{M}_p^\mathcal{T} \otimes \Gamma | m' \sigma' = r^+_S, \sigma'\}$$

$$= \forall T, \{(m', \sigma') \in \hat{M}_p^\mathcal{T} \otimes \Gamma | m' \sigma' = \{B.A.S.T\}_{k_b}, \sigma'\}$$

$$= \{(A.T.S.B.Y_i)_{k_{b2}}, \sigma_i\}$$ such that:

$$\sigma_i = \{B_7 \rightarrow B, A_7 \rightarrow A, S_7 \rightarrow S, T_7 \rightarrow T, K_{B_7} \rightarrow k_b\}$$

$$\mathcal{T}_{p,F}(T, \{B.A.S.T\}_{k_b})$$

$$= \{\text{Definition of the lower bound of the witness-function}\}$$

$$F'(T, \{B_7.A_7.S_7.T_7\}_{k_{b1}}, \sigma'_i)$$

$$= \{\text{Setting the static neighborhood}\}$$

$$F'(T, \{B.A.S.T\}_{k_b}, \sigma'_i)$$

$$= \{\text{Definition} 4\}$$

$$F(T_7, \partial[T_7]\{B.A.S.T\}_{k_b})$$

$$= \{\text{Derivation}\}$$

$$F(T_7, \{B.A.S.T\}_{k_b})$$

$$= \{\text{Since } F = F_{\text{MAX}}\}$$

$$\neg k_b^{-1} \cap \{B, A, S\} = \{A, B, S\}$$

Then, we have:

$$\mathcal{T}_{p,F}(T, \{B.A.S.T\}_{k_b}) = \{A, B, S\}$$  \hspace{1cm} (12)

2- For the secret sec:

a- Receiving step: $R^-_S = \{A.T.S.B\}_{k_b}$ (when receiving, we use the upper bound)

$$F'(\text{sec}, \{A.T.S.B\}_{k_b}) = F(\text{sec}, \{A.B.S\}_{k_b})$$

$$= T$$  \hspace{1cm} (13)

b- Sending step: $r^+_S = \{B.A.S.T\}_{k_b}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b}$ (when sending, we use the lower bound)

$$\mathcal{T}_{p,F}(\text{sec}, r^+_S) = \mathcal{T}_{p,F}(\text{sec}, \{B.A.S.T\}_{k_b})$$

$$= \mathcal{T}_{p,F}(\text{sec}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b})$$

$$= \mathcal{T}_{p,F}(\text{sec}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b})$$

$$= \mathcal{T}_{p,F}(\text{sec}, \{A.B.S\{S.sec\}_{k_a}\}_{k_b})$$

$$\forall T, \{(m', \sigma') \in \hat{M}_p^\mathcal{T} \otimes \Gamma | m' \sigma' = r^+_S, \sigma'\}$$

$$= \forall T, \{(m', \sigma') \in \hat{M}_p^\mathcal{T} \otimes \Gamma | m' \sigma' = \{B.A.S.T\}_{k_b}, \sigma'\}$$

$$= \{(A.T.S.B.Y_i)_{k_{b2}}, \sigma_i\}$$ such that:

$$\sigma_i = \{B_7 \rightarrow B, A_7 \rightarrow A, S_7 \rightarrow S, T_7 \rightarrow T, K_{B_7} \rightarrow k_b\}$$

$$\mathcal{T}_{p,F}(T, \{B.A.S.T\}_{k_b})$$

$$= \{\text{Definition of the lower bound of the witness-function}\}$$

$$F'(T, \{B.A.S.T\}_{k_b}, \sigma'_i)$$

$$= \{\text{Definition} 4\}$$

$$F(T_7, \partial[T_7]\{B.A.S.T\}_{k_b})$$

$$= \{\text{Derivation}\}$$

$$F(T_7, \{B.A.S.T\}_{k_b})$$

$$= \{\text{Since } F = F_{\text{MAX}}\}$$

$$\neg k_b^{-1} \cap \{B, A, S\} = \{A, B, S\}$$

Then, we have:

$$\mathcal{T}_{p,F}(T, \{B.A.S.T\}_{k_b}) = \{A, B, S\}$$  \hspace{1cm} (12)

3- Conformity with Theorem 2

From (10) and (12), we have:

$$\mathcal{T}_{p,F}(T, r^+_S) \supseteq \neg T^\gamma \cap F'(T, R^-_S)$$

From (13) and (15), we have:

$$\mathcal{T}_{p,F}(\text{sec}, r^+_S) \supseteq \neg \text{sec}^\gamma \cap F'(\text{sec}, R^-_S)$$

From (16) and (17), we have: the generalized role of S respects Theorem 2 (III)

From (I) and (II) and (III), we conclude that: p respects Theorem 2 So it is increasing, then, it is correct for secrecy. (IV)

IX. RESULTS, INTERPRETATION AND RELATED WORKS

As a result of our analysis, one witness-function succeeds in demonstrating the correctness of the protocol p for secrecy, whereas the two interpretation-functions fail to do so. Indeed, the witness-functions have two major advantages compared to the interpretation-functions. On the one hand, the incorporated
derivation in the upper bound of a witness-function precludes variables from playing any role in the received messages. On the other hand, variables in sent messages are carefully rummaged by the lower bound. These variables sometimes contain odd identities, interpreted as an intrusion, but often they do not, as it was the case in our protocol. This tightly depends on the protocol structure. As for the interpretation-functions, they treat variables with naivety. They just return their content (i.e., agent identities) with no further inspection. This may often constitute an obstacle in showing the protocol growth, then, its correctness. A classical scenario on which the interpretation-function DEKAN always fails is when an atomic secret $\alpha$ is received with a variable $X$ as a neighbor, and sent with another variable $Y$ as a neighbor. In that case, there is no hope to prove the growth of the protocol. Besides, in case of an analysis failure with a witness-function, we can figure out which encryption pattern causes this failure, and hence, we understand where and why a potential flaw may occur, if any. This indicates us with precision which item we have to modify in the protocol structure so that it becomes increasing, as well. The interpretation-functions do not have this capability to precisely explain why a flaw arises. They just give a raw and fuzzy indication about it. This indication is, in several cases, not helpful or even misleading. According to our experience, the false positive ratio related to interpretation-functions is much higher than the one related to the witness-functions. However, this precision has its cost. On the one hand, the protocol analysis with a witness-function is slower than the analysis with an interpretation-function. On the other hand, analyzing a protocol with a witness-function is sensitive to multi-protocol environments. In contrast, analyzing it with an interpretation-function is not, as these latter are universal.

X. CONCLUSION AND FUTURE WORK

In this paper, we have exhibited a comparative study between witness-functions and interpretation-functions throughout a detailed analysis of an ad hoc protocol. We managed to show that the witness-functions may very much succeed where the interpretation-functions failed. In a future work, we will provide the formal proof that the witness-functions mask the interpretation-functions. That means, we will formally prove that, when the witness-functions fail, the interpretation-functions necessarily fail, and when the interpretation-functions succeed, the witness-functions necessarily succeed. This will be the final step toward the deprecation of the interpretation-functions.

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