A Tool helping to Design Cryptographic Protocols

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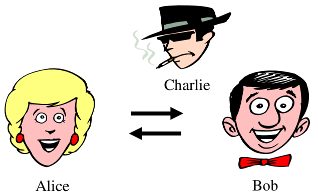
Automated Validation of Internet Security Protocols and Applications

Shared cost RTD (FET open) project IST-2001-39252

Motivation

- The world is distributed:
  - Our basic infrastructures are increasingly based on networked information systems.
  - Business, finance, communication, transportation, energy distribution, entertainment, . . .



Alice → Bob@Bank: "Transfer 100€ to account X"
Bob@Bank → Alice: "Transfer carried out"

- How does Bob know that he is really speaking with Alice?
- How does Bob know Alice just said it?
- Confidentiality, integrity, accountability, non-repudiation, privacy, . . . ?

Motivation

- The world is distributed:
  - Our basic infrastructures are increasingly based on networked information systems.
  - Business, finance, communication, transportation, energy distribution, entertainment, . . .
- Protocols essential for developing networked services and new applications.
- Security errors in protocol design are costly.

  Money: security updates are costing hundreds of millions $/€.
  Time: protocols are delayed by years.
  Confiance: eroding confidence in Internet Security and new applications.

Motivation

- The number and scale of new security protocols under development is out-pacing the human ability to rigorously analyse and validate them.
- To speed up the development of the next generation of security protocols and to improve their security, it is of utmost importance to have

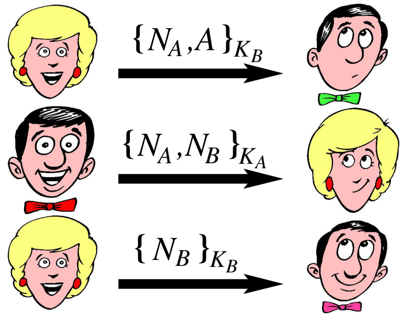
> tools that support the rigorous analysis of security protocols by either finding flaws or establishing their correctness.

- Optimally, these tools should be completely automated, robust, expressive, and easily usable, so that they can be integrated into the protocol development and standardization processes.

The State of the Art. . .

- Several (semi-)automated protocol analyzers have been proposed,
BUT automatic analysis limited to small and medium-scale protocols, e.g.:

Mutual authentication protocol (NSPK):
1. $A \to B: \ \{N_A, A\}_{K_B}$
2. $B \to A: \ \{N_A, N_B\}_{K_A}$
3. $A \to B: \ \{N_B\}_{K_B}$



"This is Alice and I have chosen a nonce N_A."

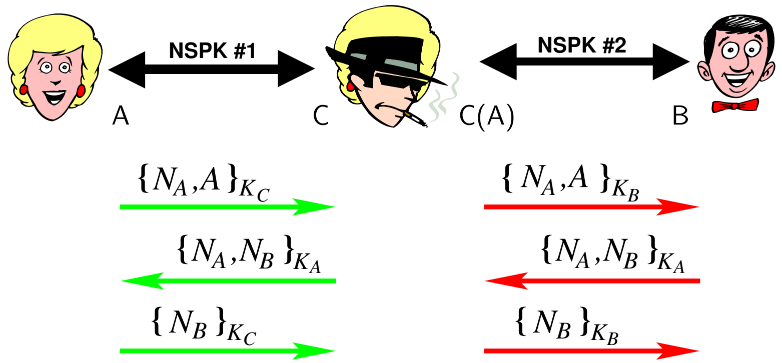
"Here is your nonce N_A. Since I could read it, I must be Bob. I also have a challenge N_B for you."

"You sent me N_B. Since only Alice can read this, and I sent it back, I must be Alice."

Protocols are typically small and convincing. . . but often wrong!

Man-in-the-Middle Attack

1. $A \to B: \ \{N_A, A\}_{K_B}$
2. $B \to A: \ \{N_A, N_B\}_{K_A}$
3. $A \to B: \ \{N_B\}_{K_B}$



B believes he is speaking with A!

What went wrong?

- Problem in step 2: $B \to A: \{N_A, N_B\}_{K_A}$
Agent B should also give his name: $\{N_A, N_B, B\}_{K_A}$

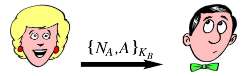
- Is this new version correct now?

. . . against this or other kinds of attacks?

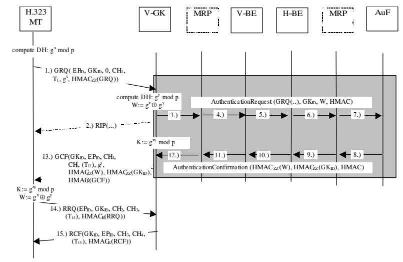
Use formal methods (and automated tools)!

The State of the Art. . .

- Several (semi-)automated protocol analyzers have been proposed,
BUT automatic analysis limited to small and medium-scale protocols.
  - For example, Clark/Jacob protocol library:
NSPK, NSSK, Otway-Rees, Yahalom, Woo-Lam, Denning-Sacco, . . .



  - Most tools come with their own specification language and user interface.



  - Scaling up to large-scale Internet security protocols is a considerable scientific and technological challenge.

...and beyond: the AVISPA Project

- A rich specification language for formalising industrial strength security protocols and thier properties.
- Advance state-of-the-art analysis techniques to scale up to this complexity.
- An integrated tool supporting the protocol designer in the debugging and validation of protocols via a uniform and user-friendly interface.
  $\Longrightarrow$ AVISPA Tool
- Tool assessed on a large collection of practically relevant, industrial protocols
  $\Longrightarrow$ AVISPA Library
- Migration of this technology to companies and standardisation organisations.

AVISPA Tool

- Push-button security protocol analyzer.
- Supports the specification of security protocols and properties by means of a rich protocol specification language.
- Integrates different back-ends implementing a variety of state-of-the-art automatic analysis techniques.
- User interaction facilitated by:
  - XEmacs mode.
  - Web interface.

A state-of-the-art (for level of scope and performance), integrated environment for the automatic analysis and validation of Internet security protocols.

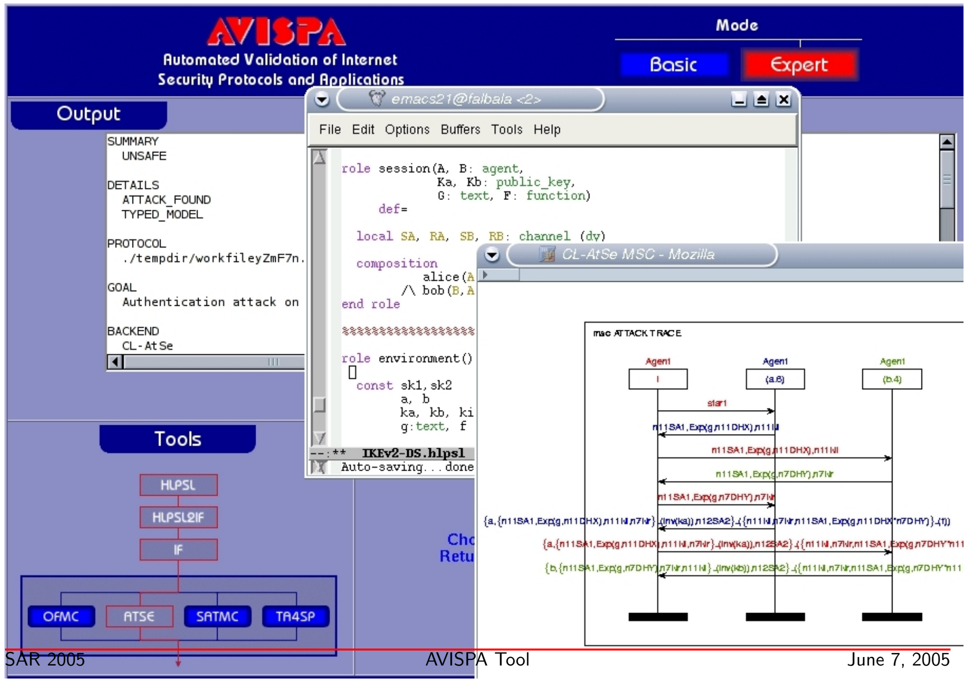
AVISPA Tool: Web Interface

- The AVISPA tool is freely accessible on the web:

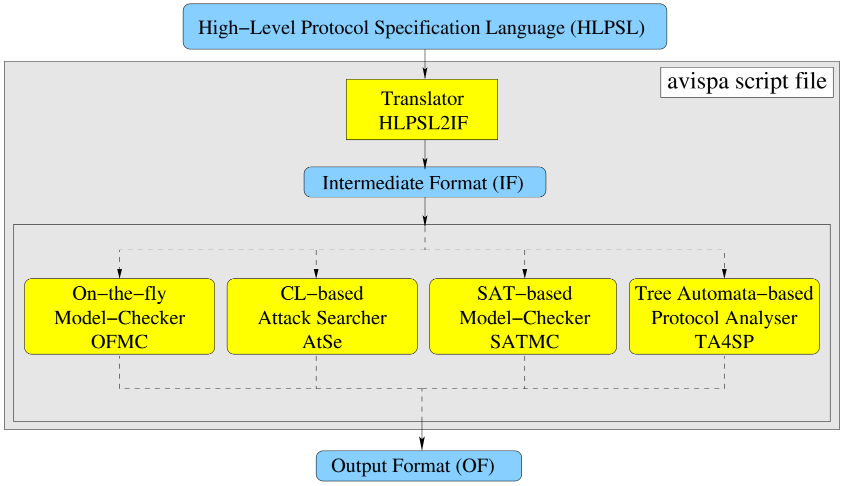
  http://www.avispa-project.org

- The interface features:
  - A simple editor for HLPSL specifications.
  - Basic/Expert user modes.
  - Attacks are graphically rendered with message-sequence charts.

just a quick look. . .



AVISPA Tool: Architecture



AVISPA Tool: HLPSL

(High-Level Protocol Specification Language)

A powerful specification language:

- modular, role-based: basic roles (participants) and composed roles (sessions, instances);
- various cryptographic bases: symmetric keys (non-atomic), public/private keys, hash functions, nonces;
- typed information (or not): simple and compound types;
- algebraic properties: concatenation, exclusive-or, exponentiation;
- channels: for exchanging messages (Dolev-Yao);
- flow control: guarded transitions;
- studied properties: secrecy, weak and strong authentication.

Explicit semantics:

- a declarative semantics based on a fragment of Lamport's temporal logic of actions (TLA);
- an operational sémantics based on a translation into a rewriting-based formalism: the Intermediate Format (IF).

AVISPA Tool: Back-ends

Implemented methods: protocol falsification, bounded and unbounded verification.

OFMC: On-the-fly Model-Checker
employs several symbolic techniques to explore the state space in a demand-driven way.

AtSe: Constraint-Logic-based Attack Searcher
applies constraints solving with simplification heuristics and redundancy elimination techniques.

SATMC: SAT-based Model-Checker
builds a propositional formula encoding all the possible attacks (of bounded length) on the protocol and feeds the result to a SAT solver.

TA4SP: Tree Automata-based on Automatic Approximations for the Analysis of Security Protocols
approximates the intruder knowledge by using regular tree languages and rewriting to produce under- and over-approximations.

AVISPA Library

- Beyond Clark/Jacob (a few seconds for the entire library, with new attacks).
- Selection of a substantial set of security problems associated with protocols that have recently been or are currently being standardized by the IETF.
- Formalisation in HLPSL of a large subset of these protocols
  $\Longrightarrow$ AVISPA Library.
- At present the AVISPA Library comprises 112 security problems derived from 33 protocols.
- AVISPA Tool assessed by running it against the AVISPA Library.

Some protocols: AAAMobileIP, CHAPv2, CRAM-MD5, DHCP-delayed-auth, EKE2, IKEv2-CHILD, IKEv2-DS, IKEv2-MAC, ISO-9798, Kerb-Basic, Kerb-Cross-Realm, Kerb-PKinit, Kerb-Preauth, LPD-MSR, PBK, SRP, TLS, UMTS_AKA.

Also: TA4SP establishes in a few minutes that a number of protocols (EKE, EKE2, TLS, UMTS_AKA, CHAPv2) guarantee secrecy.

AVISPA Tool: How to use it?

Main steps:

Given, for example, a *RFC document*,

1. Write the messages exchange in an *Alice&Bob notation*,
2. Write this exchange in the *point of vue* of each participant,
3. Specify a *basic role* for each participant, with parameters, local variables, . . .
4. Specify *composition roles*: one role representing a session, one environment role representing the required instances,
5. Specify *properties* to check: goal section, plus goal predicates in some transitions of basic roles.

Run the AVISPA Tool: the translator will verify the syntax; the chosen back-end will verify the properties.

Conclusion and Future Work

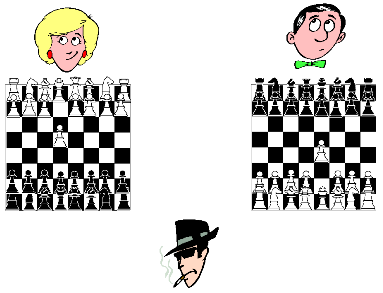
Bilan of the AVISPA Project:

- AVISPA Tool: a state-of-the-art, integrated environment, for automated analysis and validation of Internet security protocols.
- Information on `http://www.avispa-project.org`:
  - Web interface for demos;
  - AVISPA package v1.0: officially released in a couple of days!
  - Scientific papers, Slides,. . .

Future Work:

- Collaborations: Siemens AG (IETF), France Telecom.
  Large distribution of the AVISPA Tool $\Longrightarrow$ many future collaborations?
- Diversification of the activities: more properties (non-repudiation, fairness,. . .); more kinds of protocols (contributing protocols, web services, . . .).

Questions?



Demonstration on demand, or online:
`http://www.avispa-project.org`