VERIFYING SECURITY PROTOCOLS USING THE PROVERIF TOOL

Security protocols (bmevihim132)

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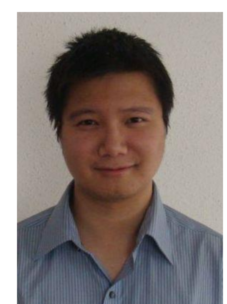

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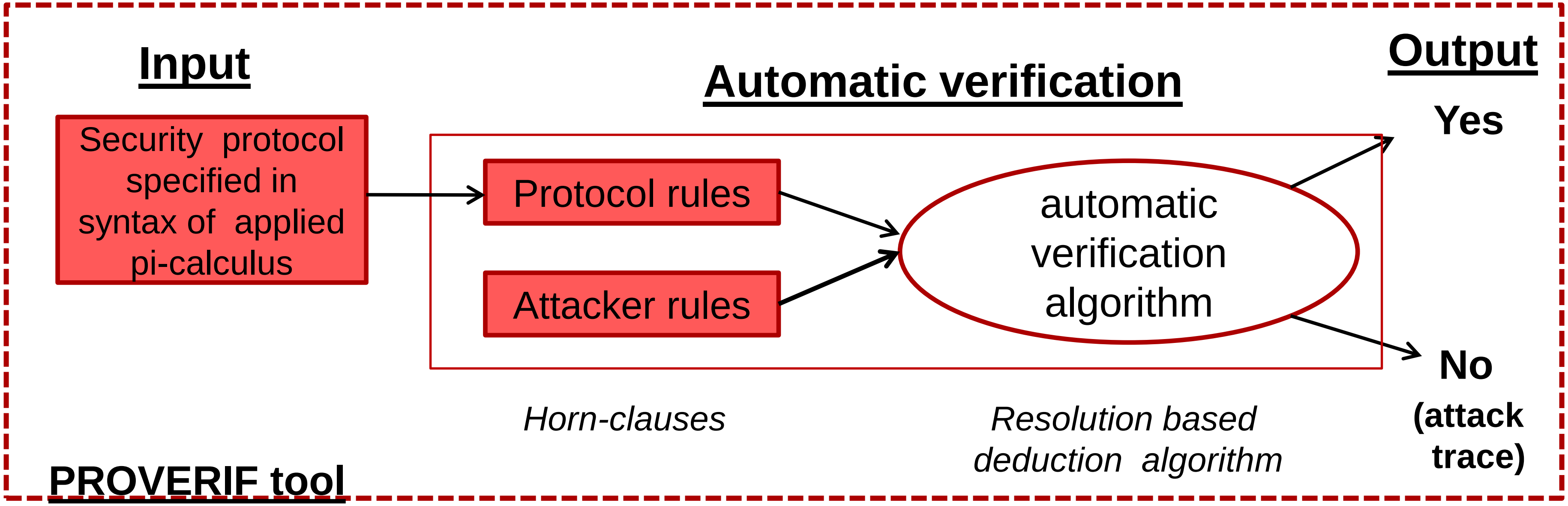
Proverif verification tool



- Bruno Blanchet, ~ 2004.
- A kind of theorem prover (based on logic), but fully automated.
- Security protocols are specified in a simplified form of applied pi calculus.
- Can verify strong secrecy, weak secrecy, forward secrecy, authenticity, anonimity.

Variants of the pi-calculus

- Pure pi-calculus [Robin Milner. 1990]
  - Calculus for concurrent computation.
  - Main features: fresh names, communication channels, name passing, recursion.

- Spi-calculus [Martin Abadi, Andrew Gordon. 1997]
  - Extend the pure pi-calculus with fixed number of crypto primitives.
  - Main features: prove security properties using bisimulations.

- Applied pi-calculus [Martin Abadi, Cédric Fournet. 2001]
  - Extend spi-calculus with additional bisimilarities, more crypto primitives.
  - Main features: much easier usage to prove security properties.

Typed applied pi-calculus

$M, N ::=$	terms
a, b, c, k, m, n, s	names
x, y, z	variables
$(M_1, \ldots, M_k)$	tuple
$h(M_1, \ldots, M_k)$	constructor/destructor application
$C ::=$	conditions
$M = N$	term equality
$M <> N$	term inequality
M	term (of type bool)
$C \ \&\& \ C$	conjunction
$C \ \|\| \ C$	disjunction
$\mathbf{not}(C)$	negation
$P, Q ::=$	processes
0	null process
$P \mid Q$	parallel composition
$!P$	replication
$\mathbf{new}\ n : t;\ P$	name restriction
$\mathbf{in}(M, x : t);\ P$	message input
$\mathbf{out}(M, N);\ P$	message output
$\mathbf{if}\ \ C\ \mathbf{then}\ P\ \mathbf{else}\ Q$	conditional
$\mathbf{let}\ \ x = M\ \mathbf{in}\ P\ \mathbf{else}\ Q$	term evaluation
$R(M_1, \ldots, M_k)$	macro usage

Pattern matching

$T ::=$	patterns
$x : t$	typed variable
x	variable without explicit type
$(T_1, ..., T_n)$	tuple
$=M$	equality test

- Variable pattern *x:t* matches any term of type *t* and binds the matched term to *x*.
- x can be used only when the type of x can be inferred from the context.
- Tuple pattern *(T1,…,Tn)* matches tuples *(M1,…,Mn)* where each component *Mi* is recursively matched with *Ti.*
- The pattern =*M* matches terms *N* where *M* = *N*.
  - *in(=M);P waits a term that matches pattern M, then behaves as P.*

Input e.g.,: in(c, x:t); Q can be written as in(c, =M); Q

ProVerif's input file – 1

- **Declaration, process definition, queries**

$< decl >::=$	*declaration*
$type\ t$	user defined type
$free\ \ name : t$	public free names
$free\ \ name : t\ [private]$	private free names
$const\ \ c{:}t$	constant c of type t
$table\ \ d(t_1,...,t_n)$	table d takes records of type $t_1,..,t_n$
$fun\ \ f(t_1,...,t_n) : t$	public constructor function
$fun\ \ f(t_1,...,t_n) : t\ \ [private]$	private constructor function
$reduc\ \ forall\ x_1{:}t_1,..., x_n{:}t_n;\ g(M_1,..., M_k) = M$	public destructor application
$reduc\ \ forall\ x_1{:}t_1,..., x_n{:}t_n;\ g(M_1,..., M_k) = M\ [private]$	private destructor application

ProVerif's input file – 2

$< procmacro > ::=$ *sub-process definition*

$let\ R(x_1, ..., x_n) = P.$ define a process with the name R.

$< mainproc > ::=$ *main process definition*

$process\ P$

$< query > ::=$ *define properties to be verified.*

$query\ attacker(M).$ want to verify weak secrecy of M.

$query\ event(M) ==> event(N).$ in any trace: event N is always before event M.

$query\ inj-event{:}M ==> inj-event{:}N.$ in any trace: at least as many N-events as M-events.

$noninterf\ x$ want to verify strong secrecy of x.

$noninterf\ x\ among\ \{M_1, ..., M_k\}$ want to verify strong secrecy of x taken value from a set.

The structure of the whole ProVerif source file is

$$< decl >^* < query >^* < procmacro >^* < mainproc >$$

Types and Names

type t	user defined type.
free name:t	free names.
free name:t [private]	private free names.

- User defined type can be anything except for pre-defined, built-in types.
  - User defined: bitstring, skey, pkey, etc.
- Free names model public data, which are available for the attacker.
  - public keys, communication channels, participant IDs, etc.
- Private names model secret data, which are not known by the attacker.
  - secret keys, etc.
- Identifiers range over an unlimited sequence of letters (a-z, A-Z), digits (0-9), underscores (_), singlequotes('), and accented letters from the ISO Latin 1 character set.
  - E.g. free **secretKey**:skey.

Constructor functions

$fun\ \ f(t_1,...,t_n):t$ public constructor function

$fun\ \ f(t_1,...,t_n):t\ [private]$ private constructor function

- Constructor function:
  - *f* is a function of arity *n*.
  - *t* is a type of the returned value, and *t1,…, tn* are types of the arguments.
  - constructor functions are available to all participants (honest and attacker).
  - private constructor function are available to only honest participants.
    - E.g., key databased (table) stored by the honest nodes.

Destructor applications

$$reduc\ \ forall\ \ x_1{:}t_1,\ldots,x_n{:}t_n;\ g(M_1,\ldots,M_k)=M$$ public destructor application

$$reduc\ \ forall\ \ x_1{:}t_1,\ldots,x_n{:}t_n;\ g(M_1,\ldots,M_k)=M\ [private]$$ private destructor application

- Destructor applications:
  - *g* is a function of arity *k*.
  - *t1,…, tn* are types of the variables *x1, …, xn*.
  - *x1, …, xn* are variables in terms *M1, …, Mk.*
  - destructor applications are available to all participants (honest and attacker).
  - private destructor applications are available to only honest participants.

Constructor and Destructor examples

Symmetric encryption (User defined)

type bitstring, key.

fun senc(bitstring,key):bitstring

reduc forall m: bitstring, k : key;sdec (senc (m, k), k) = m.

Asymmetric encryption (User defined)

type bitstring, skey, pkey.

fun pk(skey):pkey

fun penc(bitstring, pkey):bitstring

reduc forall m : bitstring, k : skey; pdec (penc (m, pk(k)), k) = m.

Constructor and Destructor examples

Digital signatures (User defined)

$type\ bitstring, sskey, spkey.$

$fun\ spk(sskey){:}spkey$

$fun\ sign(bitstring, sskey){:}bitstring$

$reduc\ forall\ m{:}\ bitstring, k : sskey; checksign\ (sign(m, spk(k)), k) = m.$

One-way functions (User defined)

$type\ \ bitstring, key.$

$fun\ \ hash(bitstring) : bitstring.$

$fun\ \ mac(bitstring, key).$

Tuples (bult-in)

$fun\ \ (t_1,...,t_k) : bitstring$

$reduc\ \ forall\ x_1{:}t_1,...,x_k{:}t_k;\ ith((M_1,...,M_k)) = M_i$

Tables

Tables and operations

$$table\ \ d(t_1,...,t_n) \qquad (*\ \ declation*)$$

$$insert\ d(M_1,...,M_n); P$$

$$get\ d(T_1,...,T_m)\ \ in\ \ P$$

$$get\ d(T_1,...,T_m)\ \ suchthat\ C\ \ in\ \ P$$

- *d* is the name of the table which takes records of type *t1, . . . , tn.*
- Processes may populate and access tables, but deletion is forbidden.
- Process *insert d(M1, . . . ,Mn); P* inserts the record *M1, . . . ,Mn* into the table *d* and then executes *P.*
- Process *get d(T1, . . . , Tn)* in *P* attempts to retrieve a record in accordance with patterns *T1, . . . , Tn.*
  - When no such record is found, the process blocks.
  - In case there are several identical records, one is chosen from them.
- C is an additional condition for the records.

Process Macros, subprocesses

- Defining *sub-processes* that will be used in the main process.
- *R* is a *macro name, P* is a *sub-process* being defined *x1,…xn* of type *t1,…,tn* are variable of *P.*
- *R(M1, . . . ,Mn)* will then expand to *P* with *M1* substituted for *x1, . . . , Mn* substituted for *xn*.

$$let \quad R(x_1 : t_1, ..., x_n : t_n) = P$$

Bracketing, precedence

- P | Q binds most closely, ! P | Q is equal to !(P | Q)
- if C then Q else P
- let x=M in P else Q
- unary processes bind least closely.

1. new n : t ; out(c , n) | new n : t; in (c, x : t); 0 | if x = n then 0 | out (c, n), is braketed as
   new n : t ; (out (c, n) | new n : t; (in(c, x : t); 0 | if x = n then (0 | out (c, n))))

2. if M = M′ then if N = N′ then P else Q, is braketed as
   if M = M′ then (if N = N′ then P else Q)

3. let x = M in let y = N then P else Q, is braketed as
   let x = M in (let y = N then P else Q)

Hello word script

1. (* *hello.pv* : *Hello World Script* *)
2. free c : channel.
3. free K_1 : bitstring [private].
4. free K_2 : bitstring [private].
5. query attacker(K_1).
6. query attacker(K_2).
7.
8. process
9. out(c, K_2);
10. 0

Public channel

Secret keys

Can Dolev-Yao attacker(s) obtain keys?

Main process

Send key K2 on channel c

Termination of process. Can be omitted.

- The verification algorithm attempts to prove that the states in which the keys are obtained by the attacker are unreachable.

not attacker(K1) is true/false

Hello world with process macros

```
1. (* Hello World Script with Macros *)
2. free c : channel.
3. free K1 : bitstring [private].
4. free K2 : bitstring [private].
5. query attacker(K1).
6. query attacker(K2).
7.
8. let R(x : bitstring) = out(c, x);0.
9. let R'(y : bitstring) = 0.
10. process R(K1) | R'(K2)
```

Macros

Main process

ProVerif output

Process :

[Process]

The specified protocol. Each row is labelled with {n}, where n is an integer.

- - Query [Query]

Completing...

Starting query [Query]

RESULT [un]reachable : Goal.

Verifying the property given in [Query] by user.

[Attack derivation]

Reconstruct and return the detected attack

set traceDisplay = long.

[Attack trace]

RESULT [Query] [result].

Finally, ProVerif reports if the Query was satisfied.

- Internally, ProVerif attempts to prove that *a state in which a property is violated is unreachable*;
- ProVerif shows the (un)reachability of some [Goal].

Running result of the hello world script

Process

$\{1\}\,\text{out}(c, K_2)$

-- Query not attacker(K_1[])

Completing...

Starting query not attacker(K_1[])

RESULT not attacker(K_1[]) is true.

-- Query not attacker(K_2[])

Completing...

Starting query not attacker(K_2[])

goal reachable : attacker(K_2[]).

The message K_2[] may be sent to the attacker at output {1}.

attacker(K_2[]).

set traceDisplay = long.

out(c, K_2) at {1}

The attacker has the message K_2.

A trace has been found.

RESULT not attacker(K_2[]) is false

Try to prove **not attacker(K1[ ])**

attacker(K1[ ]) is false

The attacker can obtain K2.

Attack trace is returned.

Queries full syntax

$q ::=$	query
F	fact
$F \texttt{==>} H$	correspondence
$H ::=$	hypothesis
F	fact
$H \, \&\& \, H$	conjunction
$H \, \vert\vert \, H$	disjunction
$(F \texttt{==>} H)$	nested correspondence
$F ::=$	fact
$\mathrm{attacker}(M)$	the adversary has M (in any phase)
$\mathrm{attacker}(M)$ **phase** n	the adversary has M in phase n
$\mathrm{mess}(N, M)$	M is sent on channel N (in the last phase)
$\mathrm{mess}(N, M)$ **phase** n	M is sent on channel N in phase n
$\mathbf{event}(e(M_1, \ldots, M_n))$	non-injective event
$\mathbf{inj-event}(e(M_1, \ldots, M_n))$	injective event
$M{=}N$	equality
$M{<>}N$	inequality

Security properties, Queries

- Reachability and weak secrecy
  - which term will be ontained by the attacker during protocol runs.
  - E.g., **query attacker(M) -** can the attacker obtain term M?

    M is ground term, does not contain destructor applications.

- Correspondence assertions, events, authentication
  - if an event *e* has been executed, then event *e′* has been previously executed.
  - processes are annotated with **events**, which mark stages reached by the protocol.
  - but do not affect the behaviour of processes.
  - definition in process: **Process** ***….*** **event e(M1,…,Mn); P ….**
  - declaration: **event e(t1,…,tn).** Where t1,…,tn are types of arguments.
  - Query: **query x1:t1,…, xn:tn; event e(M1,…,Mj) ==> event e' (N1,…,Ni)**
  - for each occurence of **e(M1,…,Mj)**, event **e' (N1,…,Ni)** has occured before.

- Injective correspondence
  - one-to-one relationship between the number of protocol runs performed by each participant.
  - E.g., Financial transaction
    - server request payment from the client.
    - server should complete payment only once for each transation started by the client.
  - Query: **query x1:t1,…, xn:tn; inj-event e(M1,…,Mj) ==> inj-event e' (N1,…,Ni)**

Naiv handshake protocol

$$C \rightarrow S : pk_C$$
$$S \rightarrow C : \{\{pk_S, k\}_{sk_S}\}_{pk_C}$$
$$C \rightarrow S : \{s\}_k$$

- Each principal has a public/private keypair.
- The client knows the server's public key.
- The aim of the protocol: client shares the secret **s** with the server.

- Security properties would like to provide
  - ***Secrecy***: the value s is known only to Client and Server.
  - ***Authentication of Client to Server*** : if Server reaches the end of the protocol and he believes he has shared the key k with Client, then Client was indeed his interlocutor and she has shared k.
  - ***Authentication of Server to Client*** : if Client reaches the end of the protocol with shared key k then Server indeed proposed k for use to Client.

Naiv handshake prot. Declaration

Symmetric encryption

- **type** key.
- **fun** senc(bitstring, key) : bitstring.
- **reduc for all** m: bitstring, k:key; sdec(senc(m,k), k) = m.

Assymmetric encryption

- **type** skey.
- **type** pkey.
- **fun** pk(skey) : pkey.
- **fun** aenc(bitstring, pkey) : bitstring.
- **reduc for all** m: bitstring, k : skey; adec(aenc(m, pk(k)),k) = m.

Digital signature

- **type** sskey.
- **type** spkey.
- **fun** spk(sskey) : spkey.
- **fun** sign(bitstring, sskey) : bitstring.
- **reduc for all** m: bitstring, k : sskey; getmess(sign(m, k)) = m.
- **reduc for all** m: bitstring, k : sskey; checksign(sign(m, k), spk(k)) = m.

Verifying weak secrecy in the Handshake protocol.

```
free c : channel .
free s : bitstring [private] .
query attacker(s) .

let clientC(pkC: pkey, skC : skey, pkS: spkey ) =
out(c, pkC) ;
in(c, x : bitstring);
let y = adec(x, skC) in
let (=pkS, k : key) = checksign(y, pkS) in
out(c, senc(s, k )).

let serverS(pkS: spkey, skS : sskey) =
in(c, pkX: pkey);
new k : key;
out(c, aenc(sign((pkS, k), skS), pkX));
in(c, x : bitstring);
let z = sdec(x, k) in 0.

process
new skC : skey;
new skS : sskey;
let pkC = pk(skC) in out(c, pkC);
let pkS = spk(skS) in out(c, pkS);
( (! clientC(pkC, skC , pkS)) | (! serverS(pkS, skS)) )
```

Client subprocess (Process Macro)

Server subprocess (Process Macro)

Main process

Verifying authenticity in the Handshake protocol.

Client believes it has terminated a protocol run with parameters *symm. key* and *its pub. key*.

Client accepted to run the protocol with Server with the *symm. key*

Server accepted to run the protocol with **a client** with the *symm. key* and *client's public key*.

Server believes it has terminated a protocol run with Client using *symm. key*.

```
free c : channel.
free s : bitstring [private].
query attacker(s).

event  acceptsClient(key).
event  acceptsServer(key, pkey).
event  termClient(key, pkey).
event  termServer(key).

query x:key, y:pkey; event(termClient(x,y)) ==> event(acceptsServer(x,y)).
query x:key; inj-event(termServer(x)) ==> inj-event(acceptsClient(x)).

let clientC(pkC: pkey, skC: skey, pkS: spkey ) =
out(c, pkC) ;
in(c, x : bitstring);
let y = adec(x, skC) in
let (=pkS, k : key) = checksign(y, pkS) in
event  acceptsClient(k).
out(c, senc(s, k )).
event  termClient(k, pkC).

let serverS(pkS: spkey, skS : sskey) =
in(c, pkX: pkey);
new k : key;
event  acceptsServer(k, pkX).
out(c, aenc(sign((pkS, k), skS), pkX));
in(c, x : bitstring);
let z = sdec(x, k) in if  pkX = pkC then event  termServer(k).
```

Client wants to be sure that when it completes the protocol it has ***indeed shared its secret with Server .***

Not injective: Server's msg can be replayed

Injective corresp.: Server believes that at the end of the prot. ***Client was indeed its partner***.

One-to-one relation

Attack against the naiv handshake protocol

$$A \rightarrow S : pk_A$$

$$S \rightarrow A : \{\{pk_S, k\}_{sk_S}\}_{pk_A}$$

$$C \rightarrow S : pk_C$$

$$A \rightarrow C : \{\{pk_S, k\}_{sk_S}\}_{pk_C}$$

$$C \rightarrow S : \{s\}_k$$

- **Man-in-the-middle** (and Interleaving) attack
  - The *attacker starts a session with the server*.
  - Server send the session key to the attacker.
  - The attacker decrypts the received message with its public key, and then encrypts the result with pkC.
  - When Client initiates a session with Server, the attacker impersonates Server.
  - The attacker knows the session key k, and can later use it to decrypt messages that Client sends to Server.

Observational equivalence - noninterf

- Intuitively, two processes P and Q are observationally equivalent, written P ≈ Q, when an active adversary cannot distinguish P from Q.

.

- Can be used to prove strong secrecy of some value s.

•Capture the adversary's ability to learn **partial information** about the secret.
  - A protocol provides strong secrecy of secret if the attacker cannot distinguish Protocol{0/secret} from Protocol{1/secret}, that is, Protocol{0/secret} ≈ Protocol{1/secret}.

The strong secrecy of values $x_1, \dots, x_n$ is defined in ProVerif by:

$$/*\ \text{free}\ x_1, \dots, x_n\ [\mathit{private}].*/$$

$$1.\ \text{noninterf}\ x_1, \dots, x_n \quad \text{or}$$

$$2.\ \text{noninterf}\ x_1\ \text{among}\ (N_1, \dots, N_k)$$

$$\dots,$$

$$x_n\ \text{among}\ (M_1, \dots, M_t)$$

- When the process under consideration is P, this query is true if and only if

P{M1/x1, . . . ,Mn/xn} ≈ P{N1/x1, . . . , Nn/xn}

Observation equivalent examples

```
free c : channel .

(*  Types *)
type key.
type bitstring.

(*  Shared key encryption, decryption *)
fun  senc(bitsring, key): bitstring
reduc forall x: bitstring, y: key; sdec(senc(x,y),y) = x.

(* The shared key *)
free  k : key [private].

(*  Query  *)
free  secret : bitstring [private]
.
(* Prove  strong secrecy of secret *)
noninterf secret.

(*  Main process *)
process
   (!out(c, senc(secret, k))) | (!in(c, x : bitstring); let s = sdec(x, k) in 0)
```

- Prove that the attacker cannot *obtain partial information (guess) of secret.*

Observation equivalent examples cont'd

```
free c : channel .

(*  Types *)
  type key
  type bitstring

(*  Hash *)
  fun  hash(bitsring): bitstring

(* The shared key *)
  free  x, n : bitstring [private].

(* Prove  strong secrecy of secret *)
  noninterf  x  among  ( n, hash(n) ).

(*  Main process *)
  process  out(c, x)
```

- Prove that the attacker cannot distinguish *n* from *hash(n).*

Observation equivalent examples cont'd

- Voters encrypt their votes with the administrator's public key.
- Prove that the attacker cannot guess voter's vote.

```
  free c : channel .

(*  Types *)
  type skey.
  type pkey.

(*  Hash *)
  fun pk(skey): pkey.
  fun aenc(bitstring, pkey): bitstring.
  reduc  forall m: bitstring, k: skey; adec(adec(m, pk(k)), k)  = m .

(* The shared key *)
  free  vote: bitstring [private].
  weaksecret vote.

 (* Process macros, that is, sub-processes. *)
  let  Voter(pkA: pkey) = out(c, aenc(vote, pkA)).
  let  Administrator(pkA: skey) = in(c, x: bitsting); let v' = adec(x, skA) in 0.

(*  Main process *)
 process
     new skA : skey;
     let skA = pk(skA) in
     out(c, pkA);
     ! ( Voter(pkA) | Administrator(skA) )
```

Observational equivalence - choice

- Prove two processes P and Q are observationally equivalent .
- P and Q have the same structure but differ only in the choice of terms.
- ProVerif provides encoding both P and Q using a „biprocess”.

$$\text{Prove } P(M) \approx P(N) \text{ for some different } M, N \text{ then } P(choice[M, N])$$

- *P* is the voter process, *skA* and *skB* are secret key of the voters.
- *vote1* and *vote2* are votes made by voters.
- **Goal: to prove privacy property**.
  - The attacker cannot distinguish the situation when A makes *vote1* and B
  - votes *vote2,* and the situation when A makes *vote2* and B votes *vote2*

$$\text{To prove } P(skA, vote1) \mid P(skB, vote2) \approx P(skA, vote2) \mid P(skB, vote1): \quad P(skA, choice[vote1, vote2]) \mid P(skB, choice[vote2, vote1])$$

Summary

- Relevant webpages

  Official page: http://www.proverif.ens.fr/
  Online demos: http://server1.dsuresearch.org/ProVerif/demo/index2.php/
  GUI Editor: http://sourceforge.net/projects/proverifeditor/

- The full manual of ProVerif (by Bruno Blanchet) will be uploaded to the course's page.

- Instructions:

1. Download ProVerif's newest version: 1.86pl3 (archive file)
2. Extract the archive file and install the program is shown in slides 16-17.
3. Try examples that can be found in the archive file.
   - The best way to undertand ProVerif is to play with example files.
   - Example files can be found in the directory *docs*: docs/<filename>**.pv**
   - Several examples with detailed comments: Needham-Schroeder, Diffie-Hellman, etc.

If do you have any question please contact me via mail:
thong[@]crysys[.]hu (* remove [and] *)

ProVerif installation

- Webpages
  - Official page: http://www.proverif.ens.fr/
  - Online demos: http://server1.dsuresearch.org/ProVerif/demo/index2.php/
  - GUI Editor: http://sourceforge.net/projects/proverifeditor/

- ProVerif's versions: 1.85; 1.86pl3; 1.87beta6 (newest)
  - Devepoders: Bruno Blanchet,and his group. Ecole Normale Supérieure, France.
  - Developed in *Ocaml* logic programming language.
  - By default, has no GUI interface.

- Installation in Linux/Mac (download Ocaml 3.0, http://caml.inria.fr/)
  - Create a directory *proverif1.86pl3* in the current directory.
    - Using GNU tar: 1) *tar -xzf proverif1.86pl3.tar.gz ; 2) tar -xzf proverifdoc1.86pl3.tar.gz*
    - Using tar: 1.) *gunzip proverif1.86pl3.tar.gz; 2.) tar -xf proverif1.86pl3.tar; 3.) gunzip proverifdoc1.86pl3.tar.gz; 4) tar -xf proverifdoc1.86pl3.tar.*
  - Build the ProVerif
    - *cd proverif1.86pl3*
    - *./build*

ProVerif installation, execution

- Installation in Windows
  - From binary
    - Does not require Ocaml !!!
    - Decomposes: *proverifbsd1.86pl3.tar.gz* and *proverifdoc1.86pl3.tar.gz* archives in the same directory.
  - From source
    - Requires Ocaml installation, OCaml bytecode compiler.
    - Decomposes: *proverif1.86pl3.tar.gz* and *proverifdoc1.86.tar.gz* archives in the same directory.
    - In the command shell go to the directory where the two files were extracted and build

      .*/build.bat***

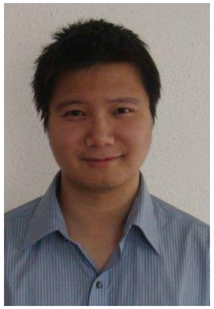
- Execution
  - Command line: *./proverif [options]* < *filename.pv* >

    Windows: 1) open cmd; 2) cd to the directory; 3) *.\proverif [options]* < *filename.pv* >
    - **.**/proverif: ProVerif's binary
    - < filename**.pv** >: ProVerif's source file.
      - By default, only honest processes should be defined by users.
    - [options]: options

Kérdések?

KÖSZÖNÖM A FIGYELMET!

Híradástechnikai Tanszék



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