An Efficient Distance Bounding RFID Authentication Protocol: Balancing False-Acceptance Rate and Memory Requirement

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Summary

- A brief introduction to RFID.
- Authentication and Mafia fraud.
- Key-references in distance bounding.
- Our Protocol.

RFID in a Nutshell

- RFID = Radio-Frequency IDentification.
- Tags and Readers (possibly connected to a back-end system).
- Tags are low-capability devices, passive.
- With or without microprocessor.
- Communication distance: a few cm to a few meters.
- Tags answer without agreement of their holders.
- Implicit agreement = being in the reader's field.

RFID Applications

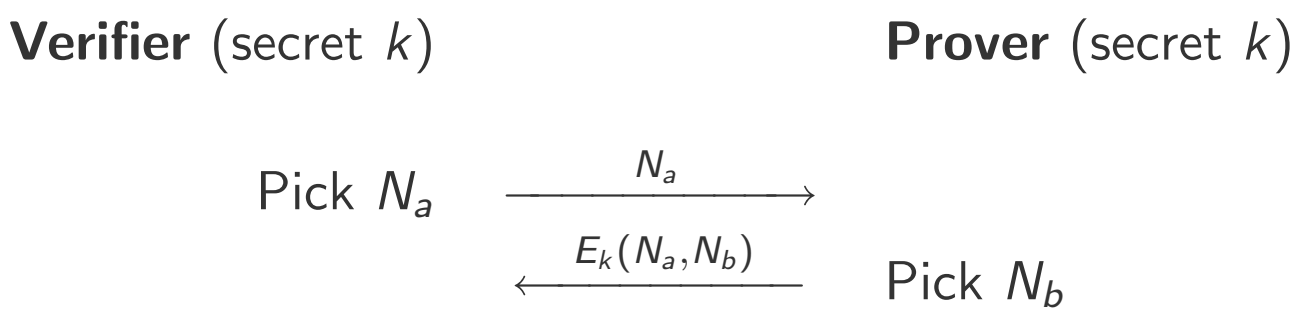
- Pet identification.
- Supply chain.
- Electronic passports.
- Mass transportation.
- Access control.
- Payment.

Authentication

"Entity authentication is the process whereby one party is assured (through acquisition of corroborative evidence) of the identity of a second party involved in a protocol, and that the second has actually participated (i.e., is active at, or immediately prior to, the time the evidence is acquired)"

Handbook of Applied Crypto, Menezes, Oorschot, Vanstone.

ISO 9798-2 Protocol 3 Unilateral



Protocol secure under some common assumptions on E, k, and N_a.

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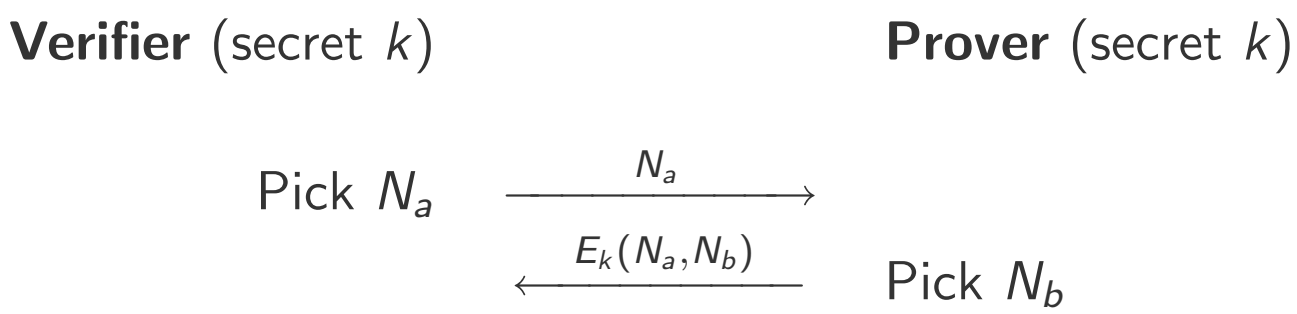

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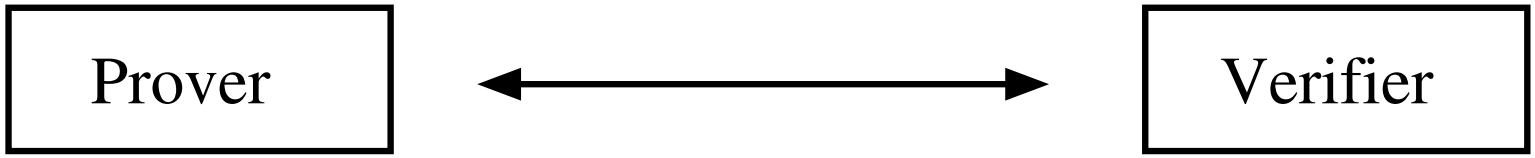
Mafia Fraud



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- Desmedt, Goutier, Bengio [Crypto87].
- Shamir about Fiat-Shamir protocol [Crypto86]: "I can go to a Mafia-owned store a million successive times and they still will not be able to misrepresent themselves as me." (The NY Times, February 17, 1987, James Gleick).

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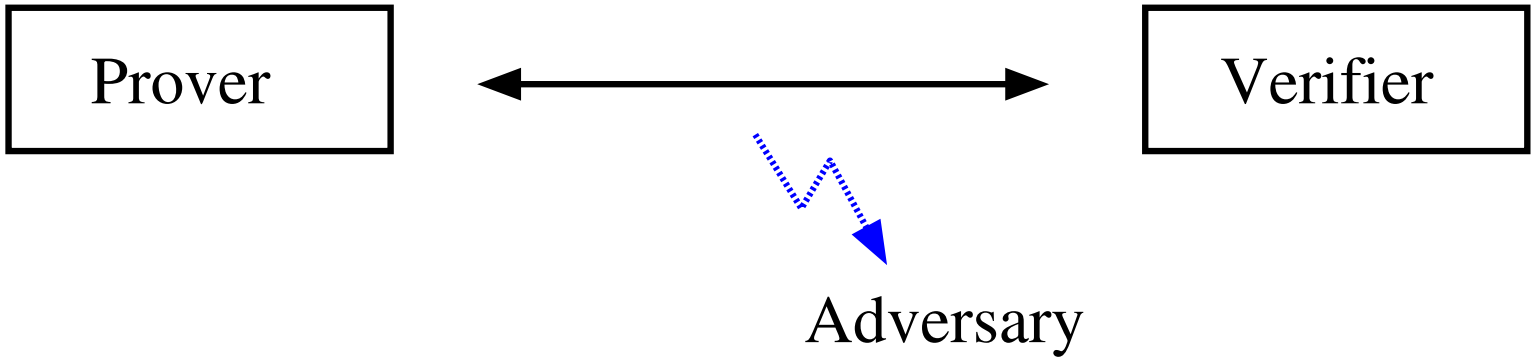

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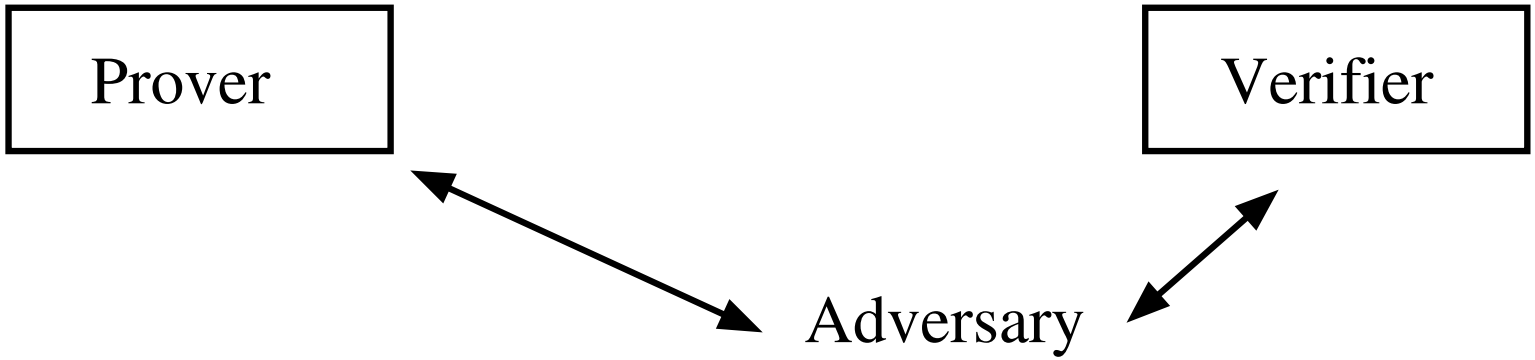

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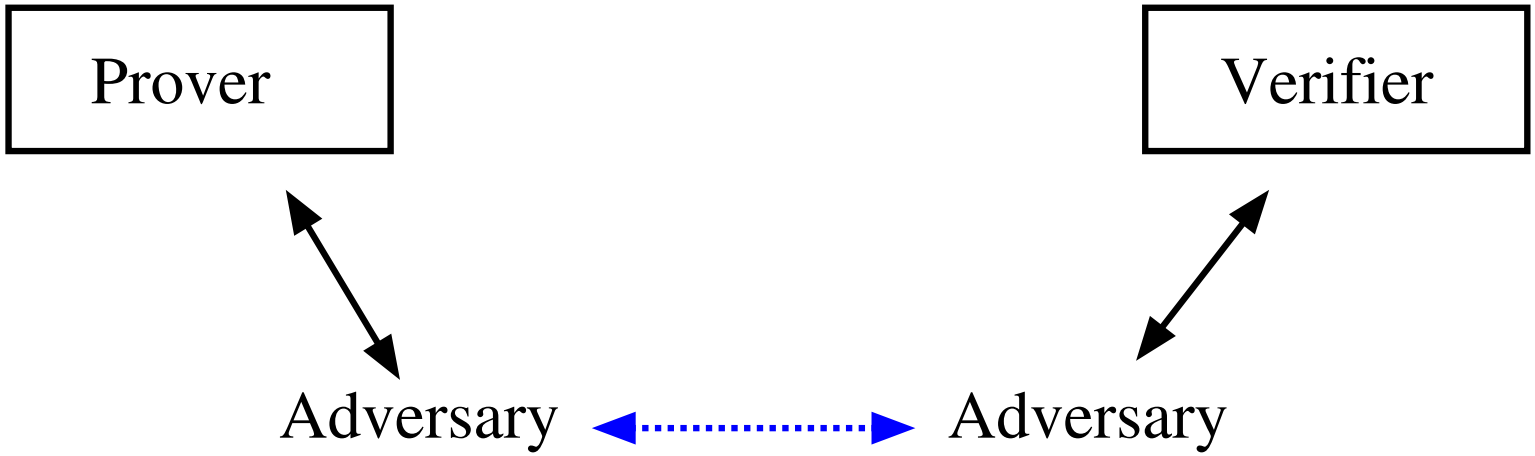

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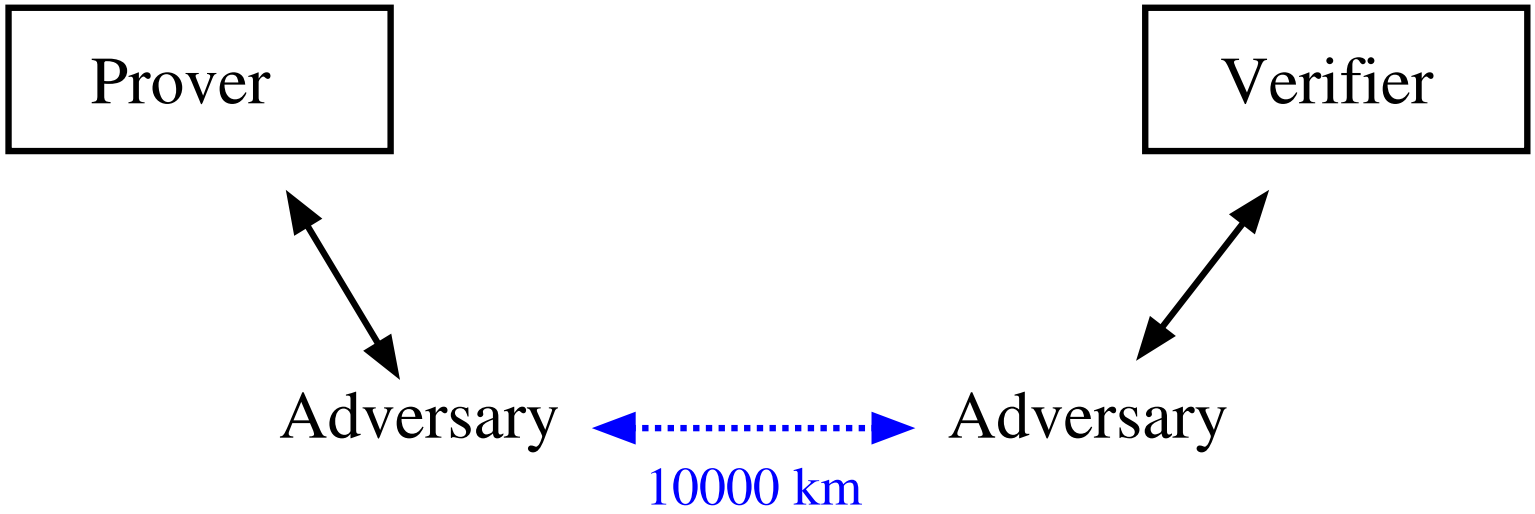

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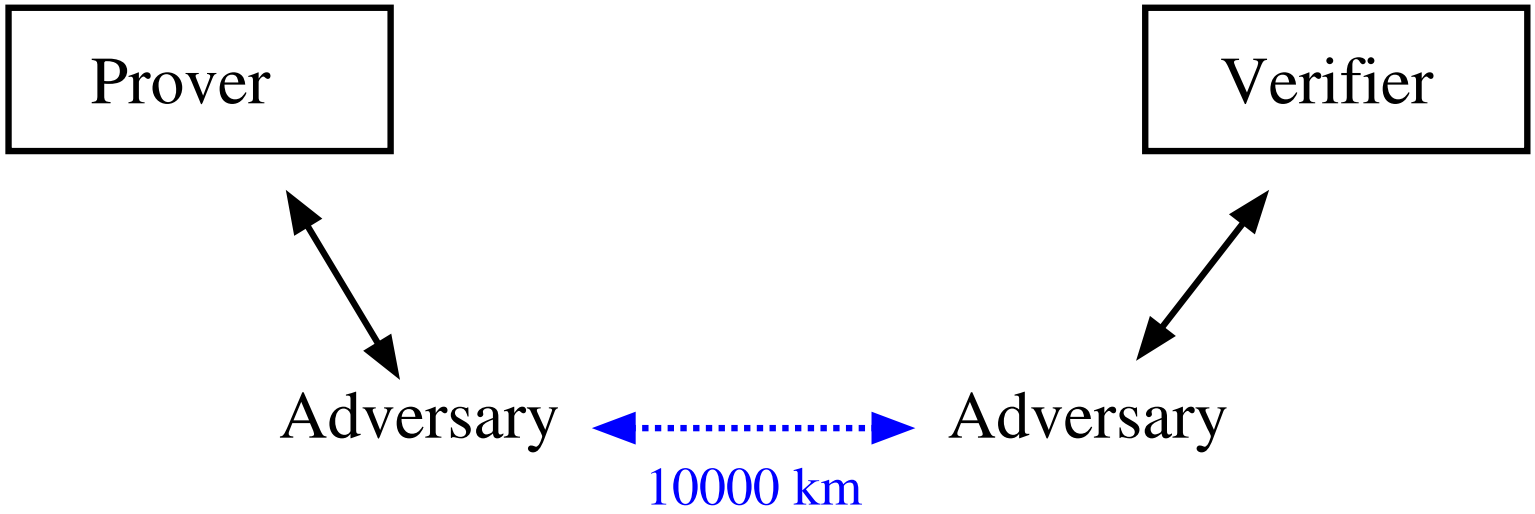

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Mafia Fraud: Example in a Queue

Do-ability of Mafia Fraud

- Successful attacks.
  - Co-axial cable over 50 cm (T. Gross 06).
  - Radio link over 50 meters (G. Hancke 05).
- Reader starts a timer when sending a message.
  - To avoid semi-open connections.
- ISO 14443 "Proximity Cards".
  - Used in most secure applications.
  - Standard on the low-layers (physical, collision-avoidance).
  - Default timer is around 5 ms.
  - Prover can require more time, up to 4949 ms.

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Distance Bounding (Proximity Check)

- Literature
  - Beth and Desmedt [Crypto90]
  - Brands and Chaum [Eurocrypt93]
  - Hancke and Kuhn [SecureComm05]
  - ...
- The verifier calculates the round trip time of a message.
  - Message needs to be authenticated.
  - Authentication is time-consuming.
  - Round trip time is noised.

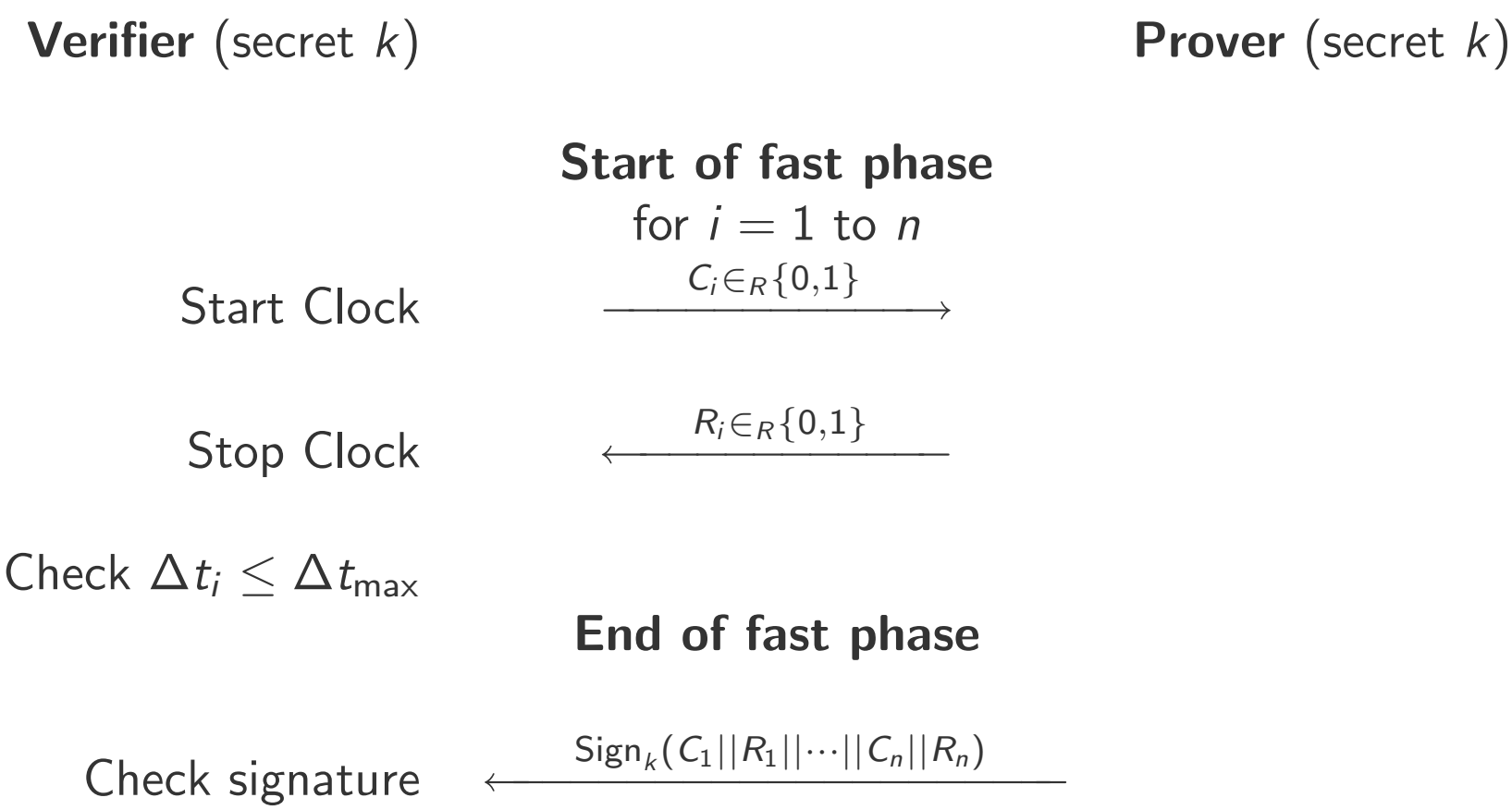
Adversary Model

- Can eavesdrop, intercept, modify or inject messages.
- Cannot correctly encrypt, decrypt, or sign messages without knowledge of the appropriate key.
- Can increase or decrease the clock frequency of a tag and thus the computation speed.
- Can increase the transmission speed on the channel up to a given bound (speed of light).

Adversary Model

- We define a neighborhood as a zone around a reader.
- We consider that a tag present in a neighborhood agrees to authenticate.
- We say that a tag T has been impersonated if an execution of the protocol convinced a reader that it has authenticated T while the latter was not present inside the neighborhood during the said execution.

Brands and Chaum's Protocol



Brands and Chaum's Drawbacks

- Security of the protocol: $(1/2)^n$.
  - On-the-fly authentication should take less than 50 ms.
  - Turn-around time does not allow a large n.
  - Security is degraded.
- There is a final signature.
  - If the protocol is interrupted, no rational decision can be taken by the verifier.

Hancke and Kuhn's Protocol

Verifier (secret k) **Prover** (secret k)

Random N_a $\xrightarrow{N_a}$

$\xleftarrow{N_b}$ Random N_b

$v^0 \| v^1 := H_k(N_a, N_b)$ where $|v^0| = |v^1| = n$

Start of fast phase

for $i = 1$ to n

Start Clock $\xrightarrow{C_i \in_R \{0,1\}}$

Stop Clock $\xleftarrow{R_i}$

$$R_i = \begin{cases} v_i^0, \text{ if } C_i = 0 \\ v_i^1, \text{ if } C_i = 1 \end{cases}$$

End of fast phase

Check correctness of R_i's and $\Delta t_i \leq \Delta t_{\max}$

Hancke and Kuhn's Drawbacks

- The final signature is no longer needed.
- Security of the protocol still depends on n.
- Security of the protocol is $(3/4)^n$ instead of $(1/2)^n$.

Open Problem

- Can we design a distance bounding protocol without final signature that resists to the Mafia fraud with probability better than $(3/4)^n$?
- In HK, if the adversary sends a wrong C_i during the *pre-ask* phase, she is not penalized for the following rounds.
- Our idea consists in using a tree instead of 2 registers.

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The Decision Tree

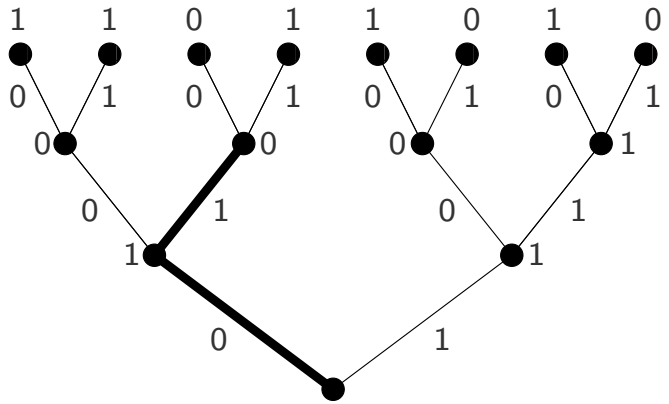

Figure: Decision tree with $n = 3$. The thick line path in the tree corresponds to the verifier's challenges $0, 1, 0$ and the prover's replies $1, 0, 0$.

Our Protocol

Verifier (secret k)		**Prover** (secret k)
	$\xrightarrow{N_a}$	
Compute $H_k(N_a, N_b)$	$\xleftarrow{N_b, [H_k(N_a,N_b)]_1^m}$	Compute $H_k(N_a, N_b)$
	Start of fast phase	
	for $i = 1$ to n	
Start Clock	$\xrightarrow{C_i \in_R \{0,1\}}$	
		$R_i := \text{node}(C_1 \dots C_i)$
Stop Clock	$\xleftarrow{R_i}$	
	End of fast phase	
Check correctness of R_i's and $\Delta t_i \leq \Delta t_{\max}$		

Success Probability w.r.t. Mafia Fraud

$$
\begin{aligned}
\Pr(\tilde{R}^n = R^n) &= \sum_{i=1}^{n} \Pr(\tilde{R}^n = R^n | t = i) \Pr(t = i) \\
&\quad + \Pr(\tilde{R}^n = R^n | C^n = 0^n) \Pr(C^n = 0^n) \\
&= \sum_{i=1}^{n} 2^{-(n-i+1)} 2^{-i} + 2^{-n} \\
&= 2^{-n}(n/2 + 1) \; .
\end{aligned}
$$

False Acceptance Rate

- A FAR of 0.01% can be reached with a single tree of depth 17, which requires 32 Kbytes of memory.
- A FAR of 0.01% can also be obtained by using two trees each of depth 9. This decreases the needed memory down to 256 bytes (0.25 Kbytes).

Conclusion

- The first protocol that requires no signature and with a FAR less than $(3/4)^n$.
- Are such protocols practicable?
- Which parameters can be modified?
- No practical solution today (except NXP Mifare Plus).