

(More) Cryptographic protocols

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Authentication and key agreement protocols

Authentication and key agreement

- ▶ Long-term keys should be used as little as possible to to reduce “attack-srufarce”
- ▶ The use of a key should be restricted to a specific purpose
e.g. you shouldn't use the same RSA key both for encryption and signing
- ▶ Public key algorithms tend to be computationally more expensive than symmetric key algorithms
- ↪ Long-term keys are used to establish short-term **session keys**
e.g. TLS over HTTP, AKA for 3G, BAC for epassports, etc.

Needham-Schroeder Public Key (NSPK)

NSPK: authentication and key agreement protocol

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[N. Roger, M. Schroeder, Michael. "Using encryption for authentication in large networks of computers". Communications of the ACM (December 1978)]

Needham-Schroeder Public Key (NSPK)

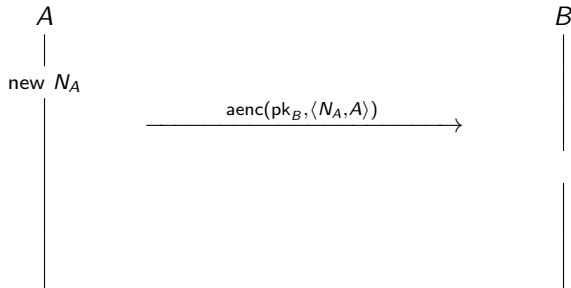
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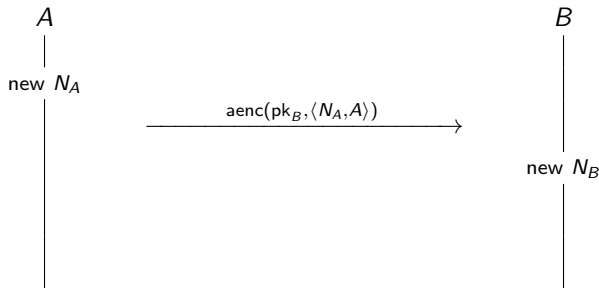
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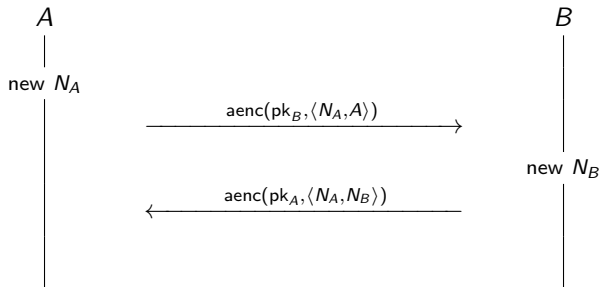
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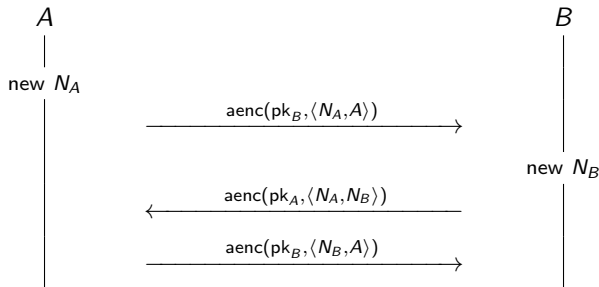
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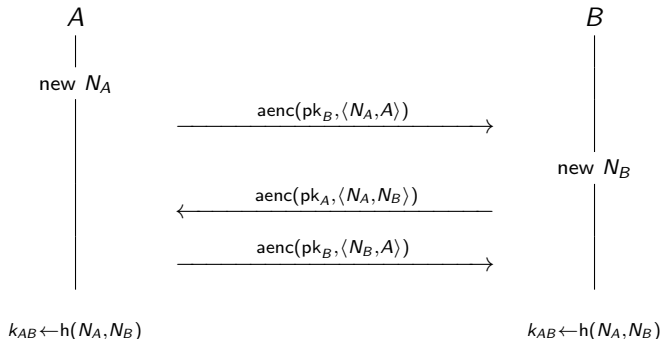
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NSPK: security requirements

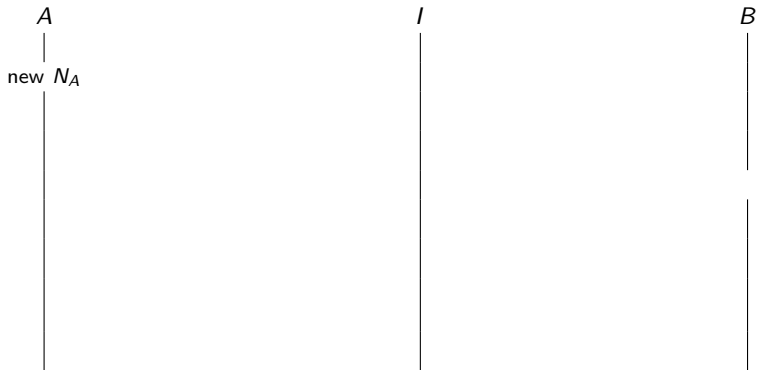
- ▶ **Authentication:** if Alice has completed the protocol, apparently with Bob, then Bob must also have completed the protocol with Alice.
- ▶ **Authentication:** If Bob has completed the protocol, apparently with Alice, then Alice must have completed the protocol with Bob.
- ▶ **Confidentiality:** Messages sent encrypted with the agreed key ($k \leftarrow h(N_A, NB)$) remain secret.

NSPK: Lowe's attack on authentication

Attack found 17 years after the publication of the NS protocol!!

NSPK: Lowe's attack on authentication

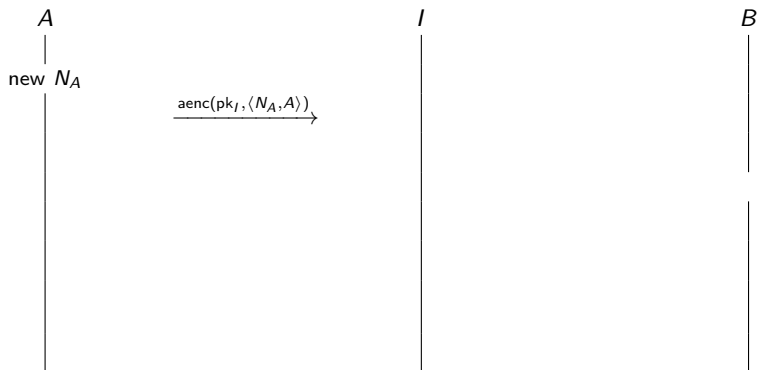
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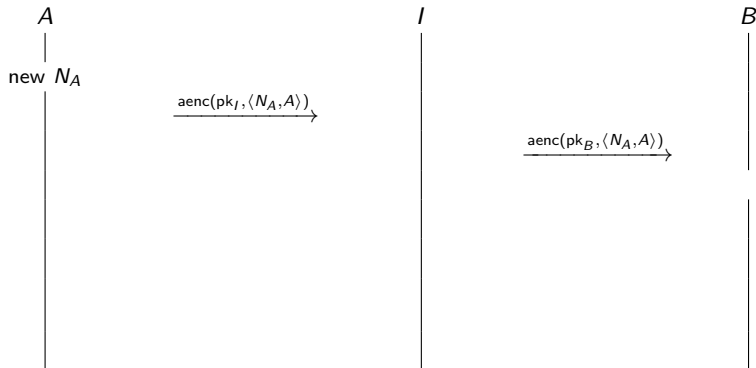
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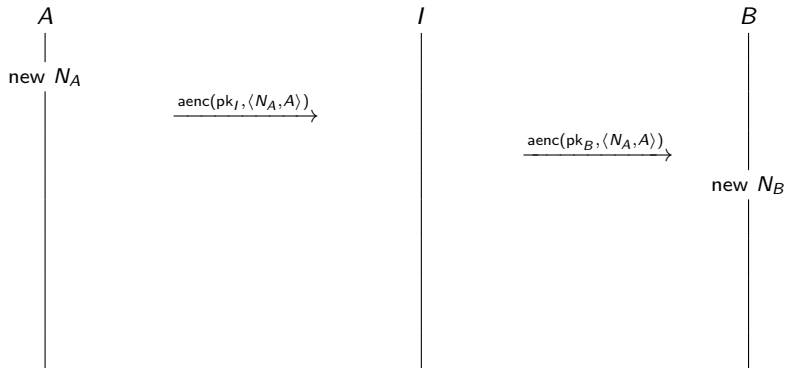
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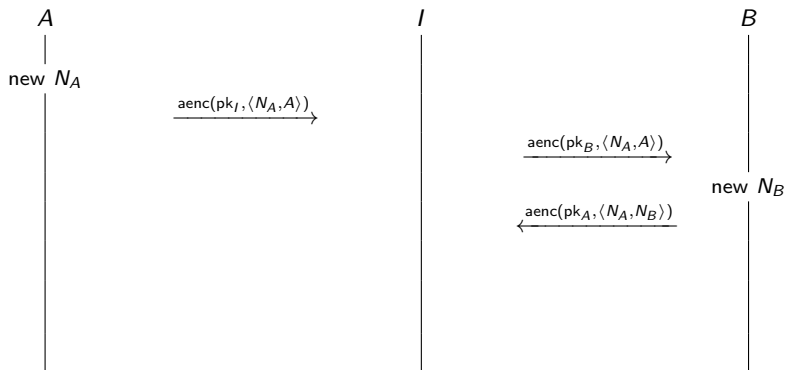
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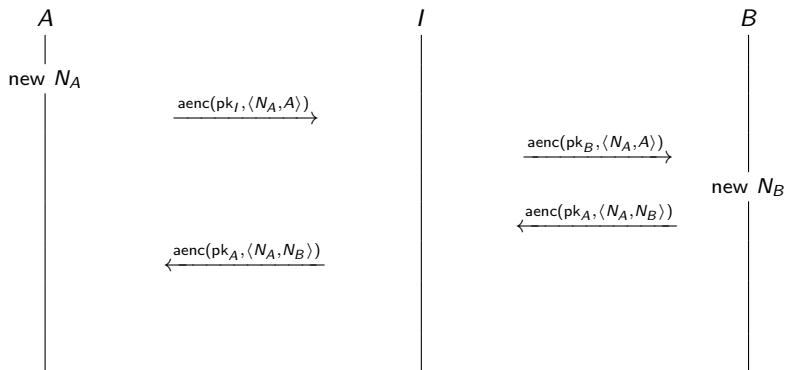
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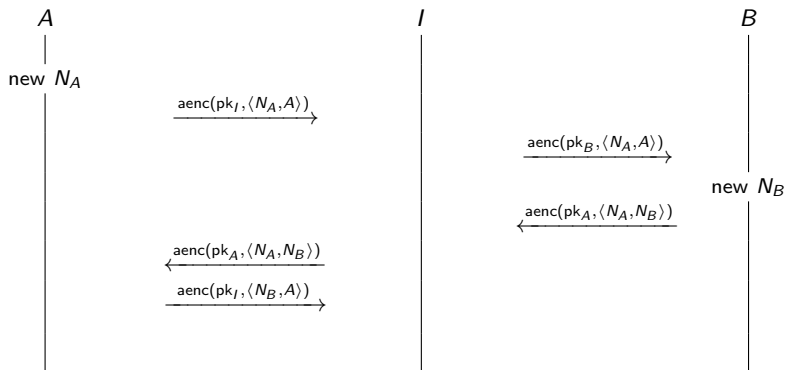
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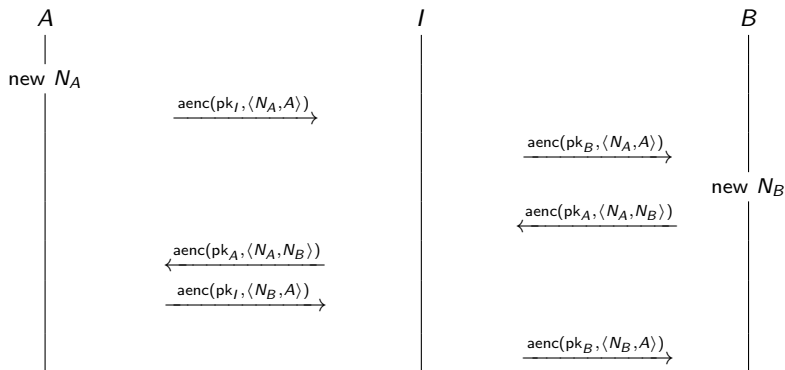
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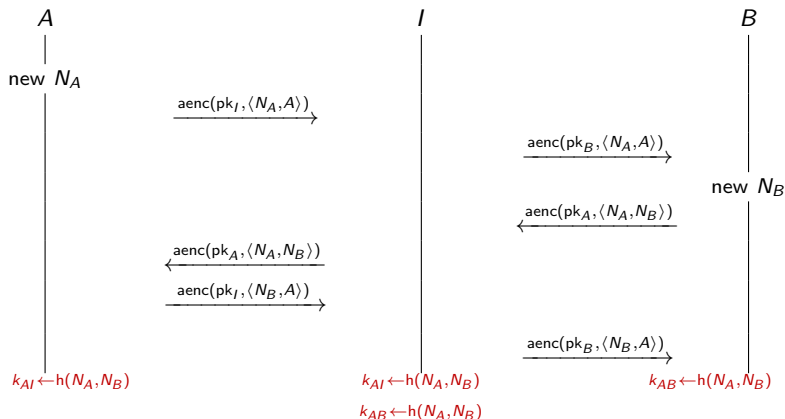
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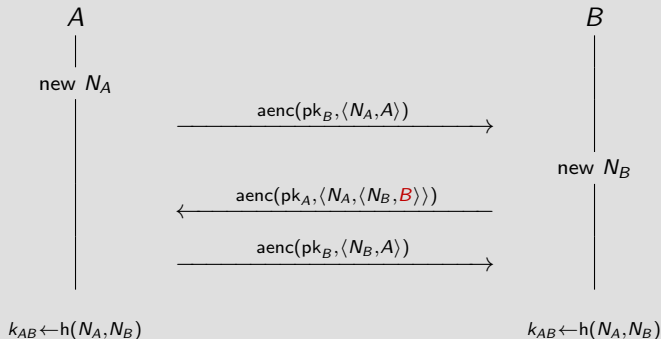
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NSPK: Lowe's fix

The Needham-Schroeder-Lowe (NSL) protocol



Forward secrecy

- ▶ The NSL protocol is secure against an attacker that controls the network.
- ▶ What if the Alice's and Bob's private keys get compromised?
- ▶ What if the government forces Alice and Bob to reveal their private keys?
- ▶ Can we still protect confidentiality?

Forward secrecy

A protocol ensures **forward secrecy**, if even if long-term keys are compromised, past sessions of the protocol are still kept confidential, and this even if an attacker actively interfered.

The Station-to-Station (StS) protocol

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The Station-to-Station (StS) protocol



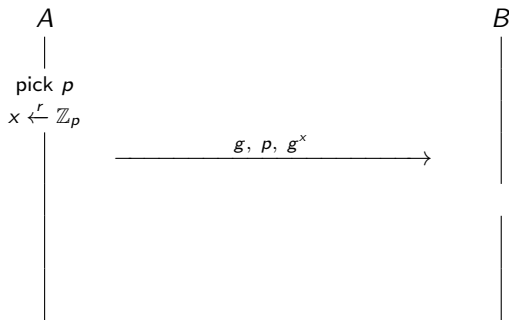
- ▶ where p is a large prime
- ▶ and g a generator of \mathbb{Z}_p^*

The Station-to-Station (StS) protocol



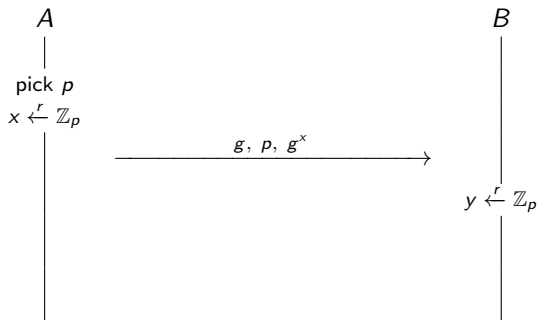
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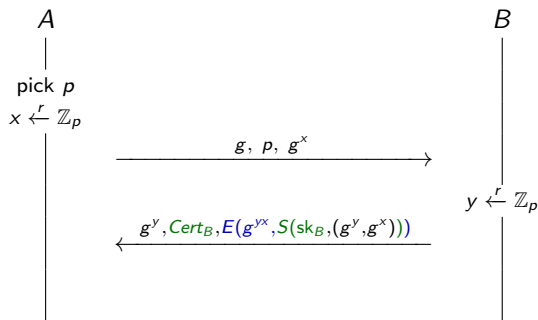
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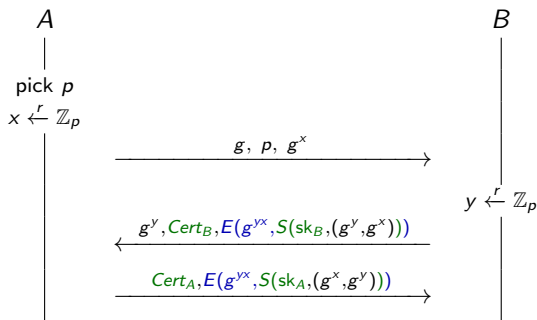
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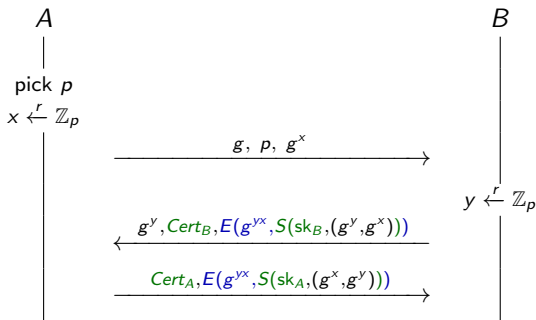
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The Station-to-Station (StS) protocol



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The StS ensures mutual authentication, key agreement, and forward secrecy

The Basic Access Control (BAC) protocol

An e-Passport is a passport with an RFID tag embedded in it.




The RFID tag stores:

- ▶ the information printed on the passport,
- ▶ a JPEG copy of the picture

BAC: authentication and key agreement protocol implemented on e-Passports

The Basic Access Control protocol (BAC)

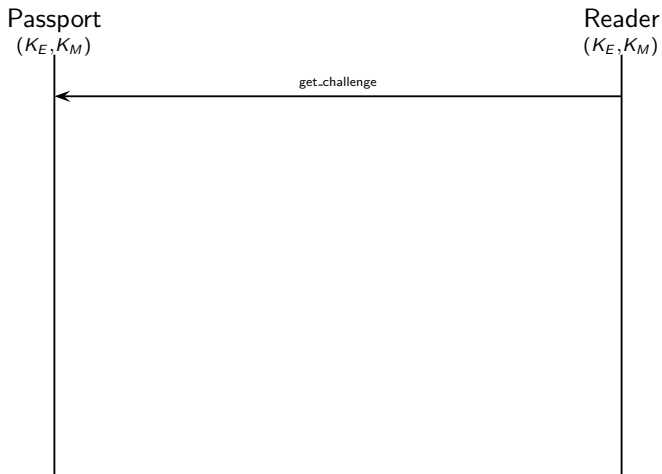
Passport
(K_E, K_M)



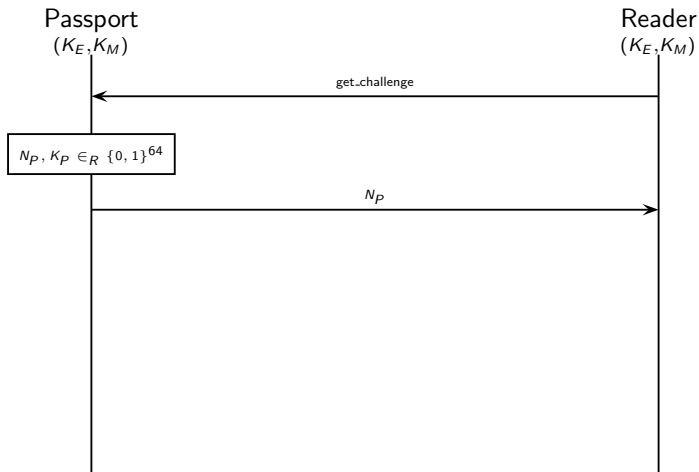
Reader
(K_E, K_M)



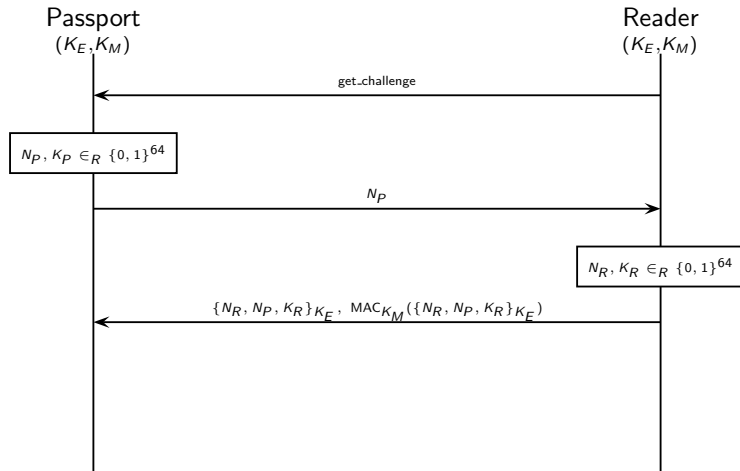
The Basic Access Control protocol (BAC)



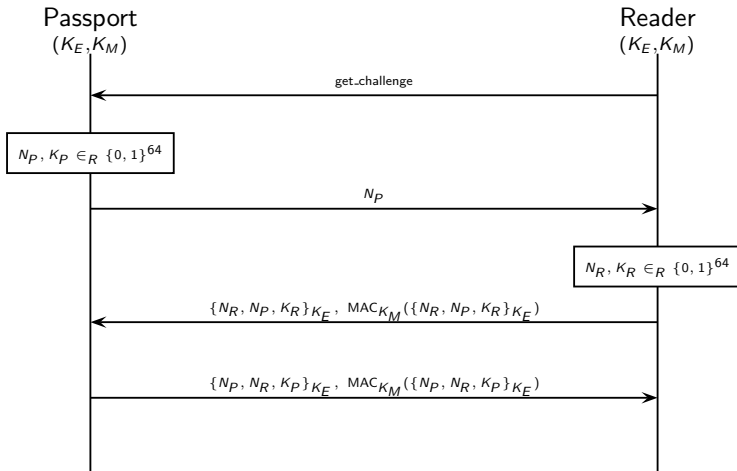
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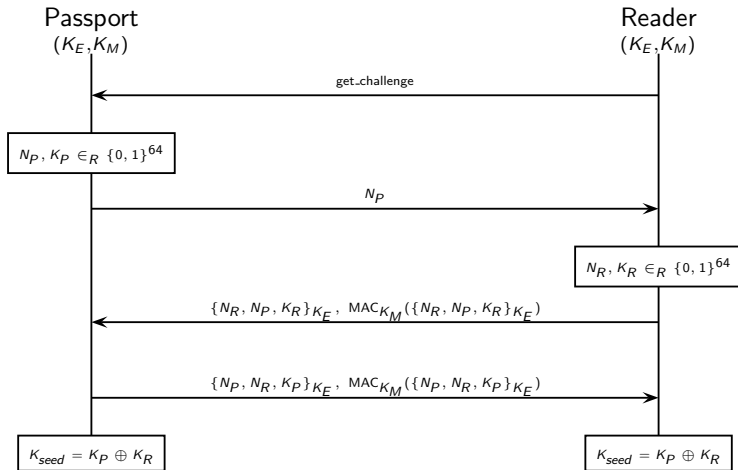
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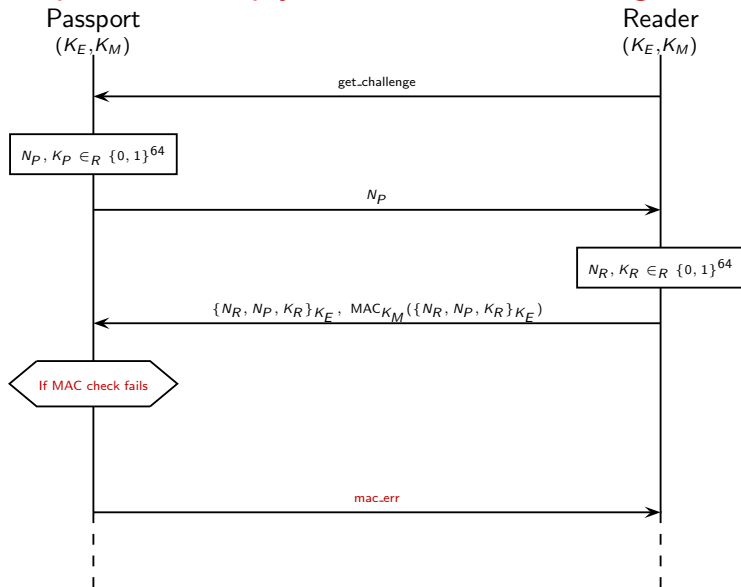
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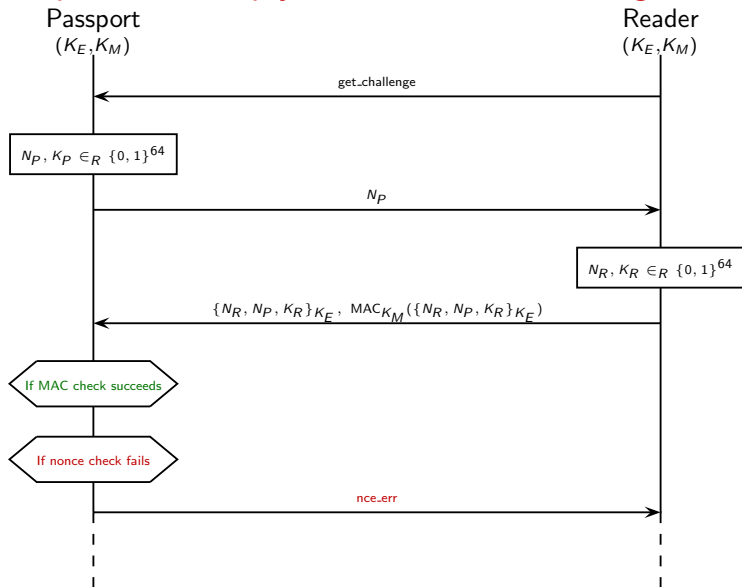
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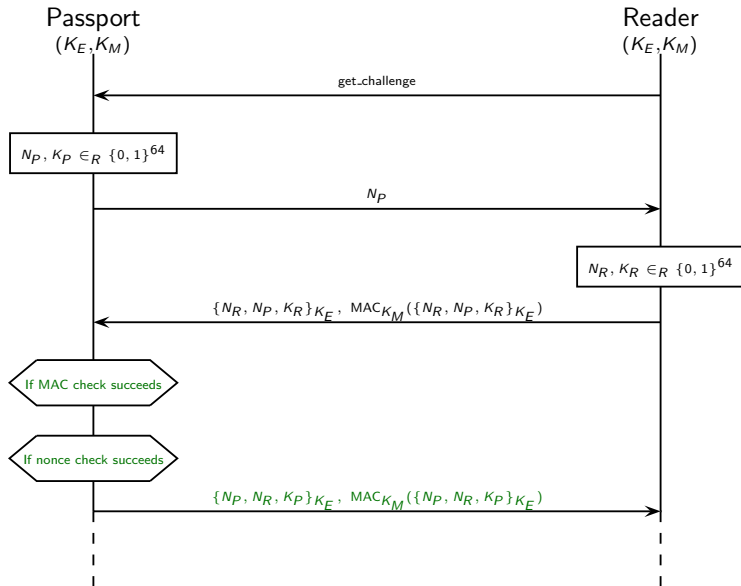
The passport must reply to all received messages



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The passport must reply to all received messages



e-Passports and privacy

- ▶ The BAC protocol provides **mutual authentication**, **key agreement**, and **confidentiality** of subsequent communication
- ▶ e-Passports further aim at providing **anonymity** and **unlinkability** to their bearers

Definition (ISO 15408)

Anonymity ensures that a user may use of a resource or service without disclosing the user's identity.

Definition (ISO 15408)

Unlinkability ensures that a user may make multiple uses of a resource or service without other users being able to link these uses together.

Different implementations of the BAC protocol

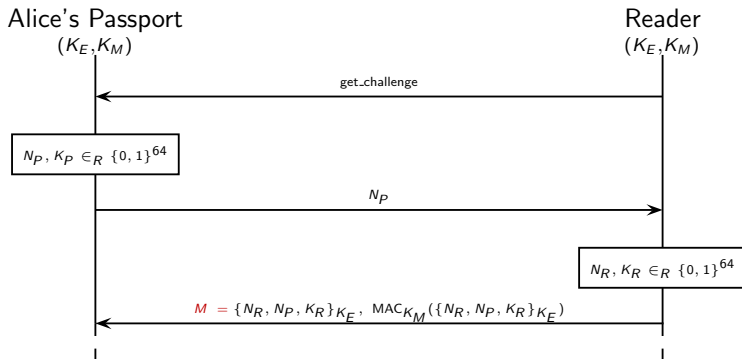
The ICAO e-Passport standard doesn't specify what the error messages should be. Each nation has implemented its own version:

- French e-Passport: $\text{mac_err} \neq \text{nce_err}$
→ French implementation allows an attacker to **track a passport**, provided he has once witnessed a successful authentication.
- British e-Passport: $\text{mac_err} = \text{nce_err}$
→ The British version of the BAC protocol **satisfies unlinkability**.

[T. Chothia, V. Smirnov. "A traceability attack against e-Passports". 14th International Conference on Financial Cryptography and Data Security 2010.]

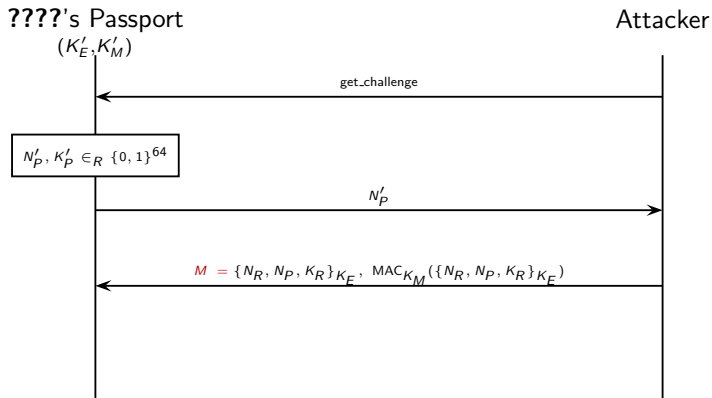
An attack on the French e-Passport (part 1)

The attacker eavesdrop on Alice using her passport

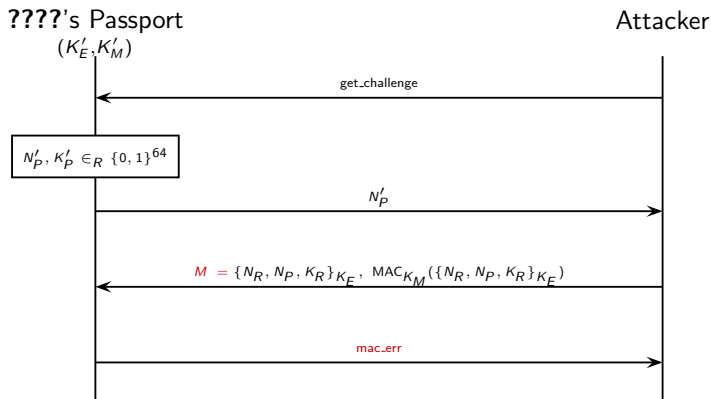


and records message M

An attack on the French e-Passport (part 2)

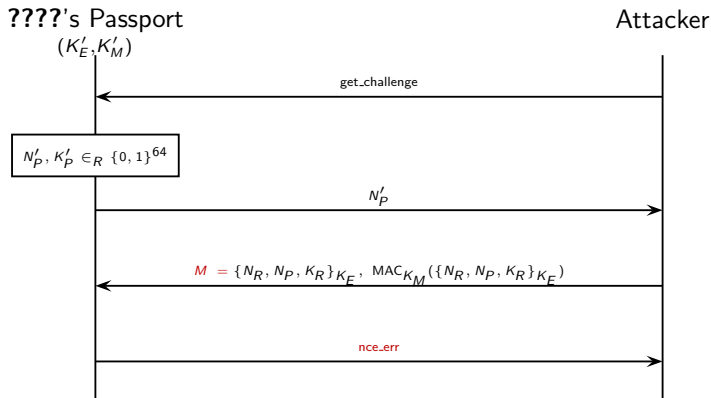


An attack on the French e-Passport (part 2)



\Rightarrow MAC check failed $\Rightarrow K'_M \neq K_M \Rightarrow$ **???? is not Alice**

An attack on the French e-Passport (part 2)



\Rightarrow MAC check succeeded $\Rightarrow K'_M = K_M \Rightarrow$ **???? is Alice**

Timing attack: the failed MAC is rejected sooner

- ▶ UK, Greek, German passports return the same error in both situations, but still...

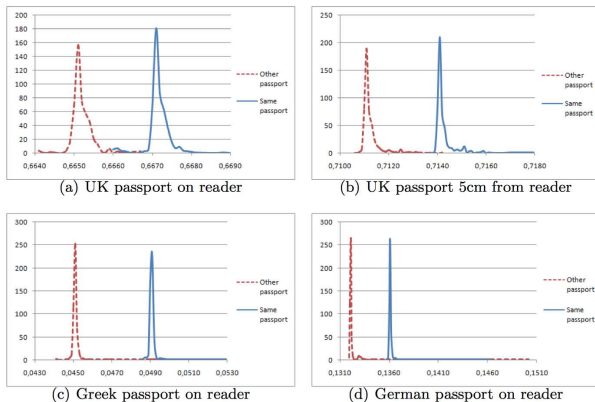


Fig. 4. Sampled Times from Replaying a Message to the Same or a Different Passport

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