Cryptography & Computer Security

Dieter Gollmann
Hamburg University of Technology

About the Speaker

You were once a
cryptographer but now
you are a reformed character.

Agenda

- Introducing cryptography
- Know Thyself
- Paradigms for cryptographic computer security services
- Keys that speak for/by themselves
- Analyzing security protocols – theory and practice

History of Ideas

- Crypto had an early start in IT security education.
  - Because it lends itself to academic teaching, pleasingly brief problem descriptions, intellectually challenging solutions?
  - As opposed to computer security; messy problem descriptions, actually building real solutions is tedious.
- One often encounters the view that crypto provides "strong" security compared to other techniques.

History of Ideas – Crypto

- Crypto has its origin in communications security.
- There is a sender and a receiver.
- The communications network is insecure.
- Sender and receiver construct secure logical tunnels.
  - With symmetric crypto, they must share secret keys.
  - With asymmetric cryptography, they need the authentic public key of their peer, e.g. provided by a Public Key Infrastructure.
- Cryptography does not solve security problems; cryptography transforms security problems into key management problems.

Computer Security 101

- Confidentiality: crypto has a solution – encryption mechanisms
- Integrity: crypto has a solution – message authentication codes, digital signatures
  - These mechanisms can also be used to authenticate a peer.
- Availability: crypto is a problem – cryptographic operations need computational and communications resources.

Know Thyself

- In communications security, you authenticate your peer.
- In computer security, you may want to authenticate yourself.
  - “Egress filter”: ensure that a request you are sending out has been created by yourself and not been slipped in by the adversary.
  - “Ingress filter”: ensure that a response you are receiving matches a request you had sent out earlier.
- “Know Thyself” as a new basic security mechanism?

Know Thyself – Cookies

- TCP SYN flooding attack:
  - Attacker sends lots of SYN requests.
  - Server replies with SYN-ACK messages, stores sequence number expected in the final ACK message.
  - Eventually server runs out of resources for dealing with half open connections.
- Solution: do not keep state locally, send the state in the challenge (sequence number).
- Construct cookies from a secret key shared with nobody and relevant session parameters.

Know Thyself – RequestRodeo

- Client-side defence against CSRF attacks.
  - Attacker inserts request in existing authenticated session.
- Proxy between browser and network marks URLs in incoming web pages with unpredictable tokens; for each token stores name of host URL had come from.
- Checks all outgoing requests:
  - URL without a token must have been been created locally; can be securely sent in current session.
  - URL with a token sent back to host it is associated with satisfies Same Origin Policy; can be sent in current session.
  - Otherwise, remove all authenticators (cookies) from URL; does not work with SSL sessions.

Paradigms

- Cryptography uses paradigms from the physical world to explain its services.
  - E.g. digital signatures as the equivalent of handwritten signatures for the digital world.
  - Whether this explanation is helpful is another matter.
- Paradigms for crypto services in computer security:
  - Vault
  - Private letter box
  - Transparent vault

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- Vault for locking away sensitive data.
  - Has to be unlocked with a key when putting data in or taking data out.
  - Implemented by symmetric encryption mechanisms.
- Private letter boxes.
  - Letter box needs some serial number (public key) so that you can distinguish between letter boxes.
  - Anybody can drop documents into the letter box.
  - Only the owner can open the letter box with a private key.

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- Transparent vault, consider e.g. public lottery draws.
- Everyone can see what is in the vault; only authorized personnel may put items in the vault.
- Private key required for putting items in the vault.
- If the vault has a unique serial number (public key), everyone can refer to items in the vault by this serial number.
- Can create protected name spaces; public key is like a database key for organizing and addressing items.

. NET Strong Names

- Assemblies protected by digital signatures:
  - Publisher's public key given in metadata.
  - Digital signature computed and written into assembly during compilation.
  - Provides origin authentication (w.r.t. name space and data integrity.
- The public key is in fact the 'identity' of the publisher.
- Strong names: public key cryptography without a Public Key Infrastructure.
- Method for locally creating globally unique names nobody else can use.

Ownership of Addresses

- Cryptographically Generated Addresses: proving ownership of dynamically allocated (IPv6) addresses.
- Address owner creates a public key/private key pair; hash of public key is interface ID in IPv6 address.
- Address claim signed with the owner's private key, signed claim sent together with public key to verifier.
- Verifier checks that the public verification key is linked to the IP address.
- We use public key cryptography without using a PKI.
- Address is the "certificate" for its public key.

Analyzing Security Protocols Theory & Practice

Sec-HH

TUHH
Technische Universität Hamburg-Harburg

Cultures in Cryptography

- Theoreticians: … address theoretical questions as opposed to real world problems …
  - Try to make protocols secure independent of the implementation.
- Practitioners: … perspective of specification document writers and that of the implementers …
  - Try to have secure implementations of protocols.

[Kenny Paterson, IEEE S&P, May/June 2011]

Protocol design – theory

- Start from abstract specification of the protocol.
- Prove security for abstract specification.
- Ensure that implementation does not introduce vulnerabilities.
- Secure implementation of provably secure protocols.
- Problem: even when the implementation is "secure by design", the proof of security takes place again in an abstract model; attacks may be possible by exploiting features outside the model.

Example for this approach

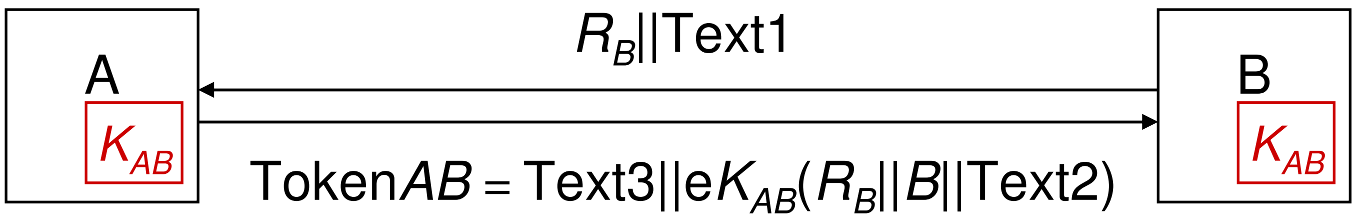
- “If you prove something about the (self-identified) cryptographic core of an authentication protocol, does this actually prove *anything* about the full-fledged scheme?”
- “In our model, compactly described in pseudocode, a protocol core (PC) will call out to protocol details (PD), but, for defining security, such calls will be serviced by the adversary.”

[Rogaway, Stegers: Authentication without Elision]

Protocol design – practice

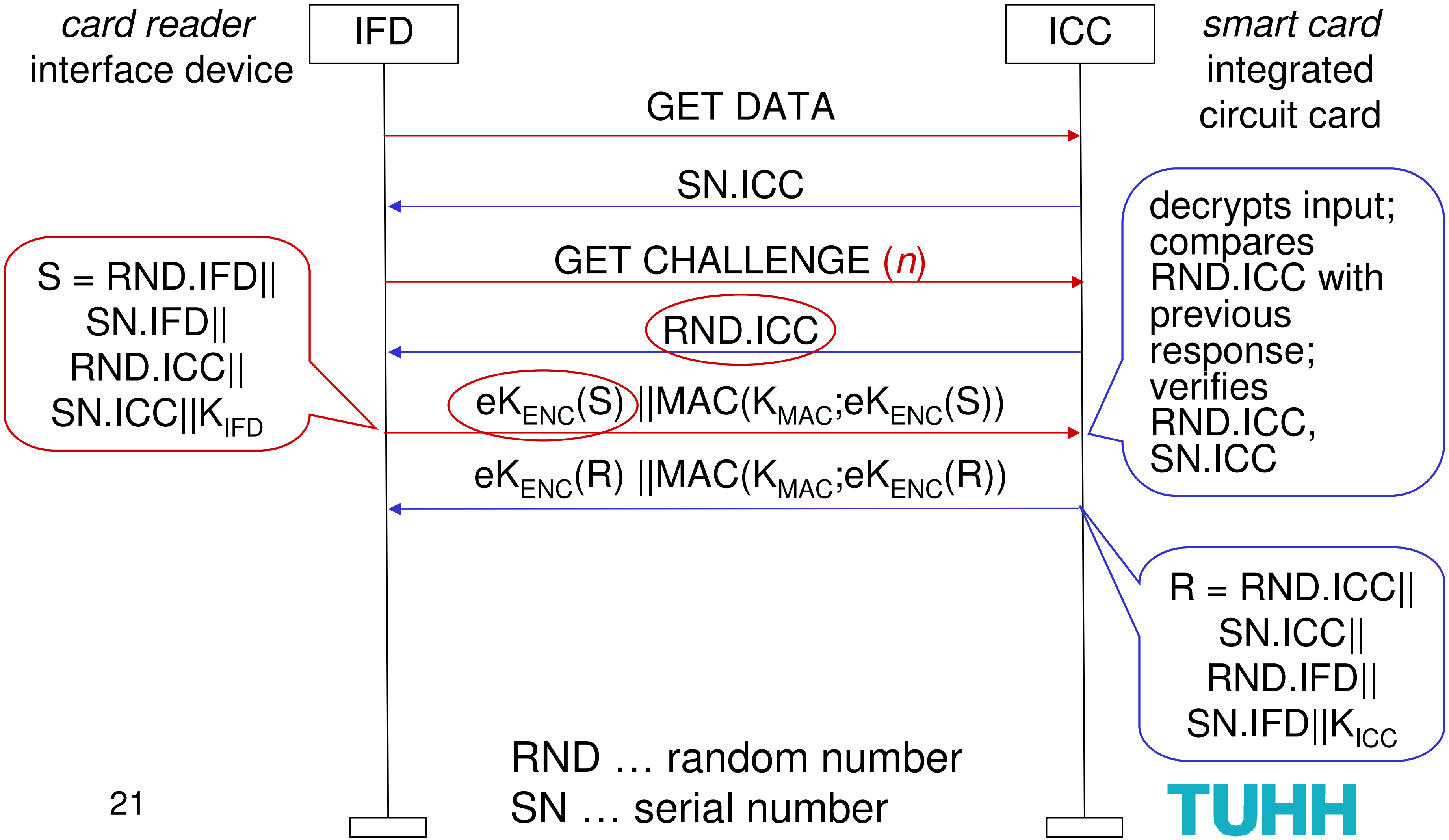
- Case study: protocols for the German eHealth card
- Protocols run between a reader and a card.
  - Card is “passive”; all protocol runs must be initiated by the reader.
- Based on CWA 14980-1 [CEN]:
  - Focus on interoperability, mainly interface specifications.
  - Internal checks in a protocol run not completely specified; this is by intent: do not restrict design space unnecessarily.
- Instruction set from ISO/IEC 7816-4

Case study: ISO 9798-2

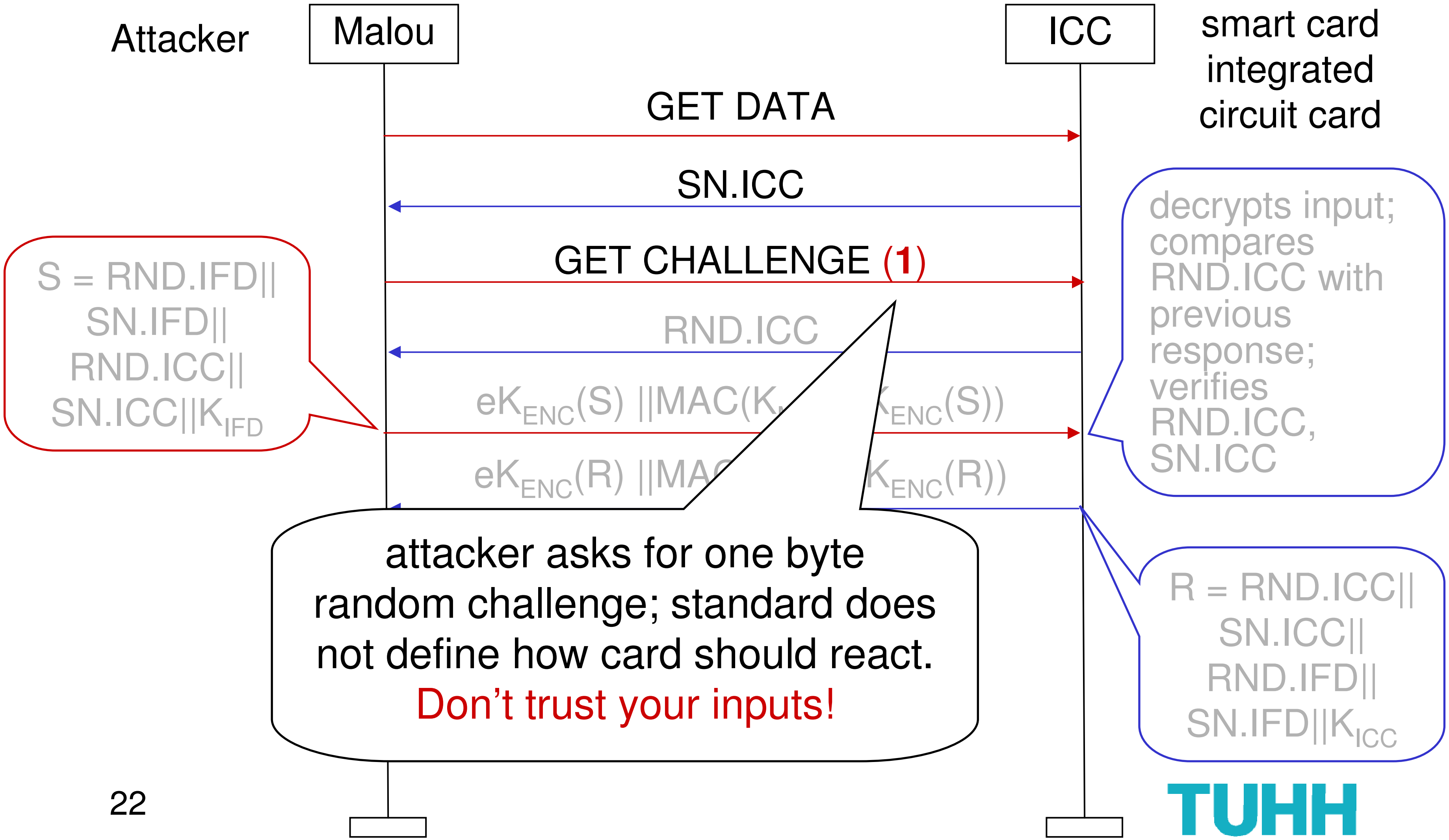


- "*B* verifies Token*AB* by deciphering the enciphered part and checking the correctness of the distinguishing identifier *B*, if present, and that the random number R_B, sent to *A* in step (1), agrees with the random number contained in Token*AB*."
- "Distinguishing identifier *B* is included in Token*AB* to prevent a so-called reflection attack."

CWA 14980-1, section 8.7.1



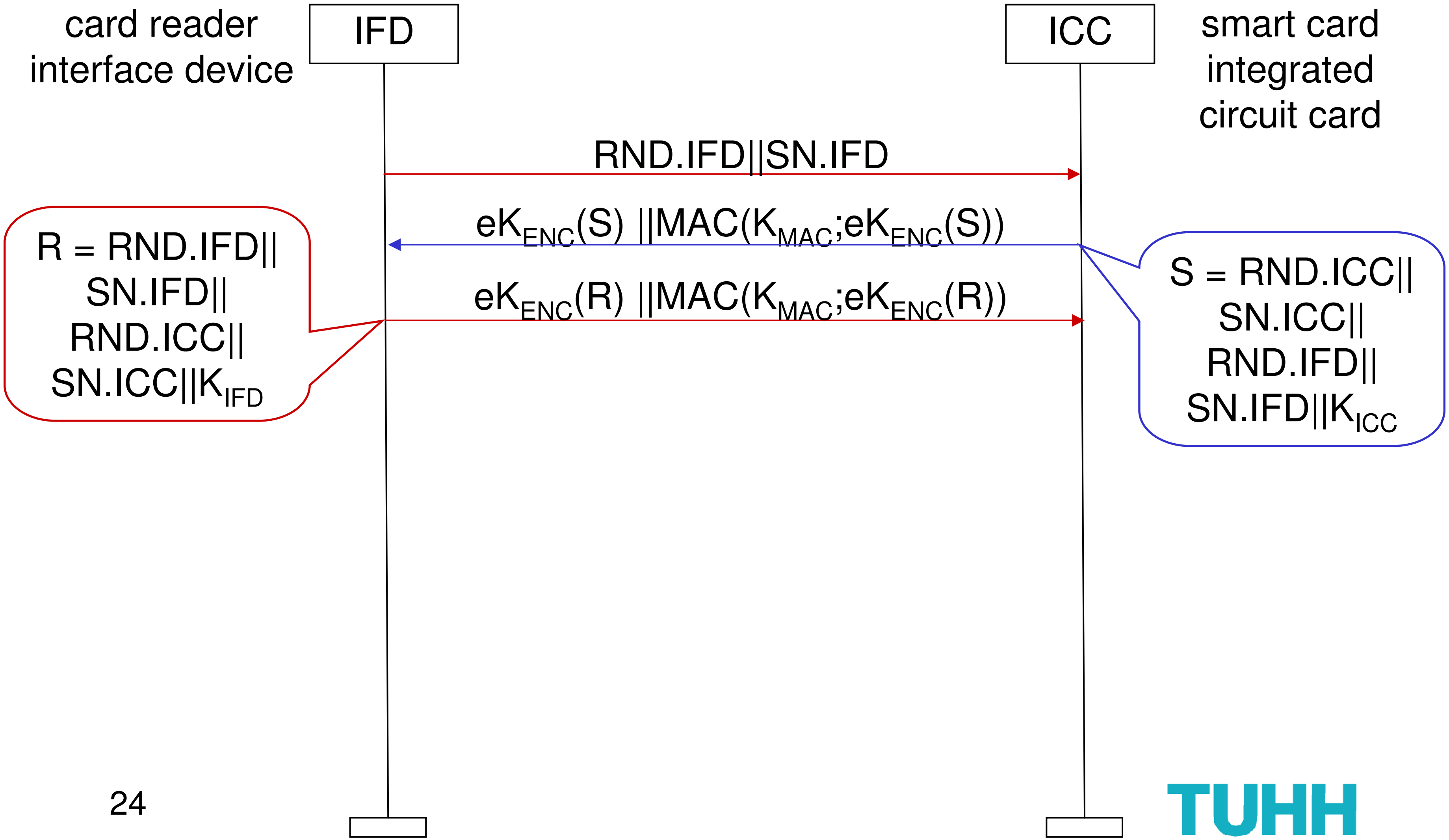
Problem?


Attacker
Malou
ICC
smart card integrated circuit card
GET DATA
SN.ICC
GET CHALLENGE (1)
RND.ICC
$eK_{ENC}(S)$ ||MAC(K $K_{ENC}(S)$)
$eK_{ENC}(R)$ ||MA $K_{ENC}(R)$)
S = RND.IFD|| SN.IFD|| RND.ICC|| SN.ICC||K_{IFD}
decrypts input; compares RND.ICC with previous response; verifies RND.ICC, SN.ICC
R = RND.ICC|| SN.ICC|| RND.IFD|| SN.IFD||K_{ICC}
attacker asks for one byte random challenge; standard does not define how card should react.
Don't trust your inputs!

Software security

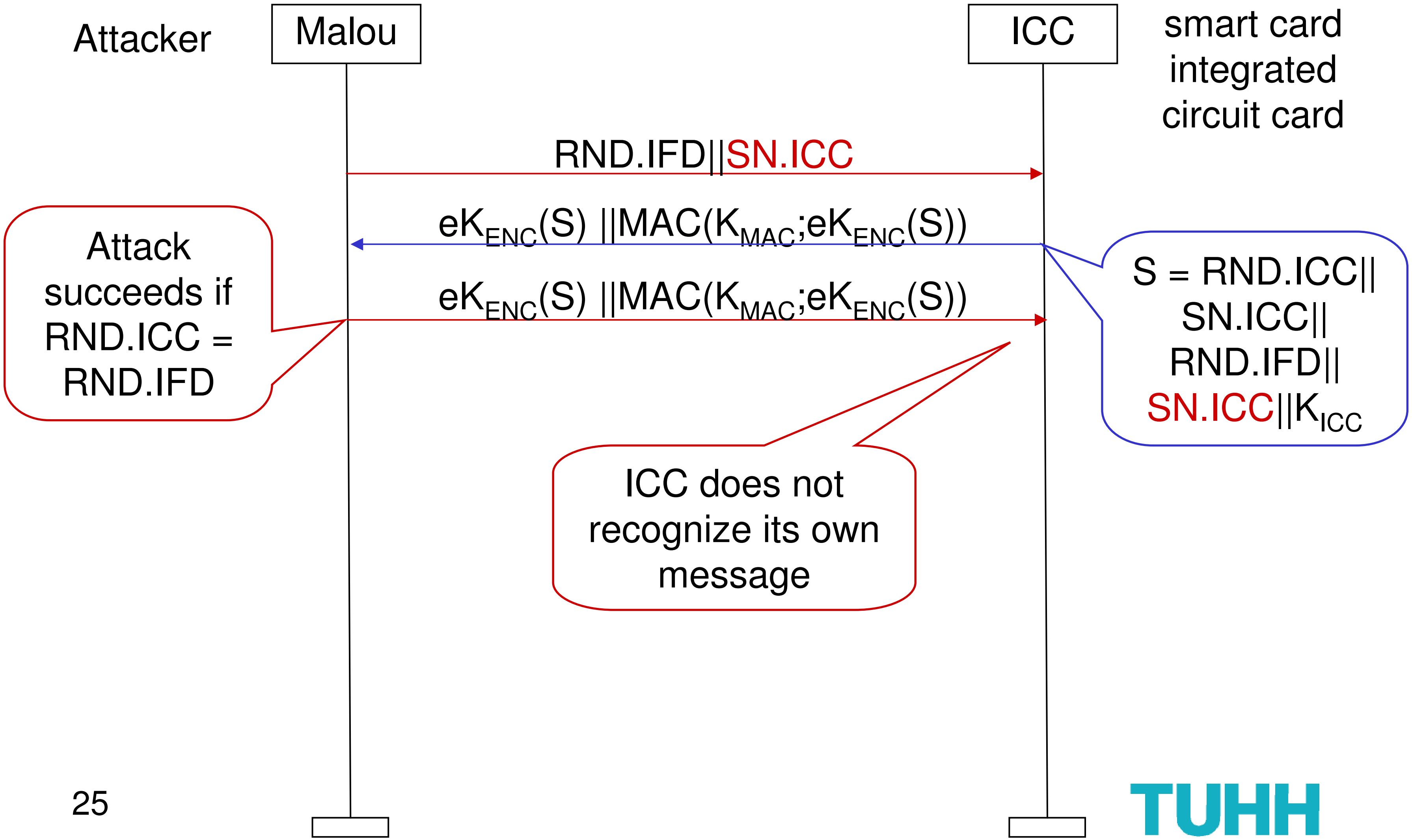
- Software is secure if it can deal with intentionally malformed input.
- In this case, the attacker does not know the secret key and tries to improve her chances of guessing a correct answer by asking for a short challenge.
- Secure software must check its inputs; can then reject or ignore illegal inputs.
- Such a check can be easily implemented on the card but is not prescribed by the standard.

… Variation



card reader interface device
IFD
ICC
smart card integrated circuit card
RND.IFD||SN.IFD
$eK_{ENC}(S)$ ||$MAC(K_{MAC};eK_{ENC}(S))$
$eK_{ENC}(R)$ ||$MAC(K_{MAC};eK_{ENC}(R))$
R = RND.IFD|| SN.IFD|| RND.ICC|| SN.ICC||K_{IFD}
S = RND.ICC|| SN.ICC|| RND.IFD|| SN.IFD||K_{ICC}

Problem (reflection attack)?



On the use of XOR

- XOR with a random value guarantees randomness??
- K_{ICC}, K_{IFD} are 32 byte random values.
- $K_{ICC} \oplus K_{IFD}$ is input for generation of the session key.
- In the previous scenario $K_{ICC} = K_{IFD}$.
- Attacker doesn't know K_{ICC}, but knows $K_{ICC} \oplus K_{ICC} = 0$ and can compute the session key.
- XOR with random value doesn't give perfect security.
- Use hash function instead and derive session key from $h(K_{ICC}, K_{IFD})$.

Remark

- These are instances of known problems.
- There exist well known and simple fixes.
- Smart cards on the market today may well defend against these attacks.
- How can a decision maker be sure?
- How can a certification body be sure that all relevant undocumented requirements are met by a card?

Conclusion

- Secure implementation of insecure protocols.
- Formal analysis of the protocols discussed previously would flag vulnerabilities.
- Formal analysis needs to be applied to protocol + (partial) card specification; may need to consider specific properties of a cryptographic algorithm.
- Formal analysis needs to consider software security.
- Thank you very much for your attention.