T-79.4501
Cryptography and Data Security

Kaisa Nyberg, professor
Billy Brumley and Jukka Valkonen, assistants

General

- http://www.tcs.hut.fi/Studies/T-79.4501/
- Course agenda
  - 12 lectures in Finnish à 2 hours, Tue, Thu 12-14 (**no lecture on Feb 7 and Feb 14**)
  - 6 exercise sessions, two groups:
    - Group 1(Finnish) Mon 12-14
    - Group 2 (English) Wed 12-14
- 4 credits, requirements: Exam (max 30 pts)
- Exams: Monday, the 6th of March, at 13-16 in T1
  Friday, the 12th of May, at 13-16 in T1
- Up to 6 exam bonus points can be obtained from active participation in exercise group.

Textbook

- *Cryptography and Network Security, Principles and Practices*, by W. Stallings. Third edition, Pearson Education 2003, ISBN 0-13-091429-0

Other useful books:

- *Handbook of Applied Cryptography,* by A.J.Menezes, P.C.van Oorschot, S.A.Vanstone, CRC Press
- *Network Security, Private Communication in a Public World*, by C. Kaufman, Radia Perlman, Mike Speciner. Second edition, Prentice Hall 2002, ISBN 0-13-046019-2
- *UMTS Security,* by V. Niemi and K. Nyberg, Wiley 2002, ISBN 0-470-84794-8

Contents

- Introduction to data security
- Classical cryptosystems
- Introduction to modern cryptography
- Block ciphers: DES, IDEA, AES
- Stream ciphers: RC4, and other examples
- Block cipher modes of operation
- Hash-functions and MACs
- Mathematical tools: Modular arithmetic, Euclid's algorithm, Chinese Remainder Theorem, Euler's totient function, Euler's theorem
- Public key cryptosystems: RSA
- Prime number generation
- Polynomial arithmetic
- Public key cryptosystems: Diffie-Hellman, El Gamal, DSS
- Authentication and Digital signatures
- Random number generation
- Authentication and key agreement protocols in practise: PGP, SSL/TLS, IPSEC, IKEv2 and EAP

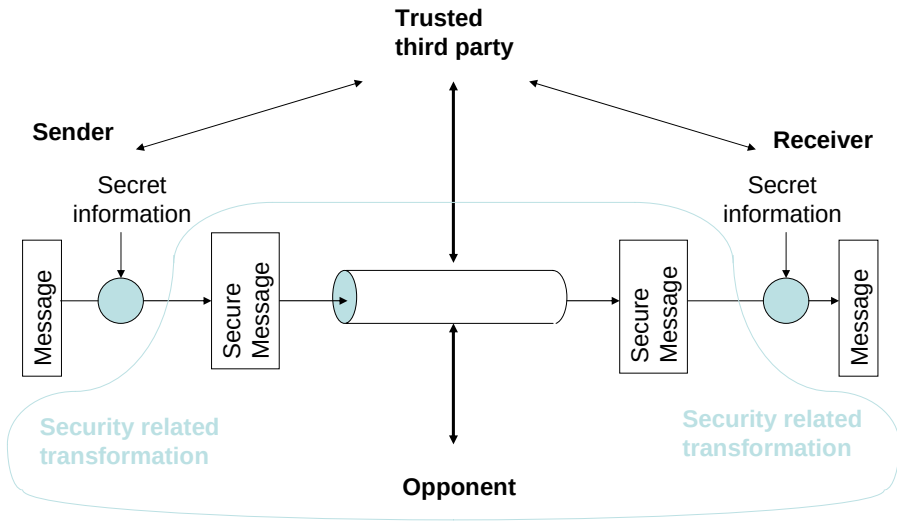
Lecture 1: Introduction to data security

- General security principles
- Communication security
- Design of a secure system
- Example: GSM security

What is Security?

- Security is an abstract concept
- Security is about protection methods against deliberate misbehaving actions
- Security in not fault-tolerance and robustness
- There is a distinction between physical security and information security.
- Physical security
  - locked rooms, safes and guards
  - tamper-resistance
  - proximity
  - biometric protection
  - identification based on physical appearance

Model for network security



Threat model

- Another way of defining security
  - First perform threat analysis: cababilities of an attacker, possible attack scenarios
  - Security can then be defined in terms of combatting the perceived threats
  - Not all threats are worth of combatting
- Dolev-Yao attacker model against cryptographic protocols: An attacker
  - Is a legitimate user of the network, and hence able to correspond with any other user
  - Can send messages to another user by impersonating any other user
  - Can receive messages intended to any other user

Computer and Communication Layers Security

System level security
- "The system is as strong as its weakest link."

Application security
- e.g. banking applications over Internet use security mechanisms which are tailored to meet their specific requirements.

Protocol level security
- well-defined communication steps in certain well-defined order.

Operating system security
- the behaviour of all elements in a network depends on the correct functionality of the operating system that controls them.

Platform security
- properties of the computing platform, e.g. protected memory space.

Security primitives
- these are the basic building blocks, e.g. cryptographic algorithms.

Design of a Secure System

Threat analysis
- What are the threats?

Risk analysis
- What is the potential damage each threat potentially can cause?

Trust model
- Whom and what can be trusted?

Requirements capture
- What kind of protection is required? What kind of protection is possible within the trust model?

Design phase
- Protection mechanism are designed in order to meet the requirements.
- Building blocks, e.g. security protocols or primitives are identified, possibly new mechanisms are created, and a security architecture is built.

Security analysis
- Evaluation of the design independently of the design phase.

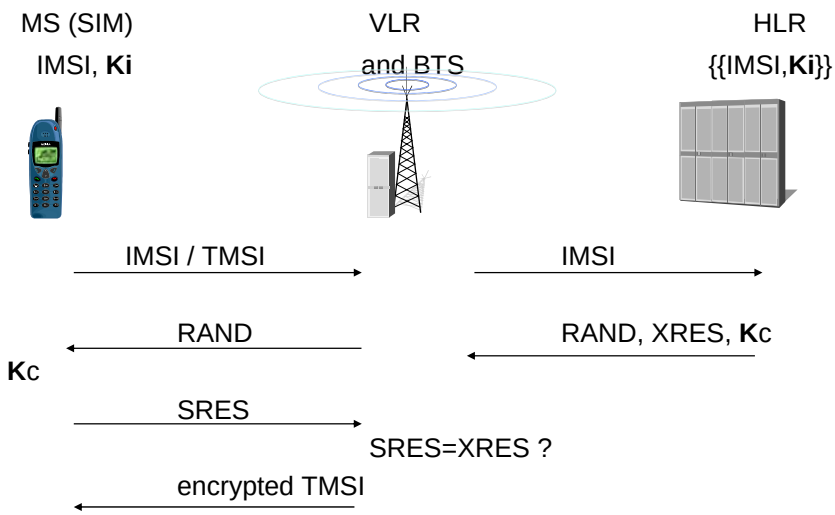
Reaction phase
- Reaction to expected security breaches and survival plan.

Example: GSM Security

Main features

- Authentication of the user
  - correct billing
- Encryption of communication over the radio interface
  - confidentiality of user and control data
  - call integrity
- Use of temporary identities
  - user privacy
  - location privacy

GSM Authentication



Criticism

Active attacks

- this refers to somebody who has the required equipment to masquerade as a legitimate network element and/or legitimate user terminal

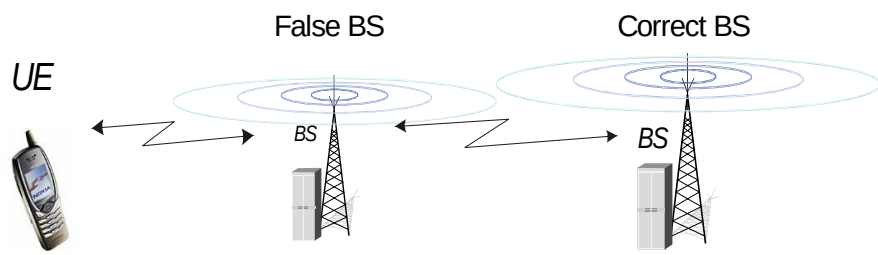
Missing or weak protection between networks

- control data, e.g. *keys* used for radio interface ciphering, are sometimes sent unprotected between different networks

Secret design

- some essential parts of the security architecture are kept secret, e.g. the cryptographic algorithms

Active Attack



Barkan–Biham-Keller Attack (2003)

Exploits weaknesses in cryptographic algorithms:

- A5/2 can be instantly broken

… AND other fundamental flaws in the GSM security system:

- A5/2 was a mandatory feature in handsets
- Call integrity based on an (weak) encryption algorithm
- The same Kc is used by different encryption algorithms
- Attacker can force the victim MS to use the same Kc by RAND replay

Two types of attacks:

1. Decryption of strongly encrypted call using ciphertext only
   - Catch a RAND and record the call encrypted with Kc and A5/3 (= strong encryption algorithm)
   - Replay the RAND and tell the MS to use A5/2 (= weak encryption alg.)
   - Analyse Kc from the received encrypted uplink signal
2. Call hi-jacking
   - Relay RAND to victim MS and tell it to use A5/2
   - Analyse Kc from the received signal encrypted by the victim MS
   - Take Kc into use and insert your own call on the line

Proposed Countermeasure

Amendment to the GSM security architecture: Special RANDs

- RAND is the only variable information sent from Home to MS in the authentication
- Divide the space of all 128-bit RANDs into different classes with respect to which encryption algorithm is allowed to be used with the Kc derived from this RAND.
- 32-bit flag to indicate to the MS that a special RAND is in use
- 16-bits to indicate which algorithms out of 8 GSM (and ECSD) and 8 GPRS encryption algorithms are allowed to be used with the key derived from this special RAND
- Effective RAND reduced from 128 bits to 80 bits. Remains to be judged if acceptable.
- Special RANDs trigged by the visited network identity. Requires careful configuration in the HLR/AuC.
- Solution assumes that HLR gets the correct VLR identifier.

Lessons learnt

- Use independent keys for different algorithms so that a key captured from one broken algorithm cannot be used to compromise security of another algorithm.
- Use strong crypto only
- Active man-in-the-middle attacks in wireless communication must be taken seriously
- Amendements to existing security system extremely difficult to implement:
  - updates to existing devices
  - backwards compatibility
  - version negotiation hard to protect (bidding down attacks)