T-79.4501
Cryptography and Data Security

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General

- Home page: http://www.tcs.hut.fi/Studies/T-79.4501/
- Course agenda
  - 12 lectures (in Finnish), Tue 12-14, Thu 10-12
    - First lecture September 12. Last lecture October 24
  - Exceptions:
    - September 13, Wednesday 12-14, hall T4, additional lecture;
    - September 21, Thursday 10-12, lecture cancelled;
    - October 10, Tuesday 12-14, lecture cancelled.
  - 6 exercise sessions, weeks 38-43:
    - Group 1 (English) Wednesday 12-14 T4
    - Group 2 (Finnish) Thursday 12-14 T4 (Oct 26 included!)
- 4 credits, requirements: Exam (max 30 pts)
- Exams:
    - Monday, the 30th of October, 2006, at 9-12 in T1
    - Thursday, the 8th of March, 2007, at 9-12 in T1
- Exercise bonus: Max 6 points can be added to the exam points based on active participation in exercise classes.

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 (1-6)

- Introduction to data security
- Classical cryptosystems
- Introduction to modern cryptography
- Polynomial arithmetic, Euclidean algorithm; Block ciphers: DES, IDEA, AES
- Stream ciphers: RC4, and other examples
- Block cipher modes of operation
- Hash-functions and MACs
- Mathematical tools: Modular arithmetic, Chinese Remainder Theorem, Euler’s totient function, Euler’s theorem

Contents (7-12)

- Public key cryptosystems: RSA
- Prime number generation
- Public key cryptosystems: Diffie-Hellman, El Gamal, DSS
- Authentication and Digital signatures
- Random number generation and Key management
- Example: Bluetooth security
- Authentication and key agreement protocols in practise: PGP, SSL/TLS, IPSEC, IKEv2 and EAP

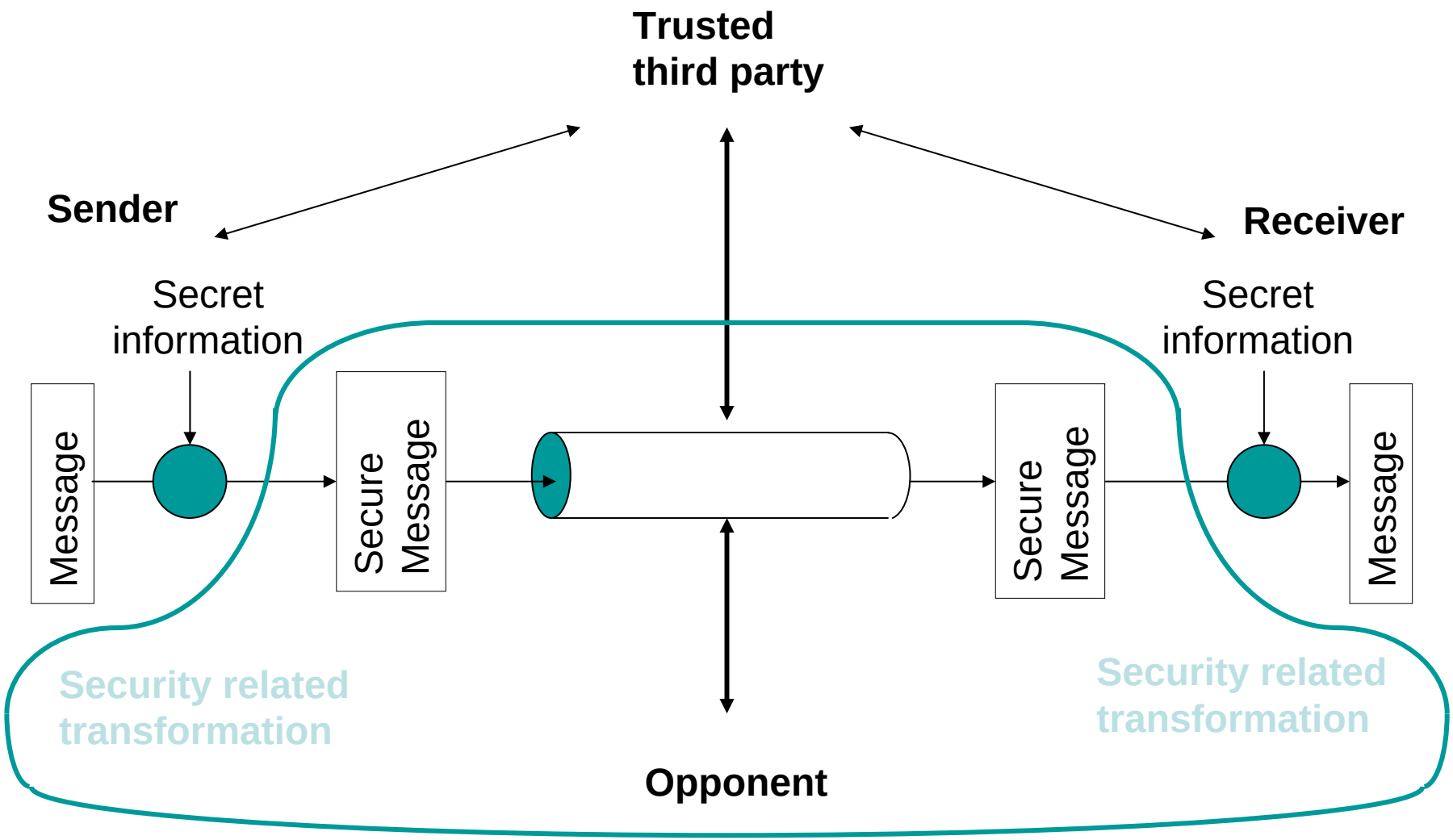
Lecture 1:
Introduction to data security

- 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
- This course is about information technical methods to protect information against an intelligent misbehaving attacker

Model for network security



Threat model

- How to define security (needs) in practise:
  - 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, absolute security cannot be achieved
- 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 security technical features

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

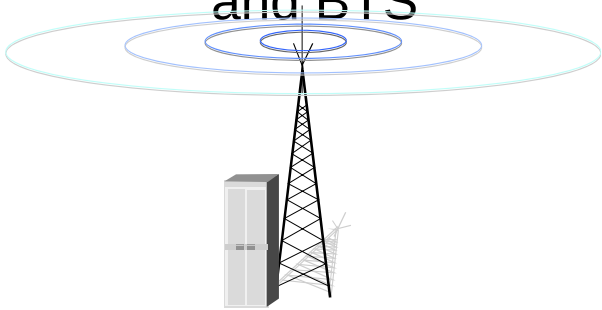
GSM Authentication

MS (SIM)

IMSI, **Ki**

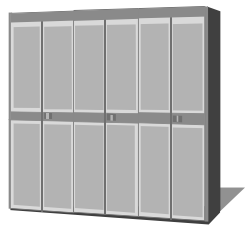
VLR

and BTS



HLR

{{IMSI,**Ki**}}



IMSI / TMSI →

IMSI →

← RAND

← RAND, XRES, **K**c

Kc

SRES →

SRES=XRES ?

← encrypted TMSI

Criticism

Active attacks possible

- It is possible with suitable equipment to masquerade as a legitimate network element and/or legitimate user terminal

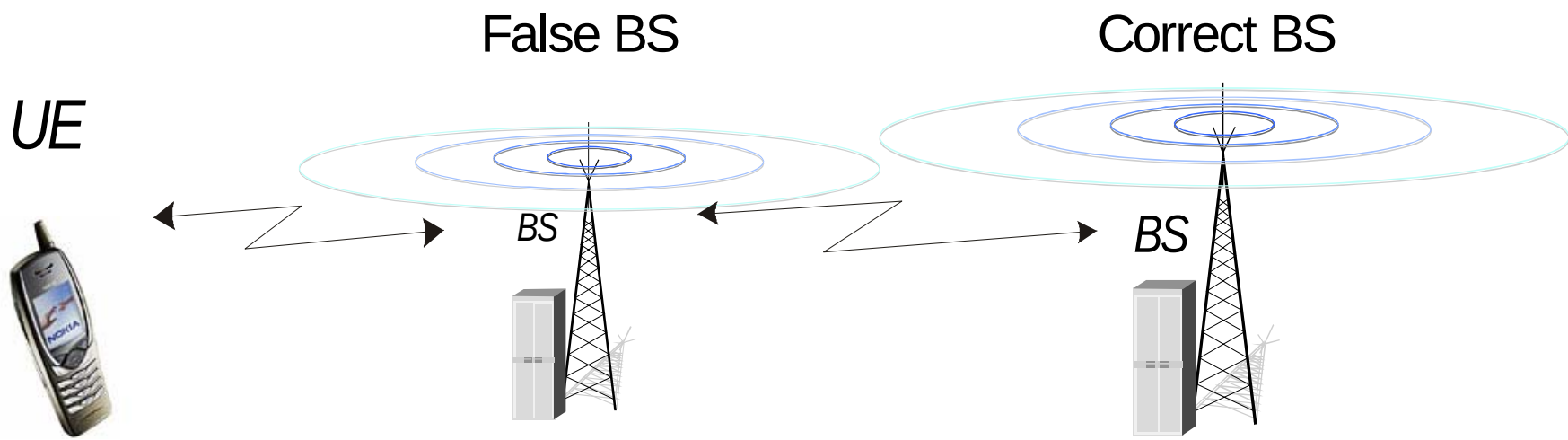
Missing or weak protection between networks

- 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 were 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

Countermeasures considered

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.

… but never realised

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
- Amendments to existing security system extremely difficult to implement:
  - updates to existing devices
  - backwards compatibility
  - version negotiation hard to protect (bidding-down attacks)