

CrypTool

A free software program

- **for creating awareness of IT security issues**
- **for learning about and obtaining experience of cryptography**
- **for demonstrating encryption algorithms and analysis procedures**

www.cryptool.de
www.cryptool.com
www.cryptool.org

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TECHNISCHE
UNIVERSITÄT
DARMSTADT

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Introduction

1. What is CrypTool?

- a freeware Program with graphical user interface
- a tool for applying and analysing cryptographic algorithms
- with extensive online help, understandable without deep crypto knowledge
- contains nearly all state of the art crypto algorithms
- “playful” introduction to modern and classical cryptography
- not a “hacker tool”

2. Why CrypTool?

- origin in Deutsche Bank’s IT security awareness program
- developed in co-operation with universities
- improve IT security related courses in universities and companies

3. Audience

- target group: students of computer science, commercial IT and mathematics
- also aimed at: interested computer users and application developers
- prerequisites: secondary school mathematics or programming skills

CrypTool Overview

1. Features

Cryptography

Classical algorithms

- Caesar
- Vigenère
- Hill
- Monoalphabetic substitution
- Homophonic substitution
- Playfair
- Permutation
- Addition
- XOR
- Vernam

To facilitate performing text book examples with CrypTool

- alphabet can be configured
- treatment of white space etc. configurable

Cryptanalysis

Attacks on classical algorithms

- ciphertext only
 - Caesar
 - Vigenère
 - Addition
 - XOR
- known plaintext
 - Hill
 - Playfair
- manual
 - mono-alphabetic substitution

Supporting analysis procedures

- entropy, floating frequency
- histogram, n-gram analysis
- auto-correlation
- ZIP compression test

CrypTool Overview

1. Features

Cryptography

Modern symmetric algorithms

- IDEA, RC2, RC4, DES, 3DES
- last round AES candidates
- AES (=Rijndael)

Asymmetric algorithms

- RSA with X.509 certificates
- RSA demonstration
 - to facilitate performing text book examples with CrypTool
 - alphabet and block length configurable

Hybrid encryption

- RSA combined with AES encryption
- visualised by an interactive data flow diagram

Cryptanalysis

Brute-force attack on symmetric algorithms

- implemented for all algorithms
- assumption:
 - entropy of the plain text is small

Attack on RSA encryption

- factor RSA modulus
- workable for bit lengths ≤ 250

Attack on hybrid encryption

- attack on RSA (see below) or
- attack on AES (see above)

CrypTool Overview

1. Features

Cryptography

Digital Signature

- RSA with X.509 certificates
 - signature procedure visualised by an interactive data flow diagram
- DSA with X.509 certificates
- Elliptic curve DSA, Nyberg-Rueppel

Hash functions

- MD2, MD4, MD5
- SHA, SHA-1, RIPEMD-160

Random generators

- SECUDE
- X^2 modulo N
- Linear Congruence Generator (LCG)
- Inverse Congruence Generator (ICG)

Cryptanalysis

Attack on RSA Signature

- RSA modulus factorisation
- workable up to approx. 250 bit

Attack on hash function/digital signature

- Generation of hash collisions to ASCII texts

Random data analysis

- FIPS-PUB-140-1 test battery
- periodicity, Vitany, entropy
- histogram, n-gram analysis
- auto-correlation
- ZIP compression test

CrypTool Overview

2. Software package contents

CrypTool program

- all functions integrated in *one* program with uniform graphical user interface
- platforms: Win32 and Linux with WINE emulator
- cryptography based on Secude library (www.secude.com)
- arbitrary precision arithmetic: Miracl library (<http://indigo.ie/~mscott/>)

AES-Tool

- standalone program for AES encryption (self extracting)

Extensive online help (Winhelp)

- context sensitive online help for *all* program functions and all menu items
- detailed examples of usage for many program features

Script (PDF) with background information on

- encryption algorithms • prime numbers • digital signature
- elliptic curves • public key certification • elementary number theory

Short story “Dialogue of the Sisters” by Dr. C. Elsner



completely bilingual
English
German

CrypTool Overview

3. New in release 1.3.xx

Most important changes (details: see ReadMe-en.txt):

Release 1.3.00 published January 2002

- completely bilingual English/German
- improved dialog box consistency and comprehensibility
- Windows 9x file size limit removed
- homophonic and permutation encryption
- random generators, random data analysis (FIPS-140-1, periodicity, n-gram)
- AES-Tool: create self-decrypting files (AES)
- demonstration: number theory and RSA crypto system (further improved in 1.3.02)
- PKCS#12 export/import for PSEs

Release 1.3.02 published June 2002

- visualisation of hybrid encryption and decryption
- visualisation of signature creation and verification
- hash value calculation of large files (without loading them into memory)
- visualisation of the sensitivity of hash functions to changes in the hashed data
- short story “Dialogue of the Sisters” by Dr. C. Elsner included

CrypTool Overview

3. New in release 1.3.xx

Release 1.3.04 published June 2003

- visualisation of Diffie-Hellman key exchange
- attack on digital signature using hash-collisions (birthday paradox)
- brute-force attack on symmetric ciphers improved
- script updated (primes, factorization) and extended (hash functions, ECC, CrypTool menu tree)
- many small improvements (especially online help) and bug fixes

Examples of use

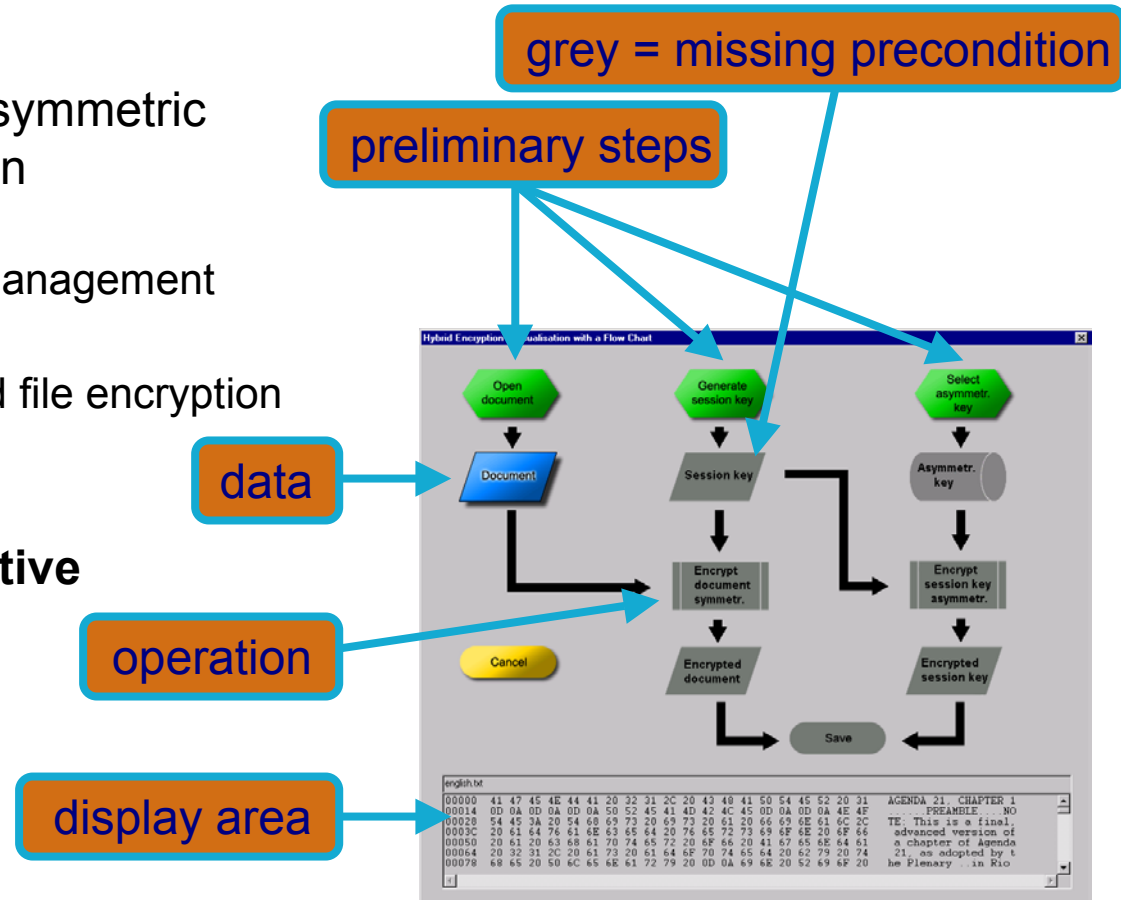
1. Hybrid encryption visualised

Hybrid encryption

- combines advantages of symmetric and asymmetric encryption
 - speed
 - simple and scalable key management
- widely used in practice
 - e-mail (S/MIME, PGP) and file encryption
 - SSL (https)

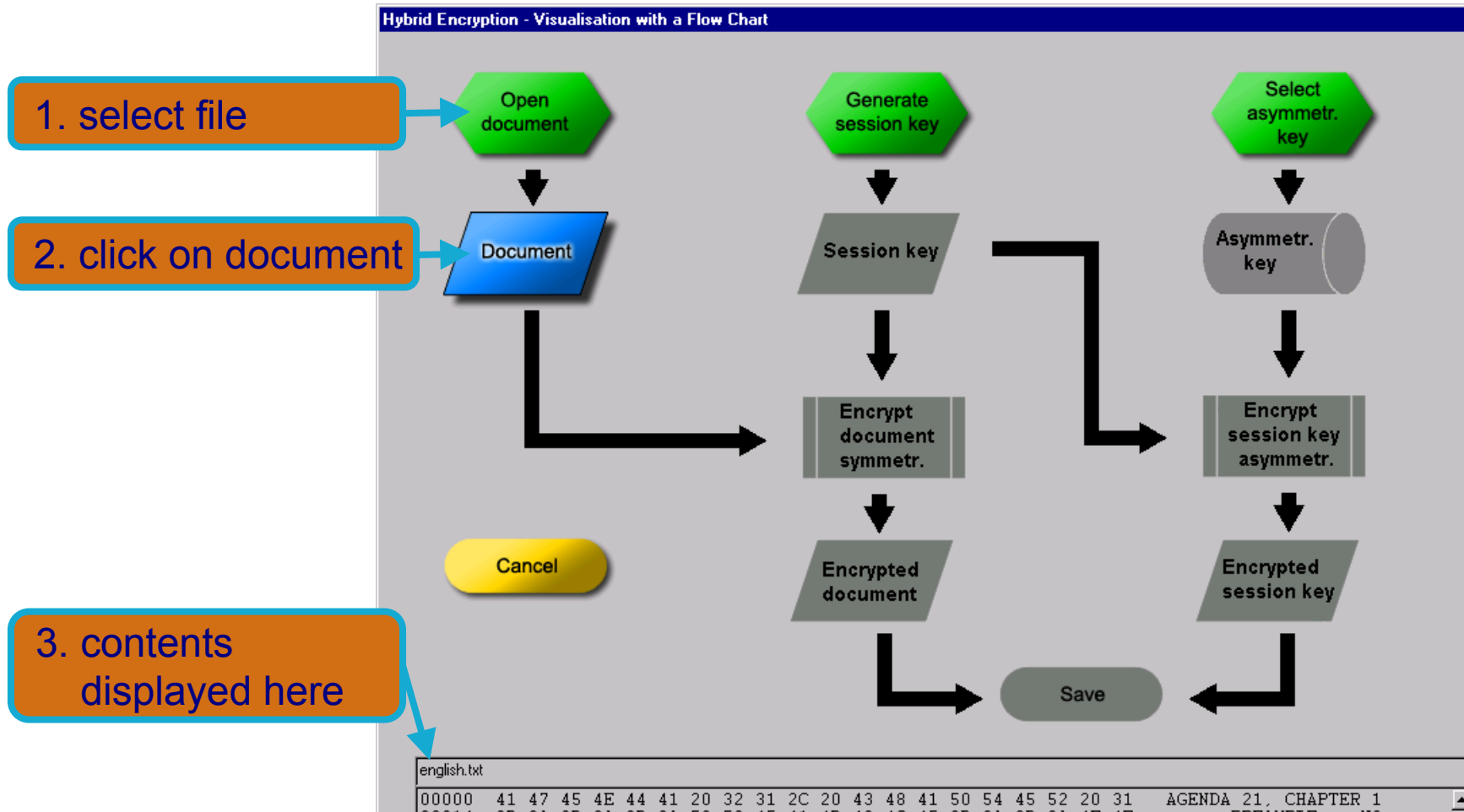
Visualisation by an interactive data flow diagram

- playful learning leads to deeper understanding



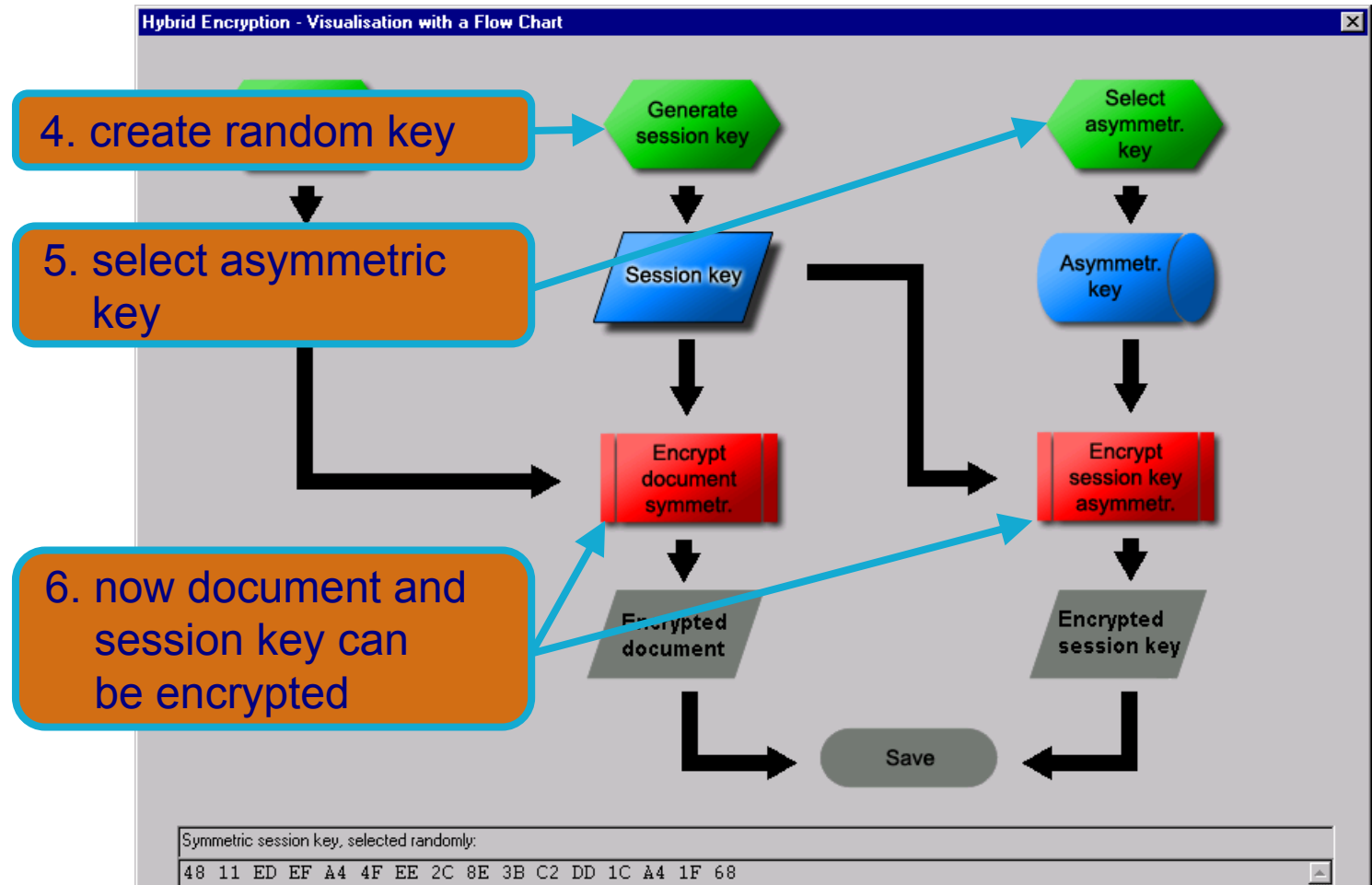
Examples of use

1. Hybrid encryption visualised: Preparation

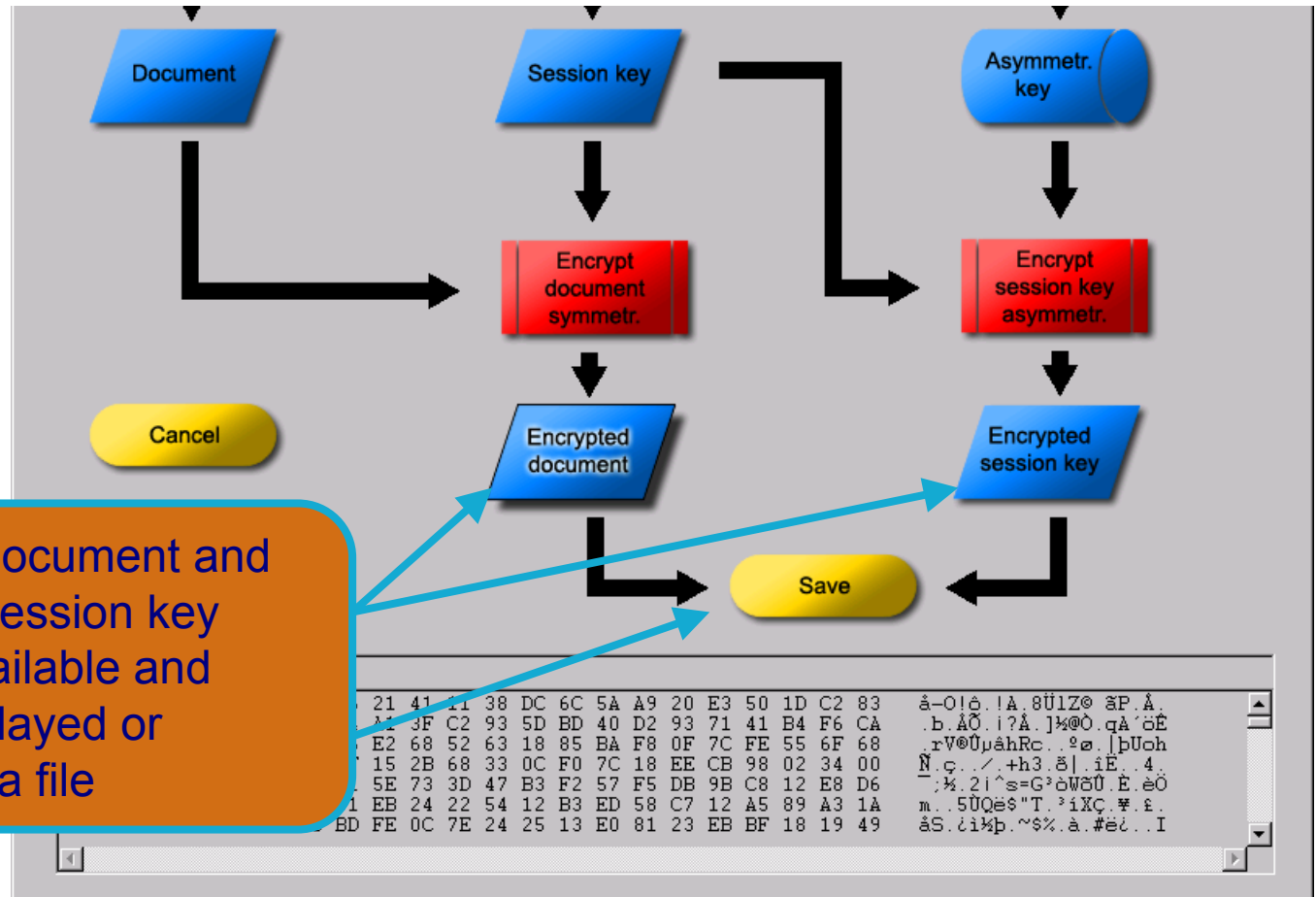


Examples of use

1. Hybrid encryption visualised: Cryptography



1. Hybrid encryption visualised: Result



Examples of use

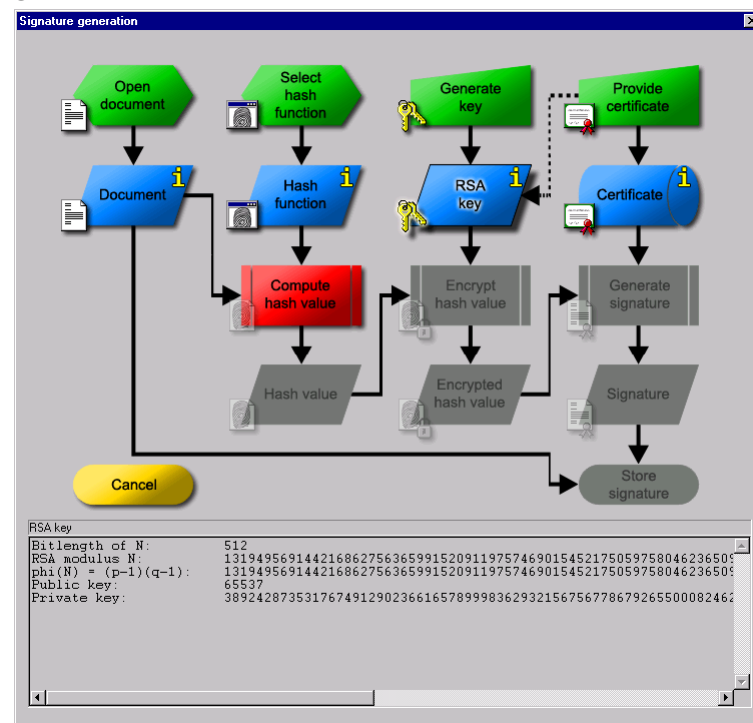
2. Digital signature visualised

Digital signature

- increasingly important
 - equivalence with manual signature (digital signature law)
 - increasingly used by industry, government and consumers
- few people know how it works

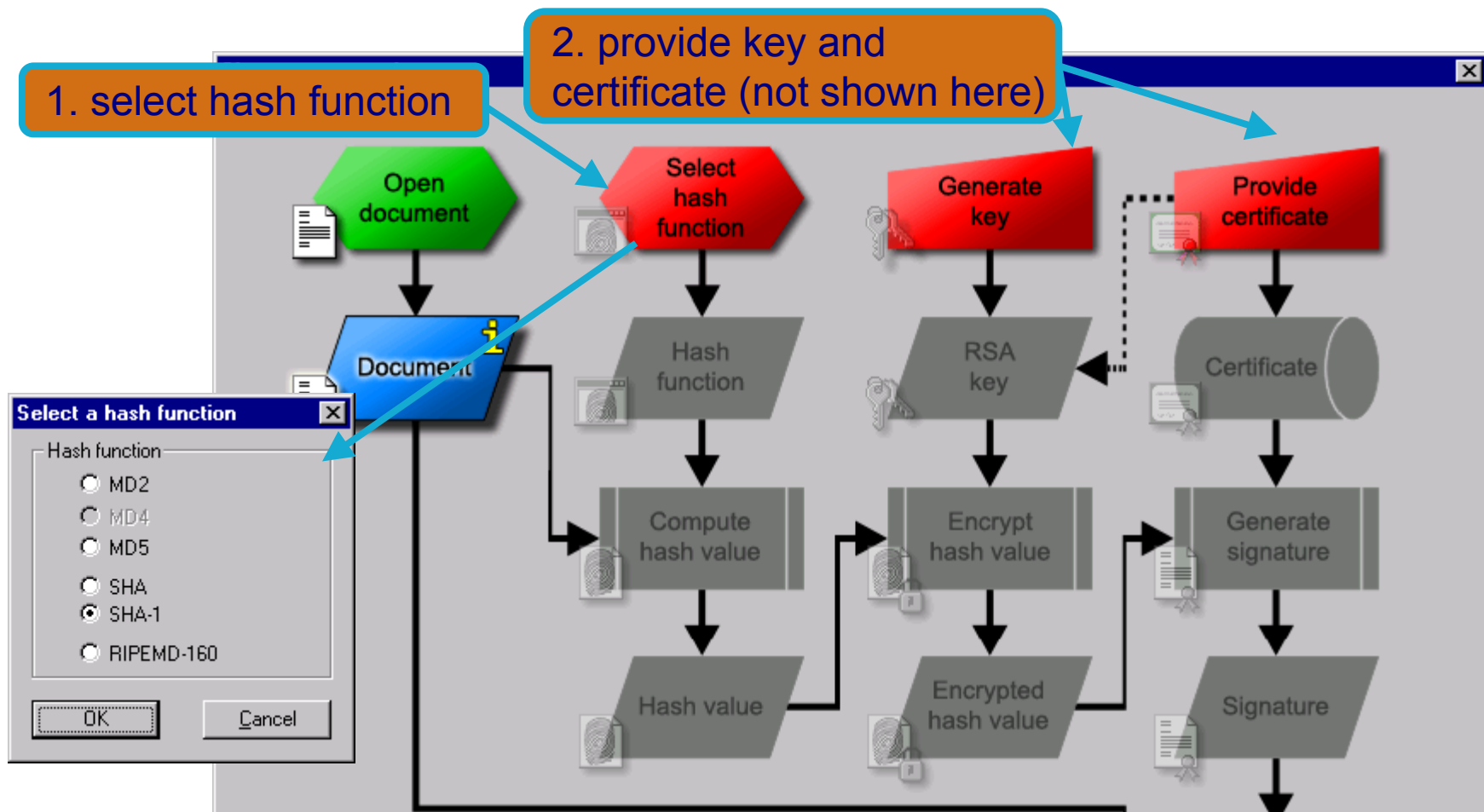
Visualisation in CrypTool

- interactive data flow diagram
- similar to the visualisation of hybrid encryption



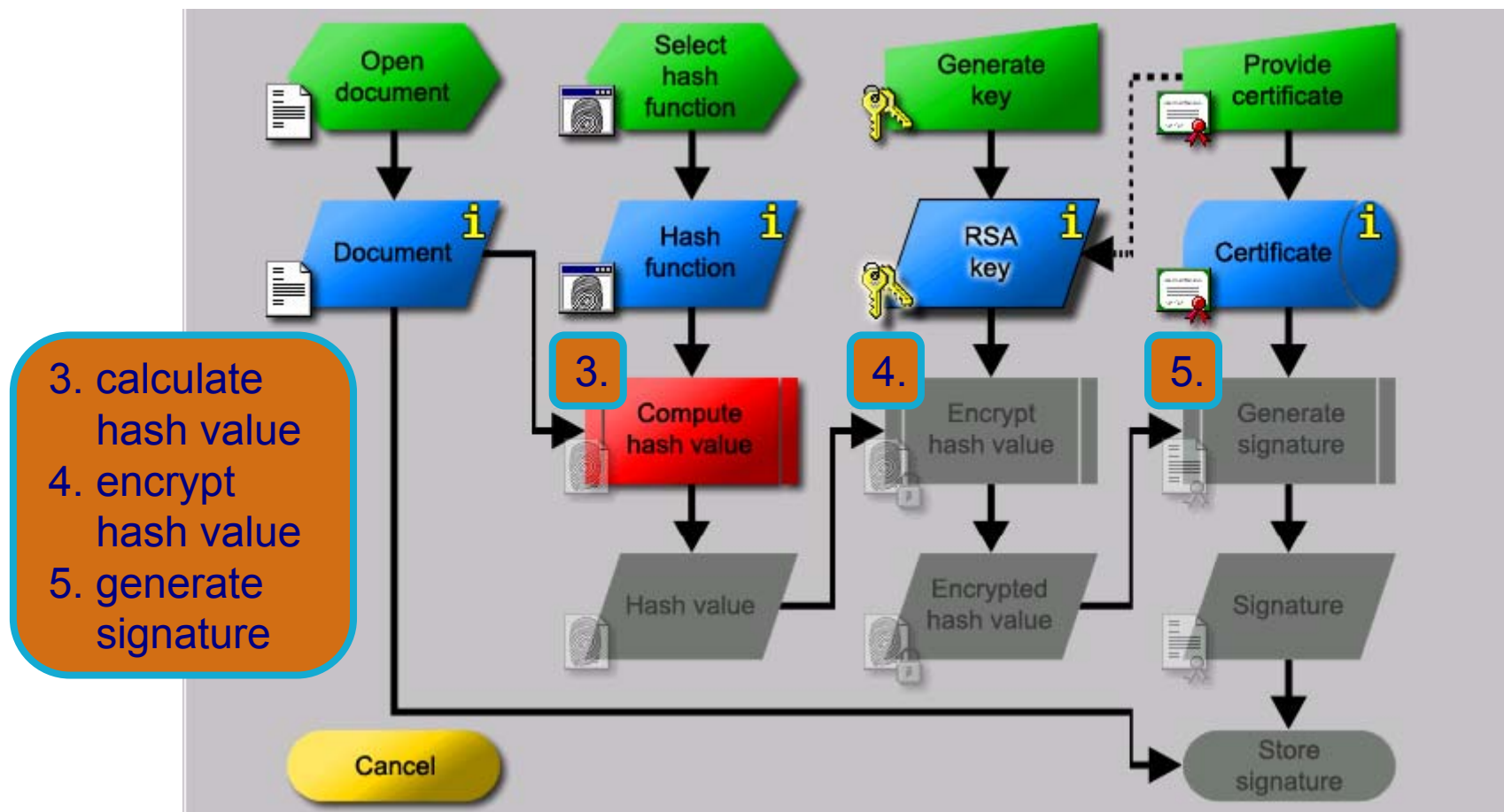
Examples of use

2. Digital signature visualised: Preparation



Examples of use

2. Digital signature visualised: Cryptography

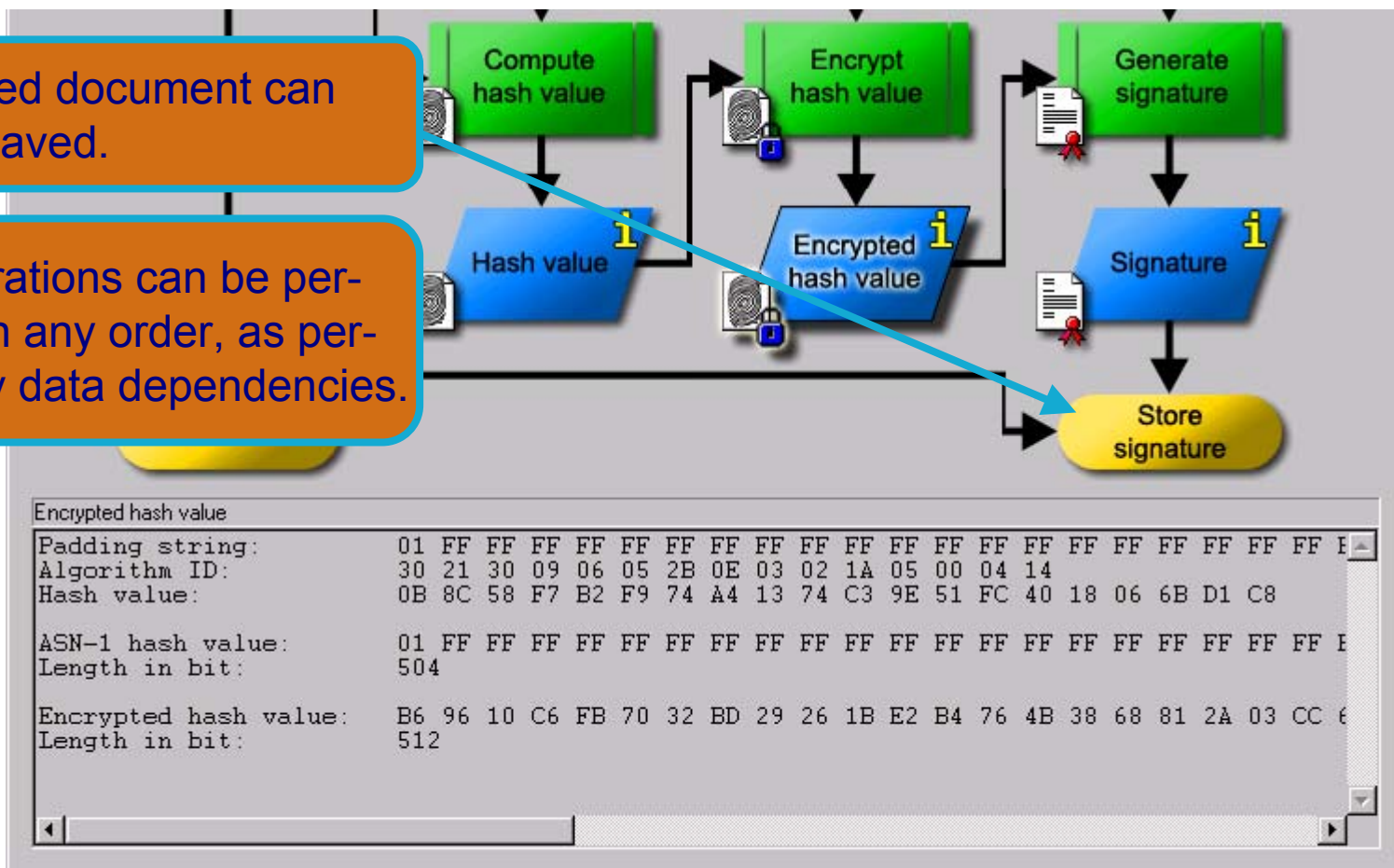


Examples of use

2. Digital signature visualised: Result

The signed document can now be saved.

The operations can be performed in any order, as permitted by data dependencies.



Examples of use

3. Attack on RSA encryption with short RSA modulus

Example from *Song Y. Yan, Number Theory for Computing, Springer, 2000*

- public key
 - RSA modulus $N = 63978486879527143858831415041$ (95 bit, 29 decimal digits)
 - public exponent $e = 17579$
- cipher text (block length = 14):
 - $C_1 = 45411667895024938209259253423,$
 $C_2 = 16597091621432020076311552201,$
 $C_3 = 46468979279750354732637631044,$
 $C_4 = 32870167545903741339819671379$
- the text shall be deciphered!

Solution using CrypTool (more detailed in online help examples section):

- enter public parameters into “RSA cryptosystem” (menu indiv. procedures)
- button “factorise the RSA modulus” yields prime factors $pq = N$
- based on that information private exponent $d = e^{-1} \bmod (p-1)(q-1)$ is determined
- decrypt the cipher text with d : $M_i = C_i^d \bmod N$

The attack with CrypTool is workable for RSA moduli up to 250 bit

Examples of use:

3. Short RSA modulus: enter public RSA parameters

The RSA Cryptosystem

☐ RSA using the private and public key -- or using only the public key

- ☐ Choose two prime numbers p and q . The number $N = pq$ is the public RSA modulus and $\phi(N) = (p-1)(q-1)$ is the Euler number. Public key e is coprime to $\phi(N)$. The private key $d = e^{-1} \pmod{\phi(N)}$ is calculated from this.
- ☒ For the purpose of data encryption or certificate checking it is sufficient to enter the public RSA parameters: the RSA modulus N and the public key e .

Factorisation attack

You may try to factorise the public RSA modulus N into its primes p and q .

Factorise RSA modulus...

RSA parameters

RSA modulus N	<input type="text" value="63978486879527143858831415041"/>	(public)
$\phi(N) = (p-1)(q-1)$	<input type="text"/>	(secret)
Public key e	<input type="text" value="17579"/>	
Private key d	<input type="text"/>	

Update parameters

☐ RSA encryption using e / decryption using d

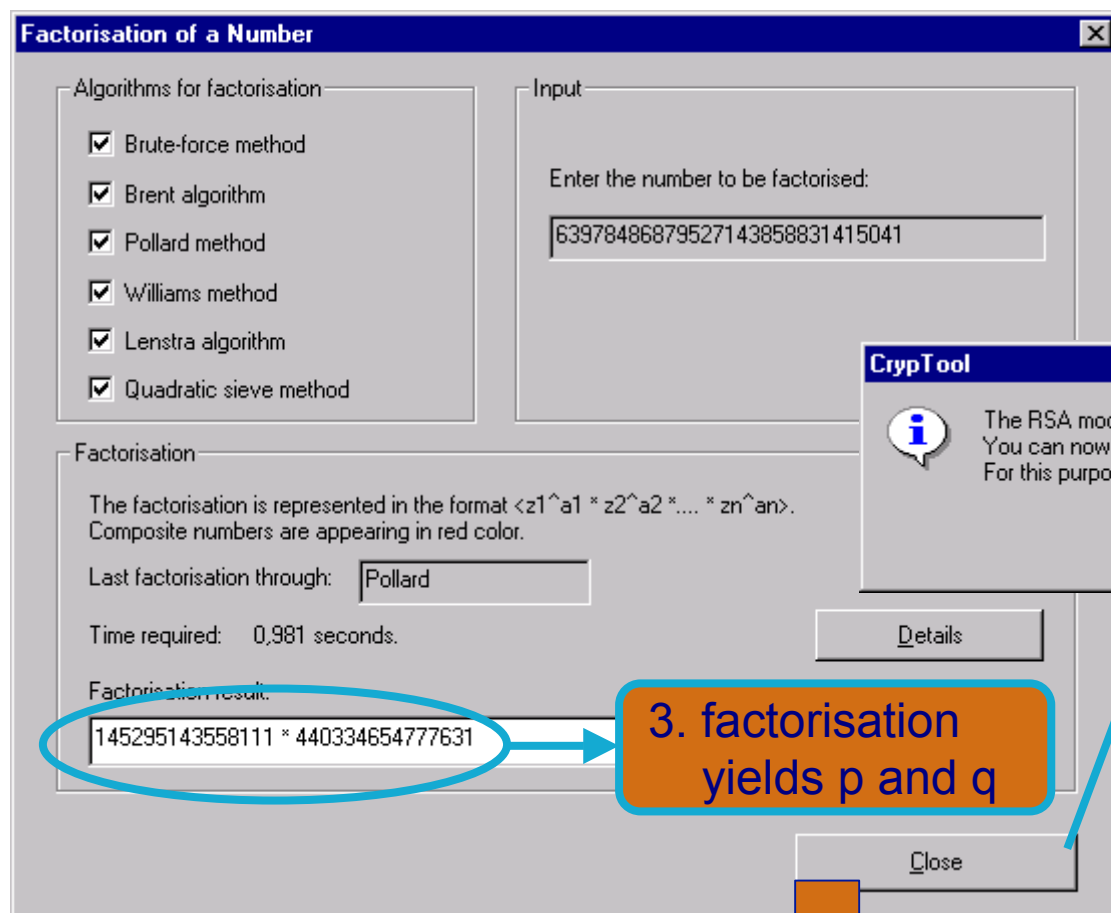
2. factorise

1. enter RSA parameters N and e



Examples of use:

3. Short RSA modulus: factorise RSA modulus



Examples of use:

3. Short RSA modulus: determine private key d

The RSA Cryptosystem

RSA using the private and public key -- or using only the public key

☒ Choose two prime numbers p and q. The number $N = pq$ is the public RSA modulus and $\phi(N) = (p-1)(q-1)$ is the Euler number. Public key e is coprime to $\phi(N)$. The private key $d = e^{-1} \pmod{\phi(N)}$ is calculated from this.

☐ For the purpose of data encryption or certificate checking it will do with the published RSA parameter: the RSA modulus N and the public key e.

Prime number entry

Prime number p: 145295143558111

Prime number q: 440334654777631

Generate prime numbers

RSA parameters

RSA modulus N: 63978486879527143858831415041 (public)

$\phi(N) = (p-1)(q-1)$: 63978486879526558229033079300 (secret)

Public key e: 17579

Private key d: 10663687727232084624328285019

Update parameters

RSA encryption using e / decryption using d

Input as ☒ text ☐ numbers

Options for alphabet and number system...

Enter either as text or as numbers in the format number[1] # ... # number[n] (numbers of base 1240752)

4. p and q have been entered automatically and secret key d has been calculated

5. adjust options

Examples of use:

3. Short RSA modulus: adjust options

Options for RSA Encryption

Text options

☐ All 256 ASCII characters

☒ Specify alphabet: Number of characters: 27

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Block length

The number of characters that are encrypted with each RSA operation.
The maximum size is subject to the length of the RSA modul N in bit, the number of characters in the alphabet and the method used for the coding.

Block length in characters: (Maximum block length 2 characters)

Number system

The numbers for RSA encryption and decryption will be represented in the following number system

☒ Decimal ☐ Binary ☐ Octal ☐ Hexadecimal

OK Cancel

6. select alphabet

7. select coding method

8. select block length



Examples of use:

3. Short RSA modulus: decrypt cipher text

RSA parameters

RSA modulus N (public)

$\phi(N) = (p-1)(q-1)$ (secret)

Public key e

Private key d

RSA encryption using e / decryption using d

Input as ☐ text ☒ numbers

Ciphertext coded in numbers of base 10

Decryption into plaintext $m[i] = c[i]^d \pmod{N}$

Output text from the decryption (into segments of size 8; the symbol '#' is used as separator).

Plaintext

9. enter cipher text

10. decrypt

Examples of use

4. Analysis of encryption used in the PSION 5 PDA

Attack on the encryption option in the PSION 5 PDA word processing application



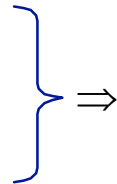
Starting point: an encrypted file on the PSION

Requirements

- encrypted English or German text
- depending on method and key length, 100 bytes up to several kB of text

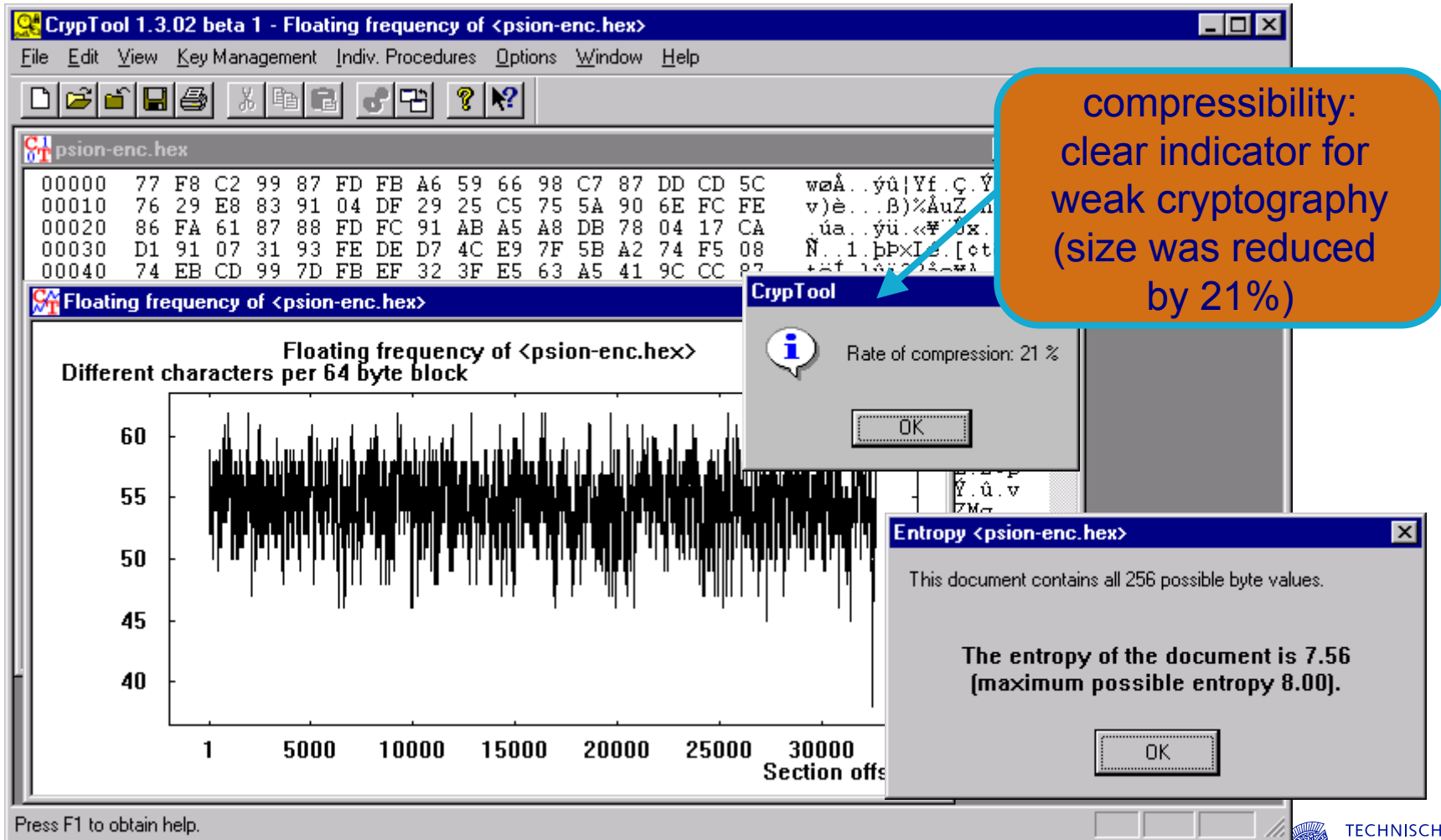
Procedure

- pre-analysis
 - entropy
 - floating entropy
 - compression test
- auto-correlation
- try out automatic analysis with classical methods



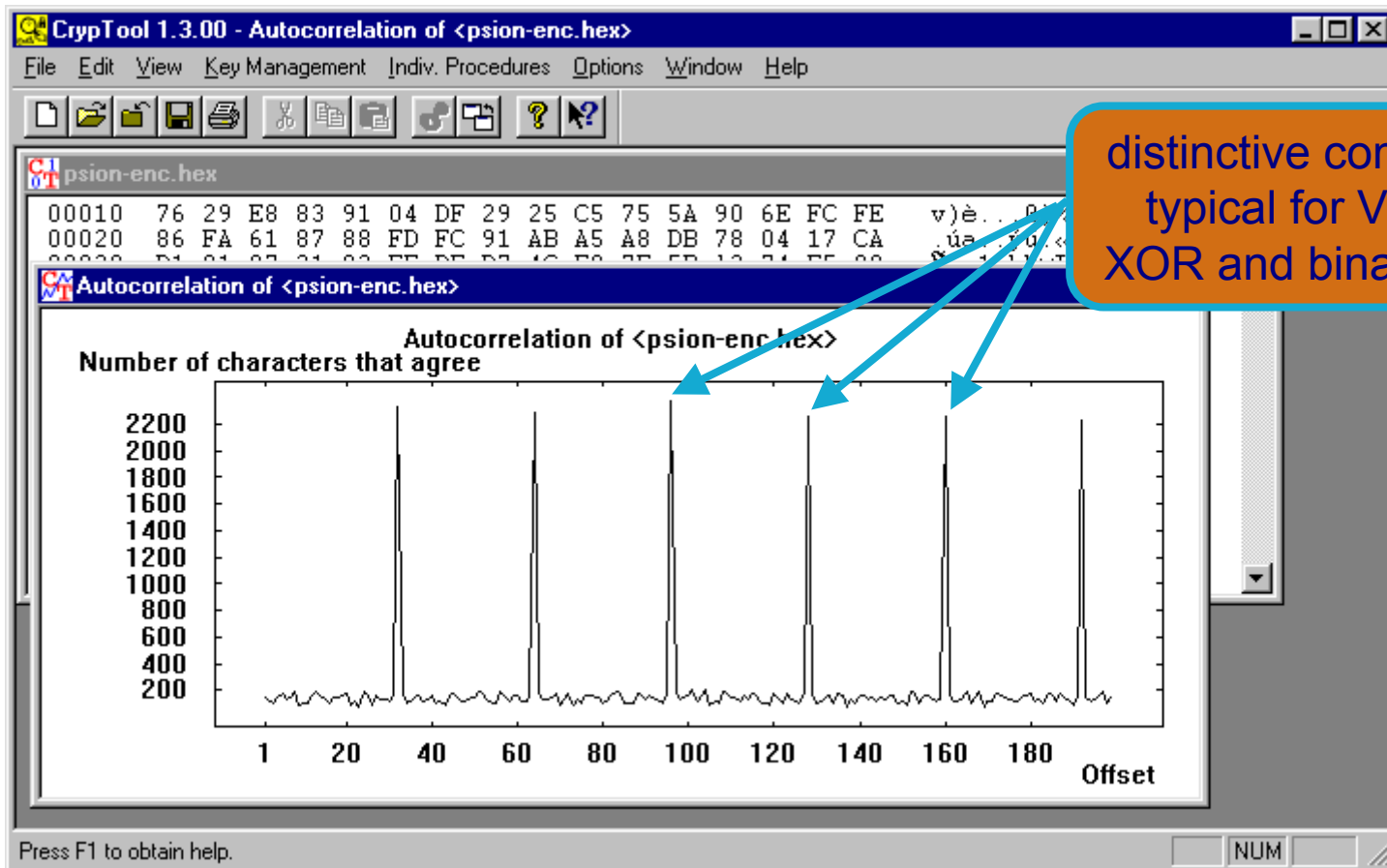
probably classical
encryption algorithm

4. PSION PDA: determine entropy, compression test



Examples of use

4. PSION PDA: determine auto-correlation



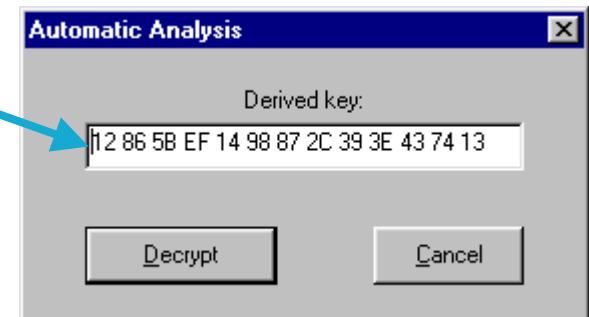
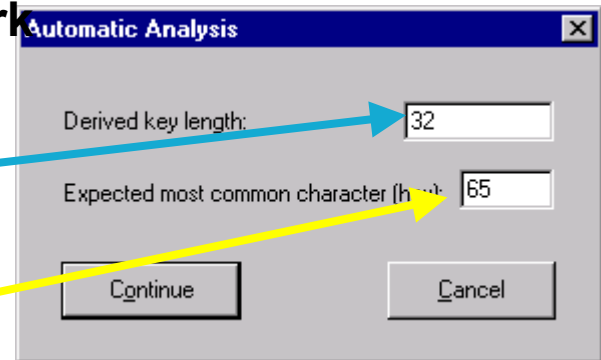
Examples of use

4. PSION PDA: automatic analysis

Automatic analysis using XOR: does not work

Automatic analysis using Binary Addition:

- CrypTool calculates the key length using auto-correlation: 32 bytes
- The user can choose which character is expected to occur most frequently: “e” = 0x65 (ASCII code)
- Analysis calculates the most likely key (based on the assumptions about distribution)
- Results: good, but not perfect



Examples of use

4. PSION PDA: results of automatic analysis

Results of automatic analysis with assumption “binary addition”:

- results good, but not perfect: 24 out of 32 key bytes correct.
- the key length was correctly determined.
- the password entered was not 32 bytes long.
⇒ PSION Word derives the actual key from the password.
- manual post-processing produces the encrypted text
(not shown)

Automatic Addition Analysis of <psion-enc.hex>, key: <12 86 5B EF 14 98 87 2C 39 3E 43 74 13 ...

Offset	Hex	Text
00000	65 72 67 AA 73 65 74 7A 20 28 55 53 74 47 29 06	erg³setz (UStG).
00010	06 06 8A 72 73 74 65 72 65 41 62 B8 A8 68 6E AE	...rstereAb,`hn@
00020	74 74 06 98 74 65 75 65 72 67 65 67 65 6E 73 74	tt...teuergegenst
00030	61 6E A9 20 75 6E 64 20 8C 65 6C B9 BA 6E 67 B8	an@ und .el¹ng,
00040	62 65 72 AA 69 63 68 06 06 A7 20 31 2E 06 28 31	ber³ich..\$ 1..(1
00050	29 20 89 65 72 20 55 6D B8 61 74 BF B8 74 65 BA) .er Um,at³,te²
00060	65 72 20 BA 6E 74 65 72 6C 69 65 67 65 6E 20 64	er ²nterliegen d
00070	69 65 65 66 6F 6C 67 65 B3 64 65 B3 65 55 6D B8	ieefolge³de³eUm,
00080	E4 74 7A AA 3A 06 31 2E 20 64 69 65 20 4C 69 65	ätz³:.1. die Lie
00090	66 65 B7 75 6E 67 65 6E 65 75 6E A9 65 73 6F B3	fe.ungeneun@eso³
000A0	73 74 69 AC 65 6E 20 4C 65 69 73 74 75 6E 67 65	stiren Leistunge
000B0	6E 2C 65 64 69 65 20 65 AE 6E 20 9A B3 74 65 B7	n,edie e@n .³te
000C0	6E 65 68 B2 65 72 20 69 6D 20 49 6E 6C 61 6E 64	neh²er im Inland
000D0	20 67 AA 67 65 6E 20 45 B3 74 67 AA B1 74 20 AE	g³gen E³tg³tt @
000E0	6D 20 52 A6 68 6D 65 6E 20 73 65 69 6E 65 73 20	m R³hmen seines
000F0	55 6E B9 65 72 6E 65 68 B2 65 6E B8 65 61 75 B8	Un¹erneh²en.eau.

Examples of use

4. PSION PDA: determining the remaining key bytes

Copy key to clipboard during automatic analysis

In automatic analysis hexdump,

- determine incorrect byte positions, e.g. 0xAA at position 3
- guess and write down corresponding correct bytes: „e“ = 0x65

In encrypted initial file hexdump,

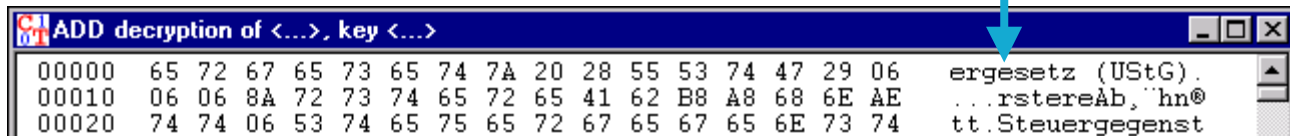
- determine initial bytes from the calculated byte positions: 0x99
- calculate correct key bytes with CALC.EXE: $0x99 - 0x65 = 0x34$

Correct key from the clipboard

- 12865B341498872C393E43741396A45670235E111E907AB7C0841...

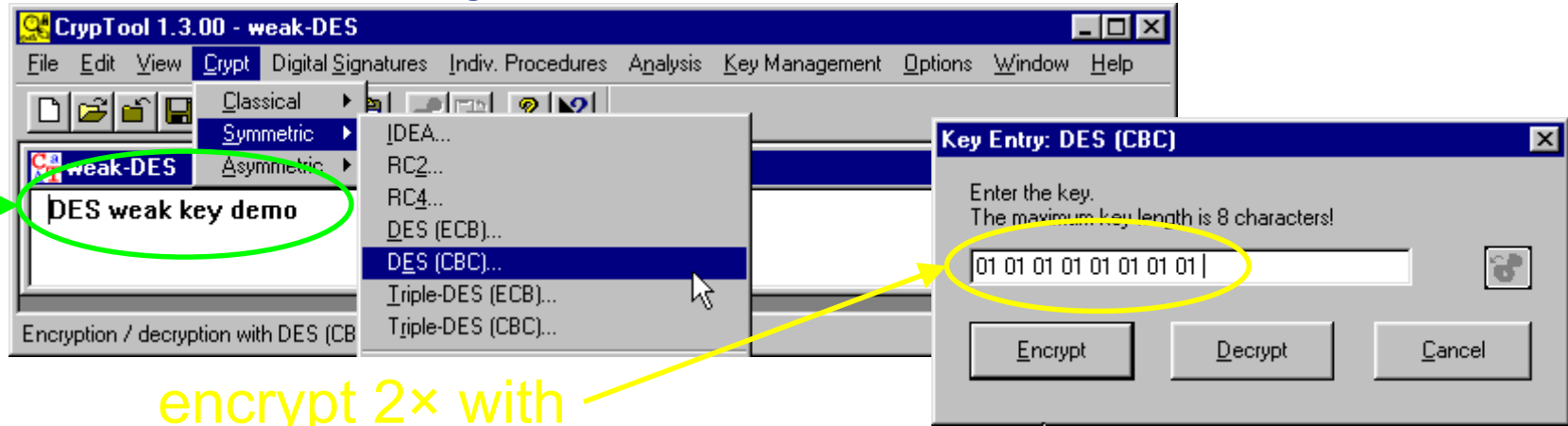
Decrypt encrypted initial document using binary addition

- bytes at position 3, 3+32, 3+2*32, ... are now correct

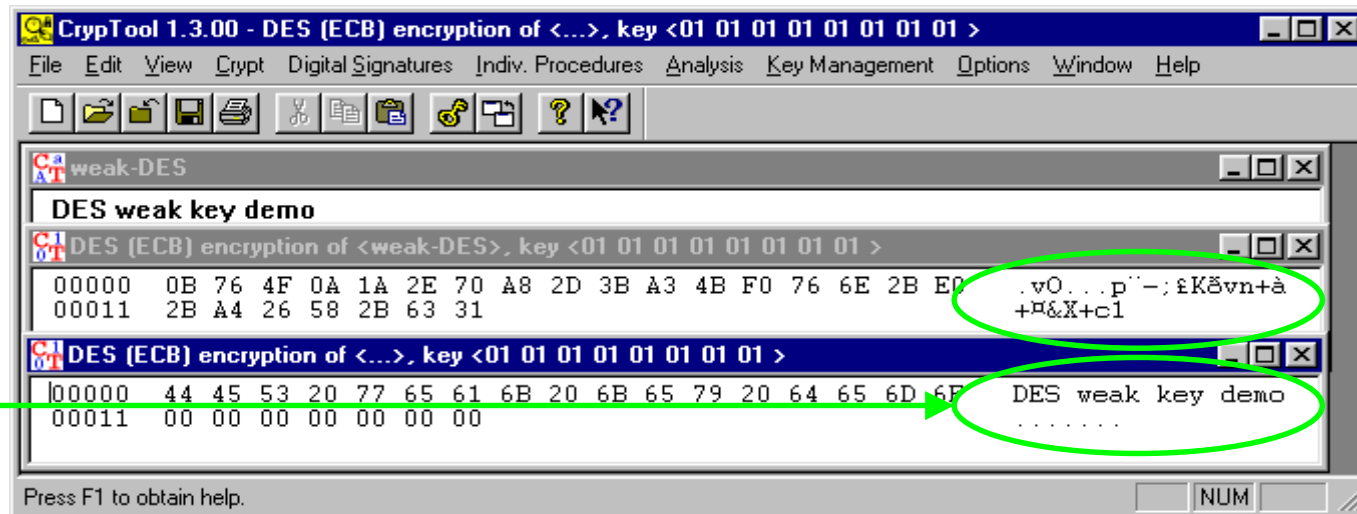


Examples of use

5. Weak DES keys



encrypt 2× with



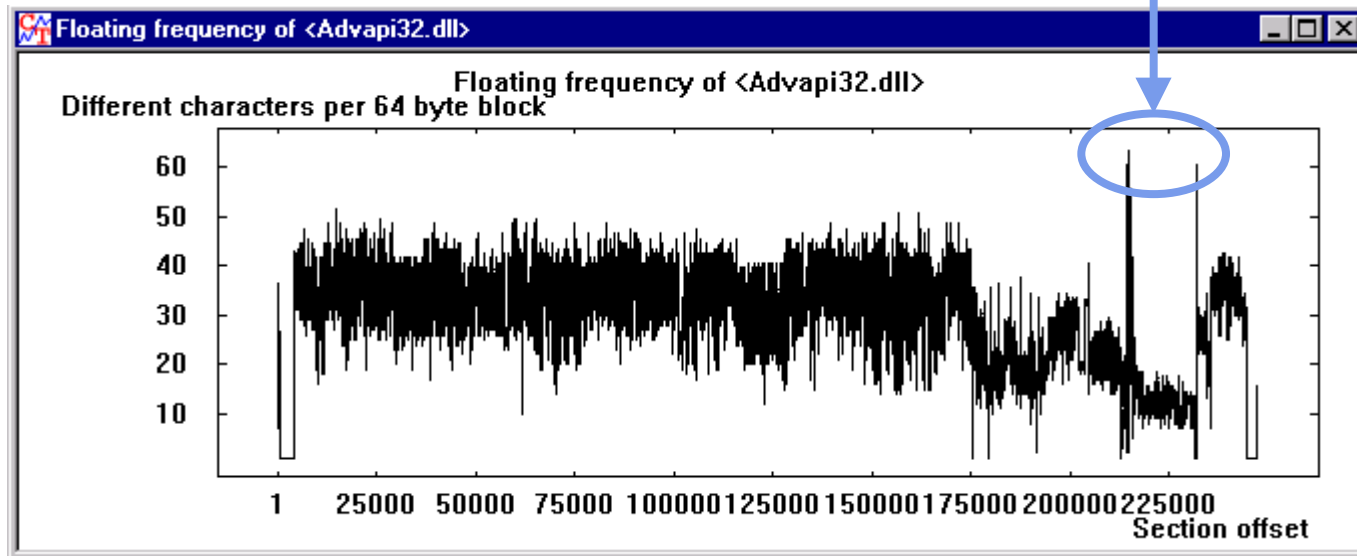
Examples of use

6. Locate key material

The function “Floating frequency” is suitable for locating key material and encrypted areas in files.

Background:

- key data is “more random” than text or program code
- can be recognised as peaks in the “floating frequency”
- example: the “NSAKEY” in advapi32.dll



Examples of use

7. Attack on digital signature: idea

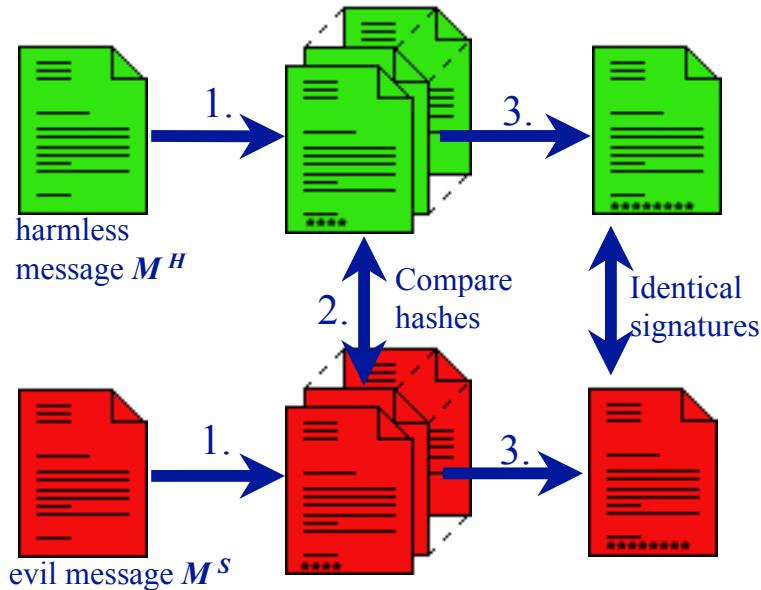
Attack on the digital signature of an ASCII text based on hash collision search

Idea:

- ASCII-Texts can be modified by changing/inserting ***non-printable*** characters, without changing the visible content
- modify two texts in parallel until a hash collision is found
- exploit the birthday paradox (birthday attack)
- generic attack applicable to all hash functions
- can be run in parallel on many machines (not implemented)
- implemented in CrypTool by Jan Blumenstein as part of his bachelor thesis "*Methods and tools for attacks on digital signatures*" (German), 2003.

Examples of use

7. Attack on digital signature: idea (2)

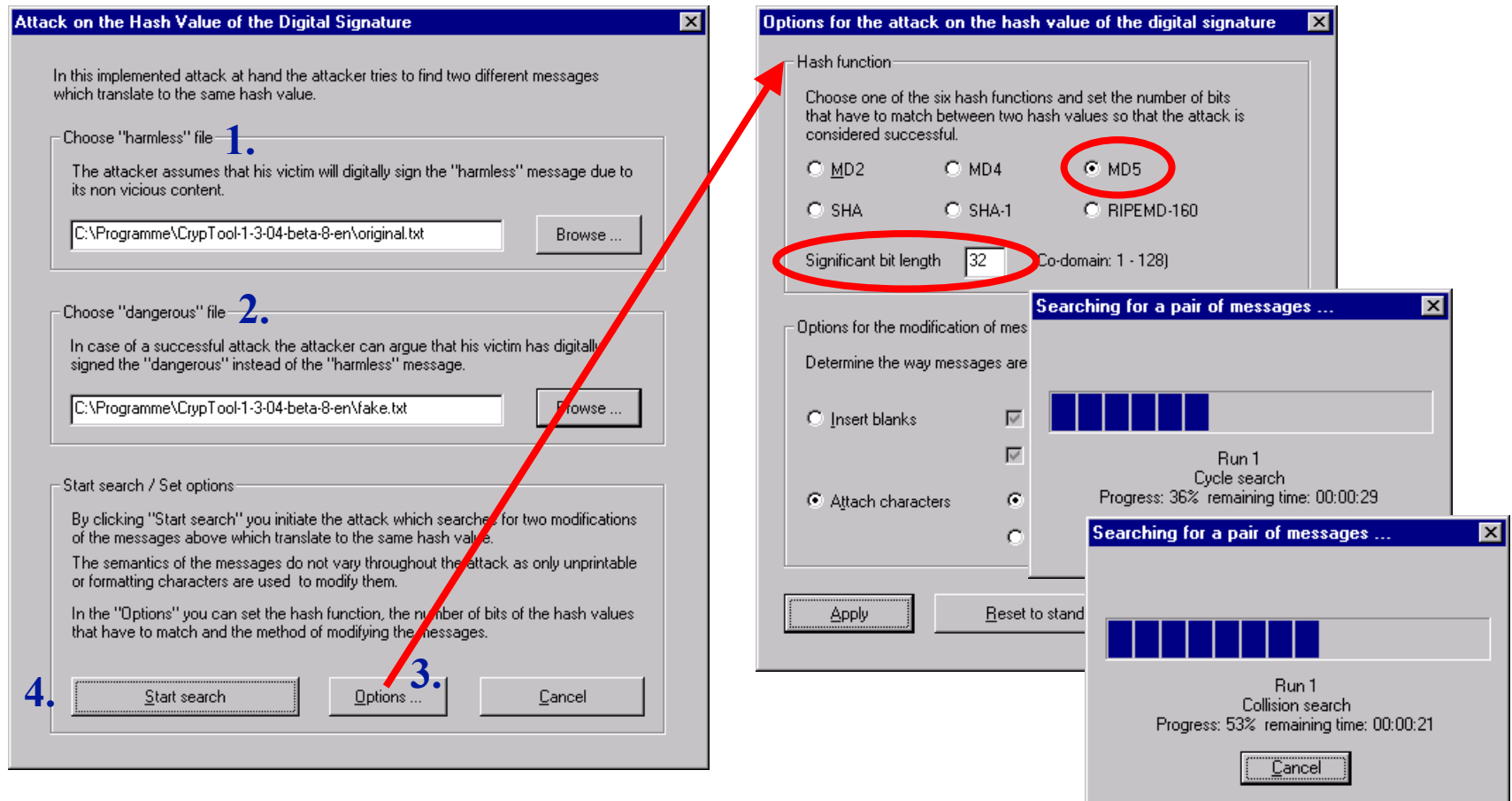


- 1. Modification:** starting from a message M create N different messages M_1, \dots, M_N with the same “content” as M .
- 2. Search:** find modified messages M_i^H and M_j^S with the same hash value.
- 3. Attack:** the signatures of those two documents M_i^H and M_j^S are the same.

We know from the birthday paradox that for hash values of bit length n :

- search collision between M^H and M_1^S, \dots, M_N^S : $N \approx 2^n$
- search collision between M_1^H, \dots, M_N^H and M_1^S, \dots, M_N^S : $N \approx 2^{n/2}$

7. Attack on digital signature: attack



Examples of use

7. Attack on digital signature: results

Harmless message: MD5, <A9 76 34 AB>

Dear Mr Shopaholic,

please order a typewriter.

Regards
Honest John

MD5: A9 76 34 AB
65 53 37 21 6F 70
1F 6C 6C 3F 2F 6D

Dangerous message: MD5, <A9 76 34 AB>

Dear Mr Shopaholic,

please order a Porsche and a prepaid insurance scheme for Mr. Dodgy.

Regards
Honest John

MD5: A9 76 34 AB
AC 10 96 30 CC 47
24 D5 70 D8 84 71

The first 32 bits of the hash values are identical.

Experimental results

- 72 Bit *partial collision* (equality of the first 72 hash value bits) were found in a couple of days on a single PC.
- Signatures using hash values of up to 128 bit can be attacked today using massive parallel search!

Further development

Work in process

- visualisation of challenge-response authentication
- attack on single-sided authentication with CR and weak encryption
- mass pattern search

Planned for near future

- visualisation of SSL protocol
- visualisation of Man-in-the-Middle attack
- demonstration of a side-channel attack

Planned for remote future

- visualisation of different security protocols (e.g. Kerberos)
- visualisation of attacks on these different security protocols
- port to Linux or Java
- many more ideas can be found in the readme file, chapter 6

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