SECURITY

DT211/DT228/3/

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Cryptography

The Basic Idea:

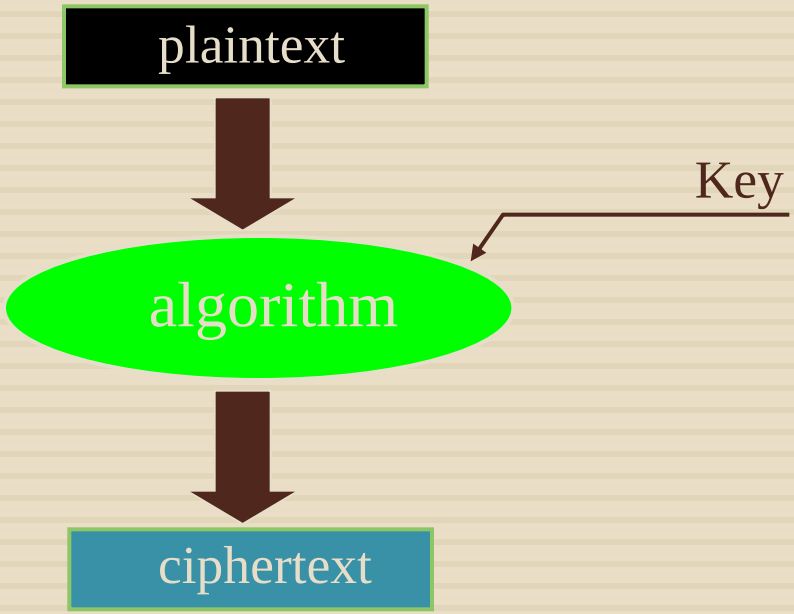
Two approaches:

1) Make algorithm secret and don't use a key.

Bad Idea

2) Make algorithm public but keep the key secret.

Good Idea



Before Computers Substitution ciphers ruled:

Caesar (Shift by N): 26 possibilities, easy to decode

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C

Key Phrase: Lots of possibilities, a bit harder to decode

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
B	U	S	H	A	N	D	G	O	R	E	F	I	J	K	L	M	P	Q	T	V	W	X	Y	Z	C

Random Mapping: 4×10^{26} possibilities, harder to decode

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
N	D	T	V	G	K	L	M	R	E	P	O	F	I	J	Q	U	S	W	X	B	H	A	Y	Z	C

Before Computers

Cryptanalysis:

First known publication:
"A Manuscript on Deciphering Cryptographic Messages"

By the ninth century Arab scholar:
Abu Yusuf Ya'qub ibn Is-haq ibn as-Sabbah ibn 'omran ibn Ismail al-Kindi

Statistical "Frequency Analysis" of letters & words can easily break any mono-alphabetic substitution cipher.

In English: most common letters: E, T, A, O, I, N, S, …
most common 2 letters words: ON, AS, TO, AT, IT…
most common 3 letters words: THE, AND, FOR, WAS,…

Vigenere square (1586)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
1	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
2	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
3	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
4	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
5	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
6	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
7	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
8	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
9	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
10	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
11	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
12	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
13	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
14	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
15	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
16	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
17	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
18	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
19	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
20	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
21	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
22	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
23	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
24	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
25	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
26	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Vigenere square

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
1	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
2	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
3	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
4	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
5	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
6	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
7	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
8	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
9	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
10	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
11	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
12	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
13	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
14	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
15	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
16	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
17	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
18	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
19	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
20	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
21	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
22	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
23	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
24	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
25	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
26	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Keyword VOTEVOTEVOTEVOTEVOTE…

Plaintext ihavethreestinkydogs…

Ciphertext DVTZZHAVZSLXDBDCYCZW…

Immune to frequency analysis !

However:

IF

If the key is as long as the message

AND

The key is completely random

THEN

The encryption is perfect (can’t be broken) !!!

This is an example of Symmetric Key Encryption

Plaintext	DEAD		1101 1110 1010 1101
Key	BEEF	⊕	1011 1110 1110 1111
Ciphertext		=	0110 0000 0100 0010 = 6042
Ciphertext	6042		0110 0000 0100 0010
Key	BEEF	⊕	1011 1110 1110 1111
Plaintext		=	1101 1110 1010 1101 = DEAD

Real Simple: Same key to encode and decode

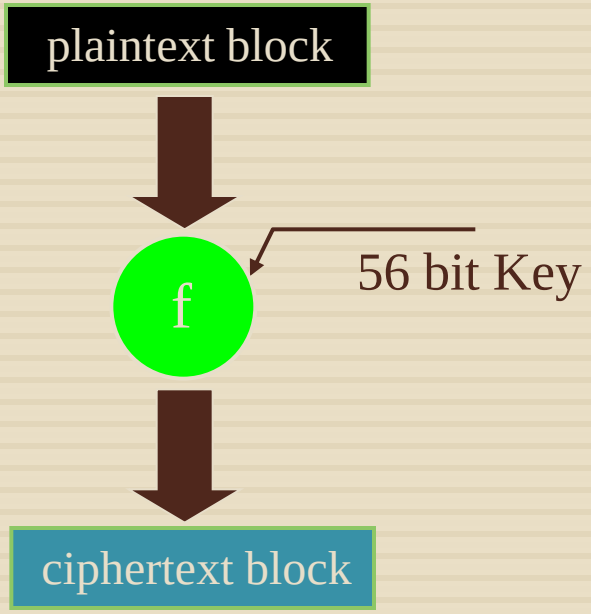
DES Advantages:

Very Fast:

Ideally suited for implementation in hardware (bit shifts, look-ups etc).

Dedicated hardware (in 1996) could run DES at 200 Mbyte/s.

Well suited for voice, video etc.



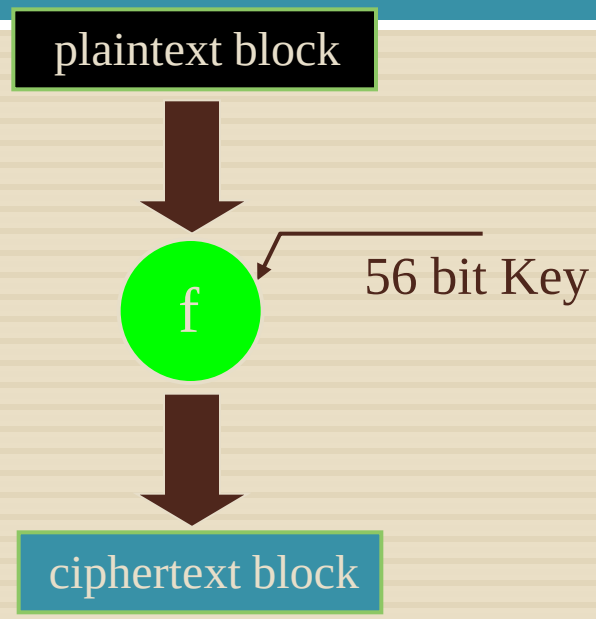
DES Security:

Not too good:

Trying all 2^{56} possible keys is not that hard these days.

If you spend ~$25k you can build a DES password cracker that can will succeed in a few hours.

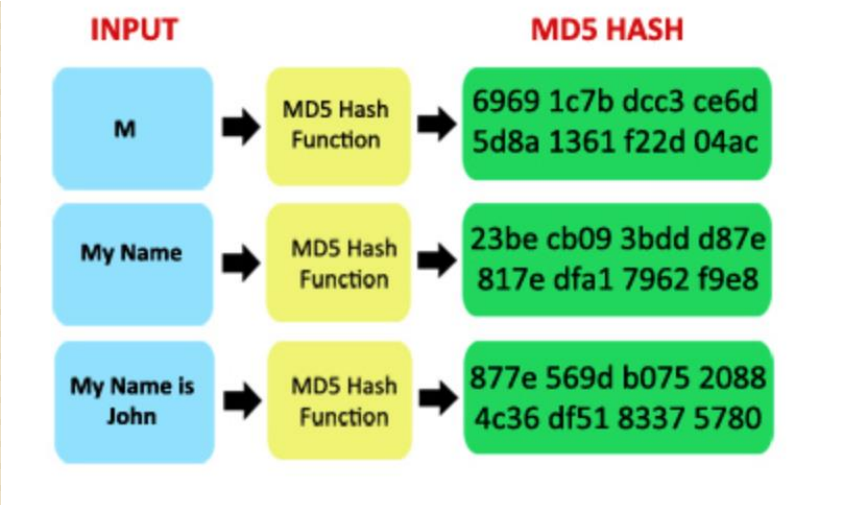
EFF



Back in 1975 this would have cost a few billion $$. It is widely believed that the NSA did this.

Similar algorithms with longer keys are available today (IDEA).

HASH



SHA1

- It produces a 160-bit digest from a message with a maximum length of $(2^{64} - 1)$ bits, and resembles the MD5 algorithm

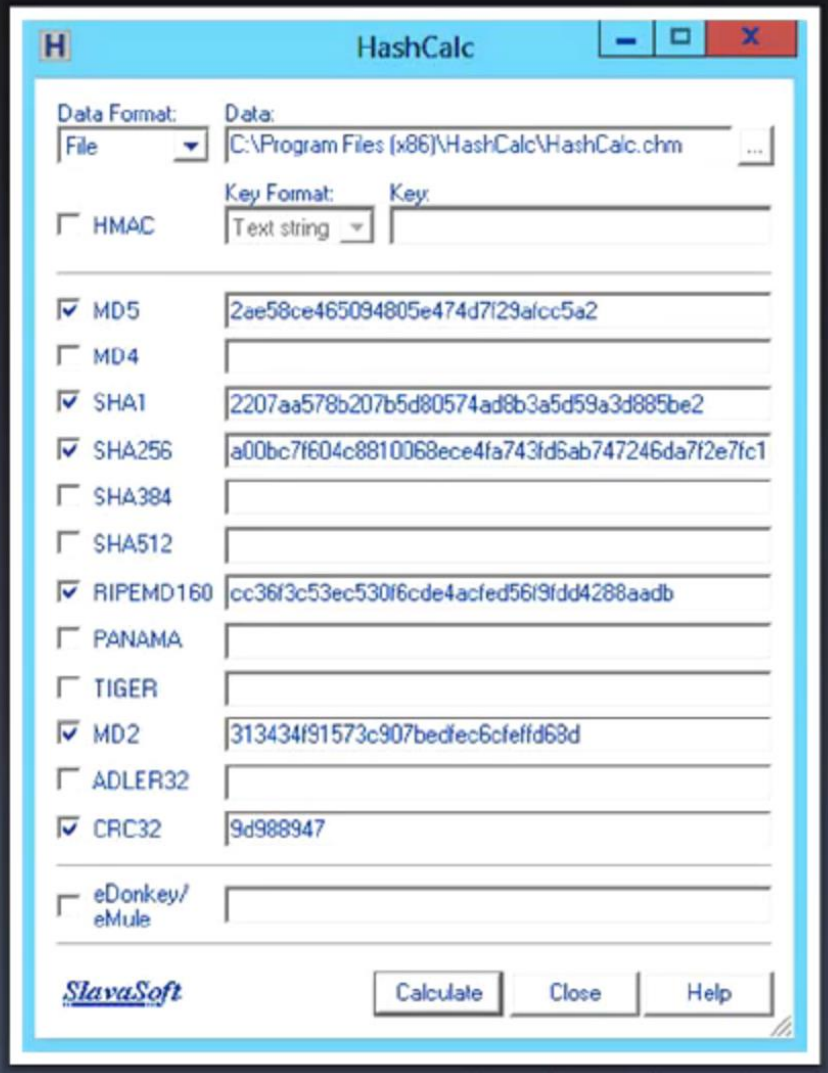
SHA2

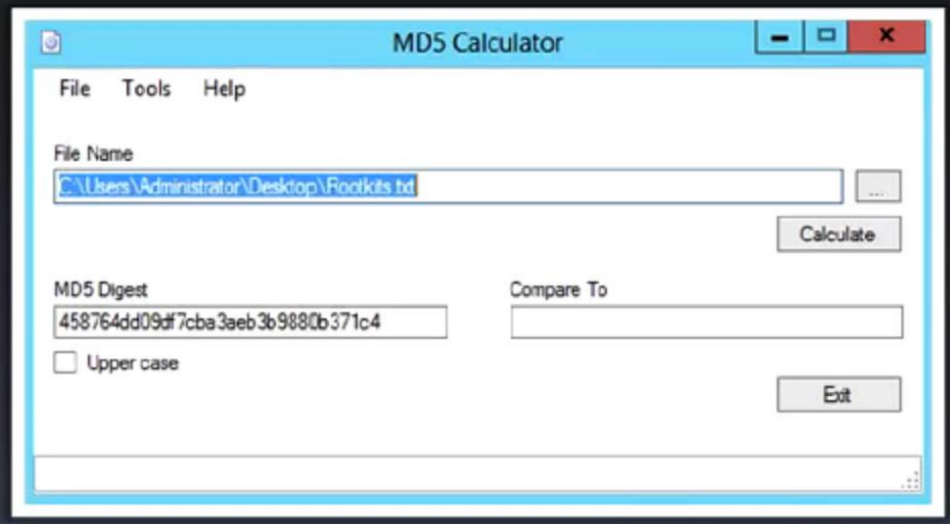
- It is a family of two similar hash functions, with different block sizes, namely SHA-256 that uses 32-bit words and SHA-512 that uses 64-bit words

SHA3

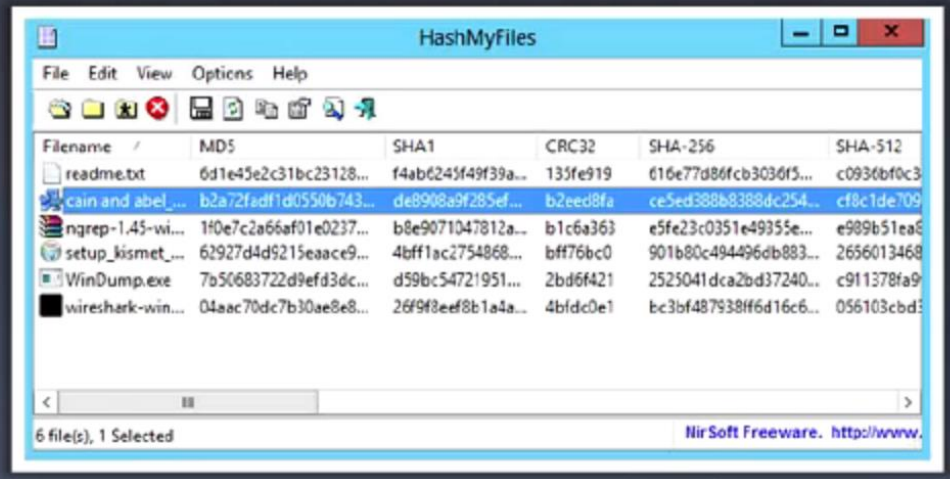
- SHA-3 uses the sponge construction in which message blocks are XORed into the initial bits of the state, which is then invertibly permuted

Hash Tool





http://www.bullzip.com



RSA (Rivest, Shamnir, Adleman: 1977)

IDEA: Alice has a "public" encryption key that everyone knows, and a "private" decryption key that only she knows. Bob looks up her public key, encrypts his message, and sends it to her. She decrypts it with her private key.

1) Pick two large prime numbers p and q. These are secret.
2) Calculate $n = pq$
3) Pick another number e such that e and $(p-1)(q-1)$ are relatively prime.
4) The numbers n and e make up your public key. Publish them!

5) Calculate d such that $ed = 1 \bmod (p-1)(q-1)$ {i.e. $d = e^{-1} \bmod (p-1)(q-1)$ }
6) The number d is your private key.

Encrypt message m via $c = m^e \bmod n$

Decrypt the ciphertext c via $m = c^d \bmod n$

This is what happens when you buy a book from Amazon.com

Example:

- This is an extremely simple example and would not be secure using primes so small, normally the primes p and q would be much larger.
- Select the prime integers q=11, q=3.

- **n=pq=33; φ(n)=(p-1)(q-1)=20**
- **Choose e=3**
  - **Check gcd(3,20)=1**
- **Compute d=7**
  - **(3)d ≡ 1 (mod 20)**
- **Therefore the public key is (n, e) = (33, 3) and the private key is (n, d) = (33, 7).**
- **Now say we wanted to encrypt the message M=7**
- **$C = M^e \bmod n$**
- **$C = 7^3 \bmod 33$**
- **C = 343 mod 33**
- **C = 13**

Example:

So now the cyphertext C has been found. The decryption of C is performed as follows.

$M' = C^d \bmod n$

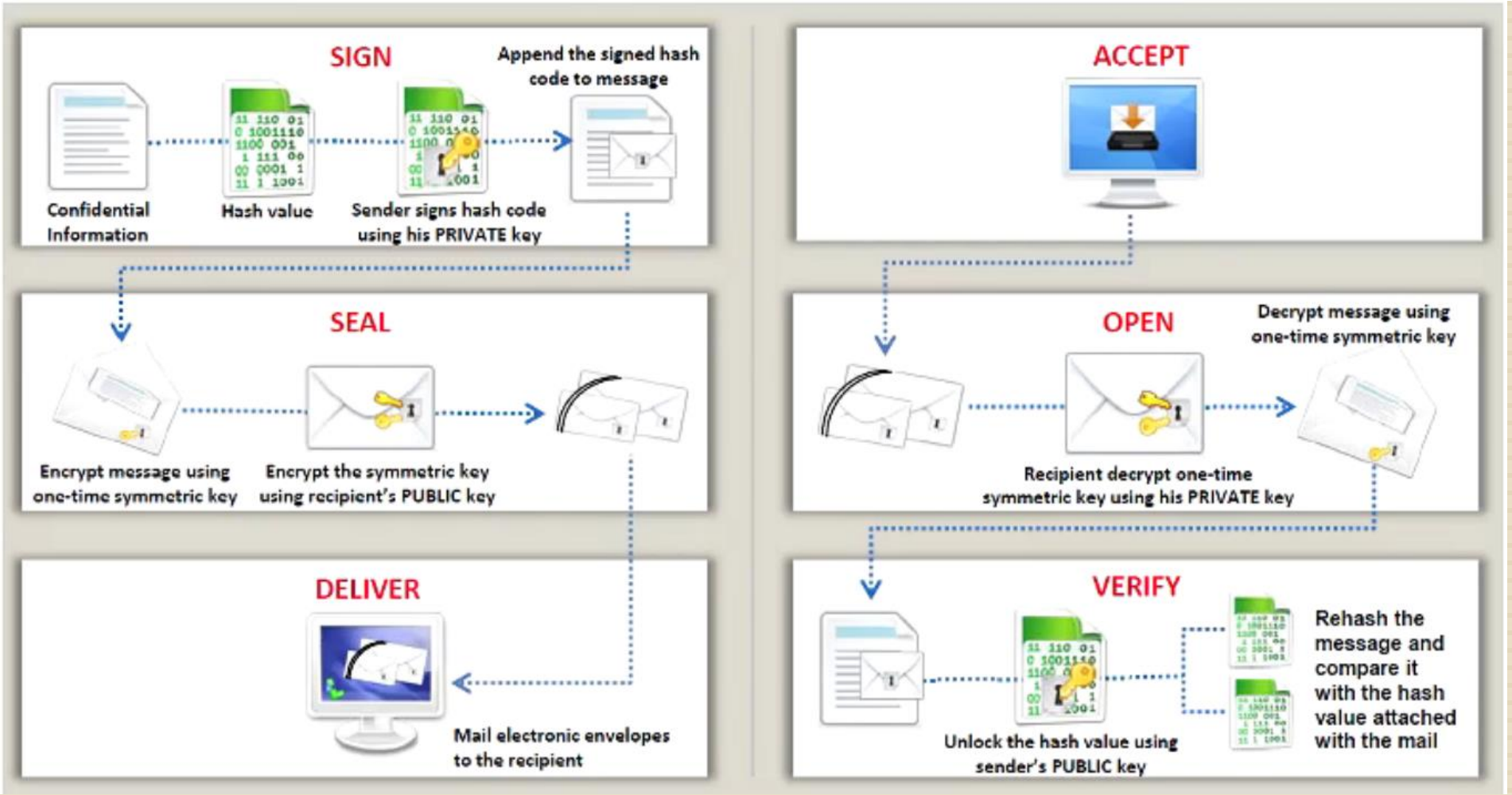
$M' = 13^7 \bmod 33$

$M' = 62{,}748{,}517 \bmod 33$

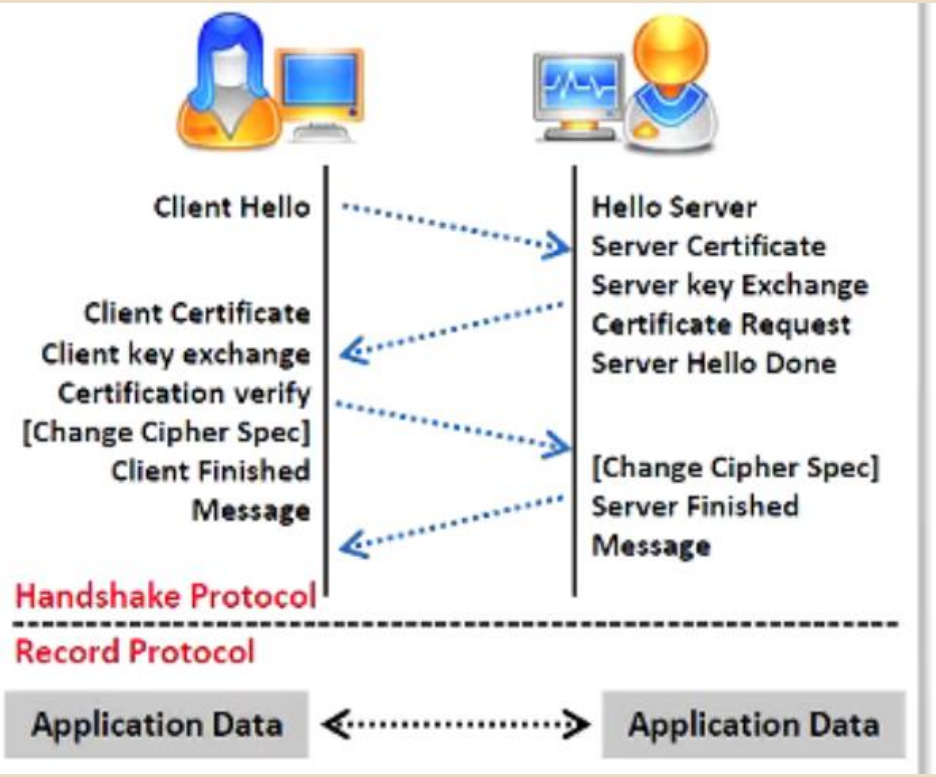
$M' = 7$

As you can see after the message has been encrypted and decrypted the final message M' is the same as the original message M. A more practical way to use the algorithm is to convert the message to hexadecimal and perform the encryption and decryption steps on each octet individually.

SSL


SIGN
Append the signed hash code to message
Confidential Information
Hash value
Sender signs hash code using his PRIVATE key
SEAL
Encrypt message using one-time symmetric key
Encrypt the symmetric key using recipient's PUBLIC key
DELIVER
Mail electronic envelopes to the recipient
ACCEPT
OPEN
Decrypt message using one-time symmetric key
Recipient decrypt one-time symmetric key using his PRIVATE key
VERIFY
Unlock the hash value using sender's PUBLIC key
Rehash the message and compare it with the hash value attached with the mail

- TLS is a protocol **to establish a secure connection** between a client and a server and ensure privacy and integrity of information during transmission
- It uses the RSA algorithm with 1024 and 2048 bit strengths

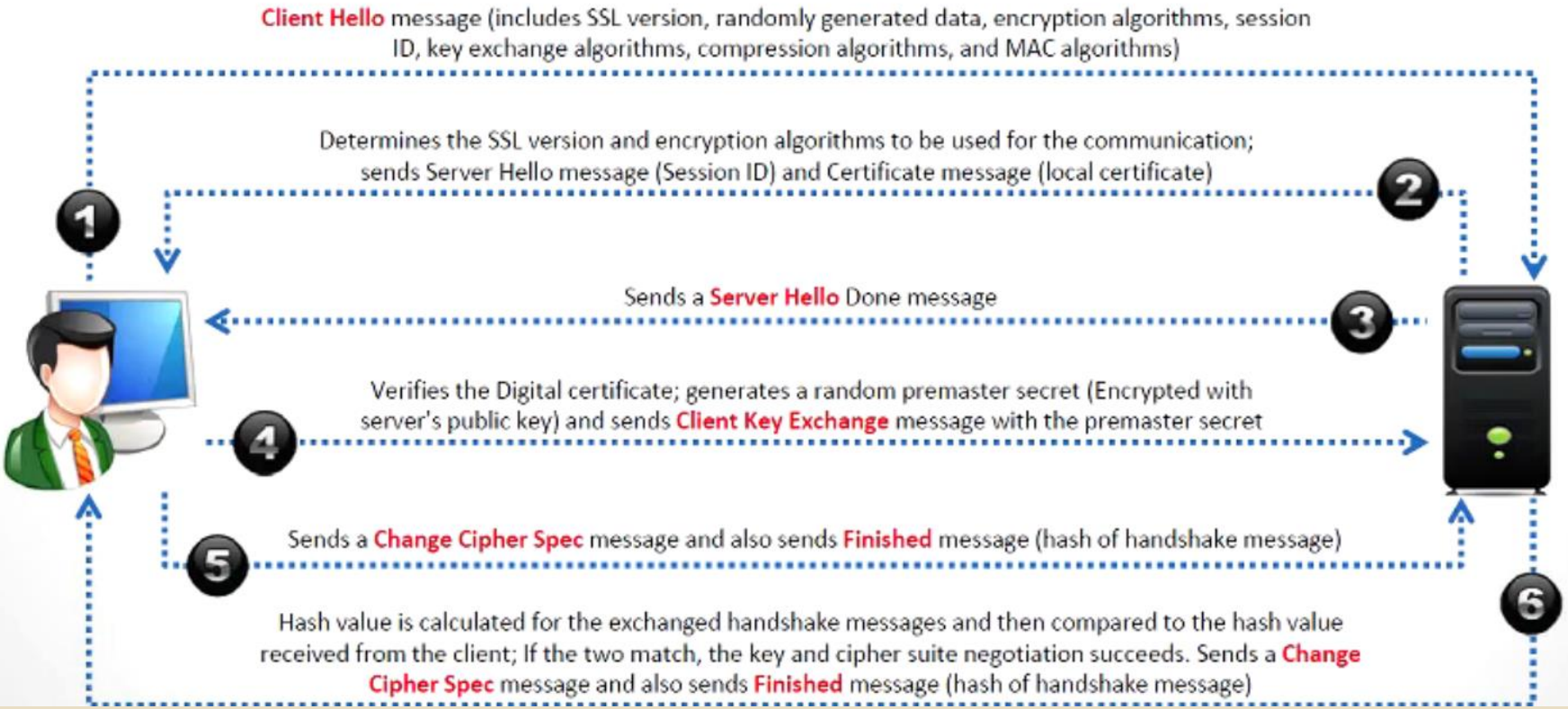


Digital Signature Algorithm

FIPS 186-2 specifies the Digital Signature Algorithm (DSA) that may be used in the generation and verification of digital signatures for sensitive, unclassified applications

RSA(SSL)

- It uses **RSA asymmetric (public key) encryption** to encrypt data transferred over SSL connections



Attacks

Trickery and Deceit

It involves the use of social engineering techniques to extract cryptography keys

Brute-Force

Cryptography keys are discovered by trying every possible combination

One-Time Pad

A one-time pad contains many non-repeating groups of letters or number keys, which are chosen randomly

Frequency Analysis

It is the study of the frequency of letters or groups of letters in a ciphertext

It works on the fact that, in any given stretch of written language, certain letters and combinations of letters occur

Brute-Force

Attack Scheme

Defeating a cryptographic scheme by **trying a large number of possible keys** until the correct encryption key is discovered

Brute-Force Attack

Brute-force attack is a **high resource and time intensive process**, however, more certain to achieve results

Success Factors

Success of brute force attack depends on **length of the key**, **time constraint**, and **system security mechanisms**

Power/Cost	40 bits (5 char)	56 bit (7 char)	64 bit (8 char)	128 bit (16 char)
$ 2K (1 PC. Can be achieved by an individual)	1.4 min	73 days	50 years	10^20 years
$ 100K (this can be achieved by a company)	2 sec	35 hours	1 year	10^19 years
$ 1M (Achieved by a huge organization or a state)	0.2 sec	3.5 hours	37 days	10^18 years

RSA Security:

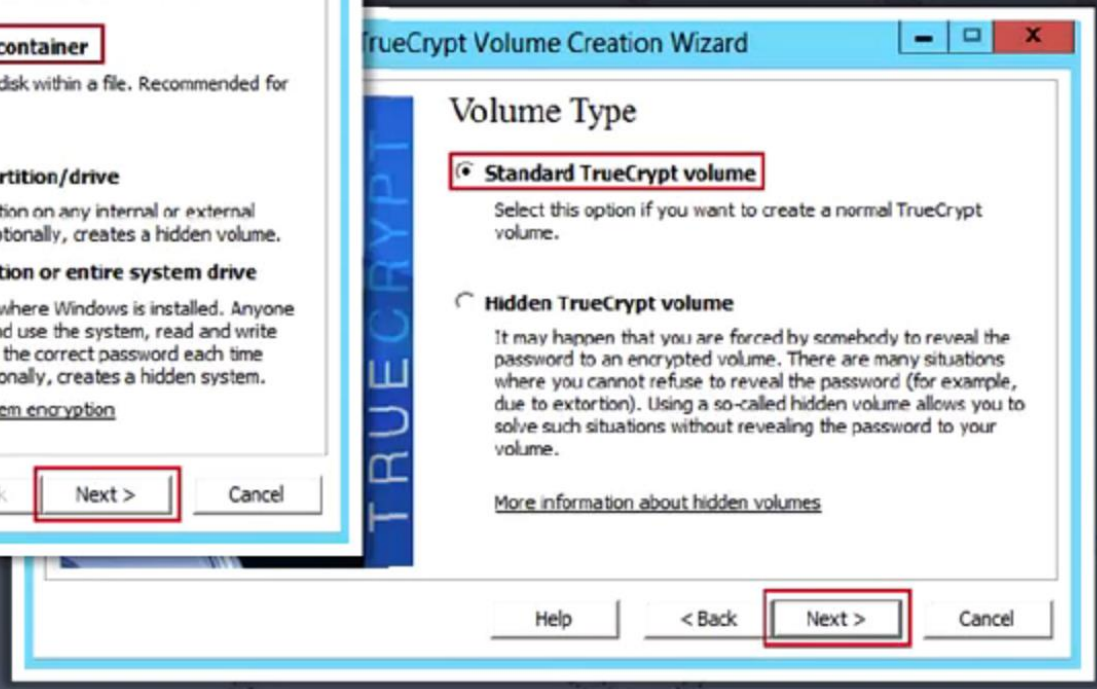
RSA is secure because its very hard to factor n to find p and q if n is sufficiently big. (Discrete logarithms).

"Sufficiently Big" means ~2048 bits

"Hard" means that all the computers on earth could not do it in the age of the universe.

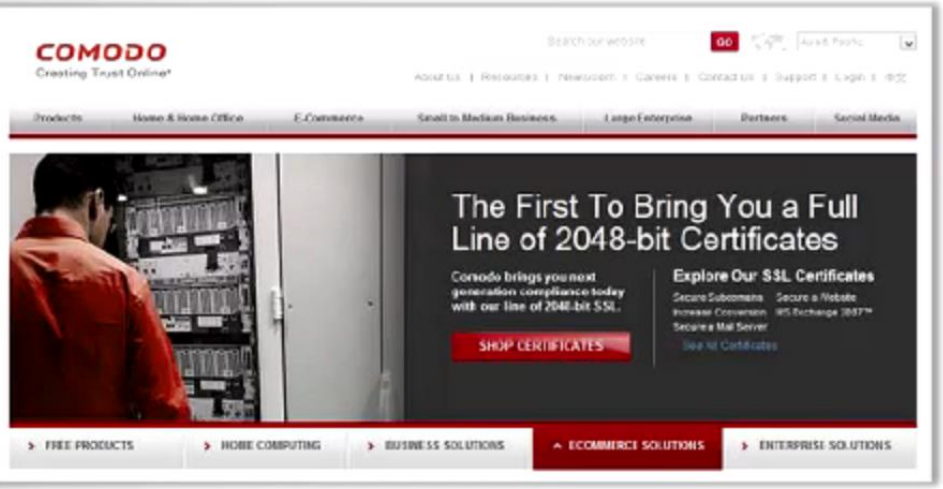
TrueCrypt

- TrueCrypt is disk encryption software that **creates a virtual encrypted disk** within a file and mounts it as a real disk
- It encrypts an **entire partition or storage device** such as USB flash drive or hard drive

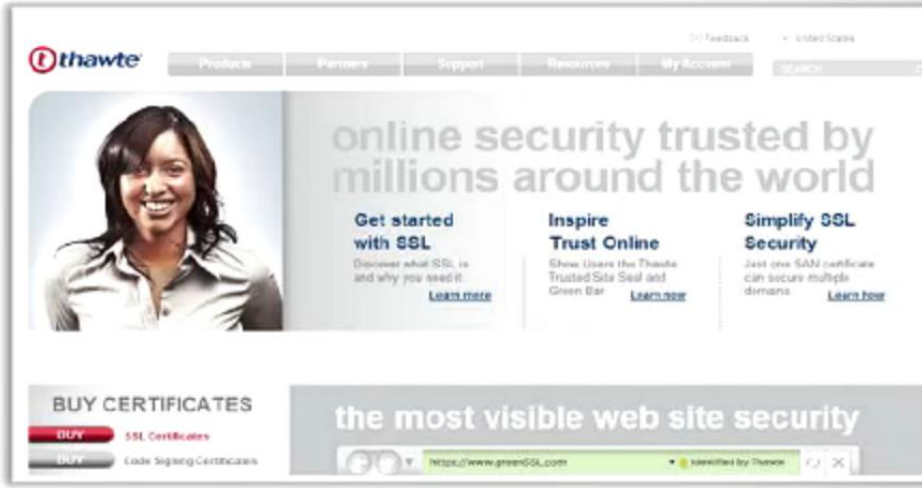


http://www.truecrypt.org

Certification



http://www.comodo.com



http://www.thawte.co