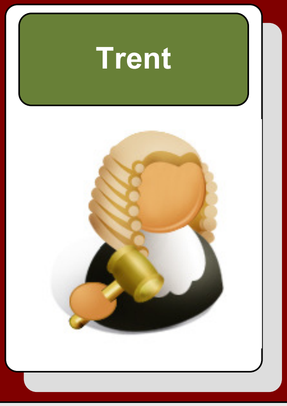
Encryption

Introduction
Before electronic communications
Codes
A few fundamentals
Key-based encryption
Cracking the code
Brute force
Block or stream
Private-key methods
Encryption keys
Passing keys
Public-key encryption
One-way hash
Encrypting disks
PGP encryption



Author: Prof Bill Buchanan

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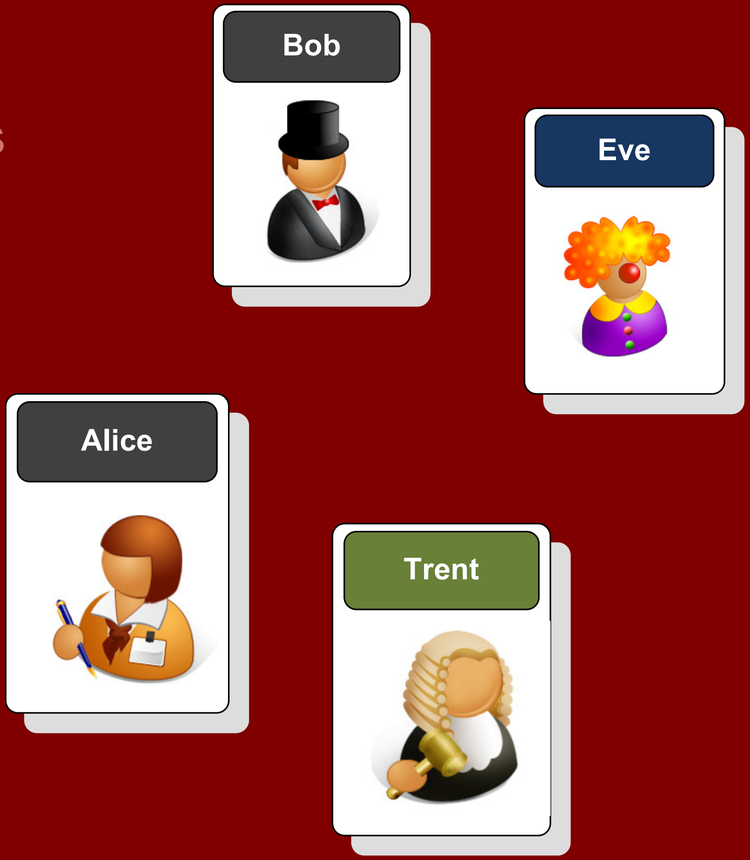


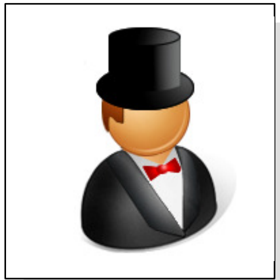
Introduction

Meet the cast

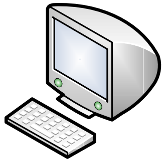
Bob and Alice – good
Eve – bad
Trust – trusted?

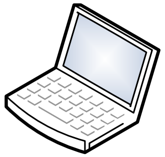
Eve

Intruder

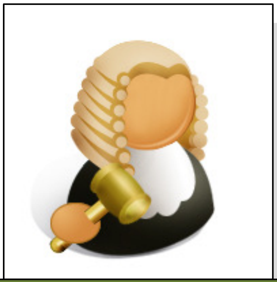


Bob





Alice

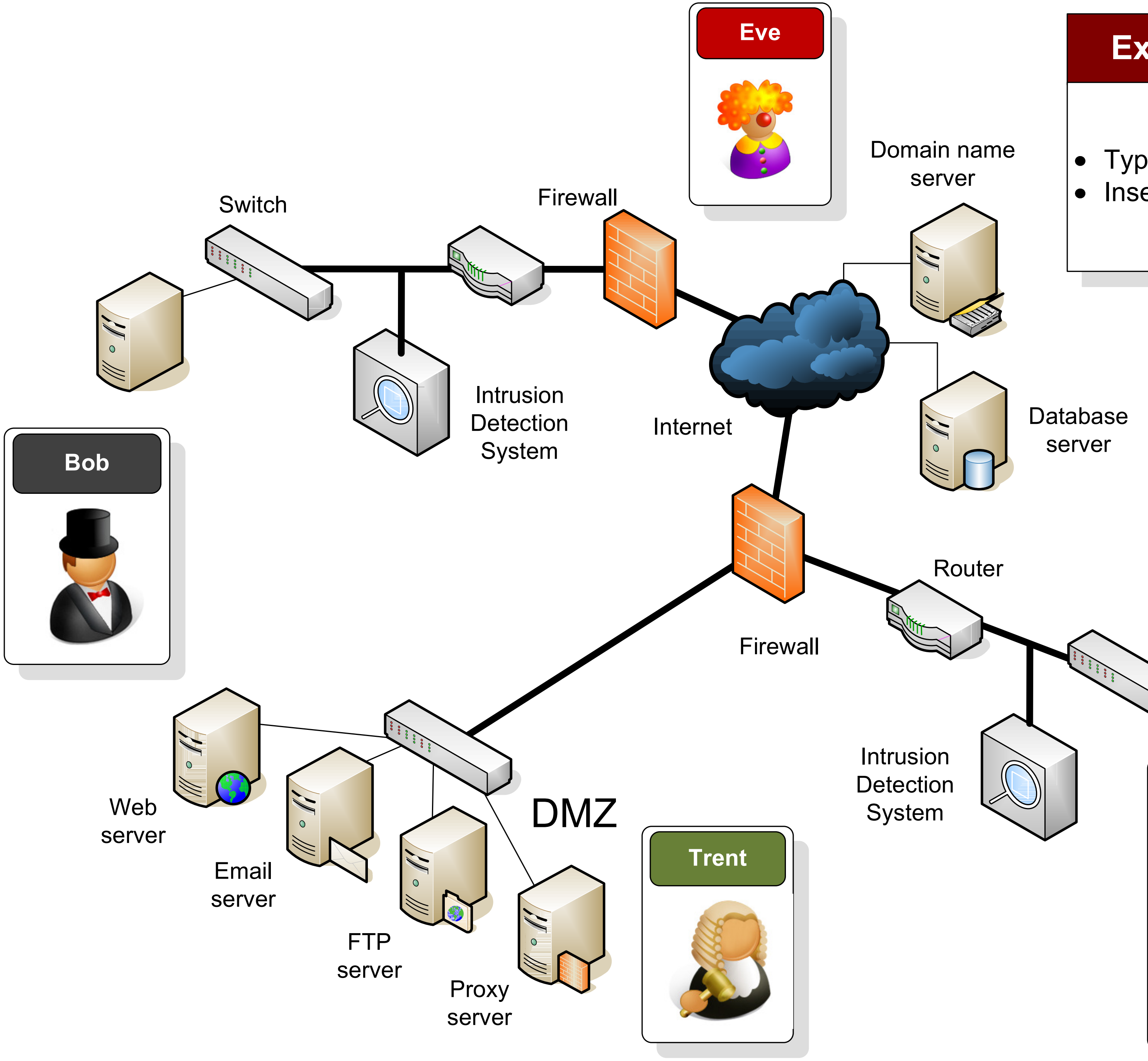


Trent

Trusted third party

Existing protocols

- Typically text-based.
- Insecure.



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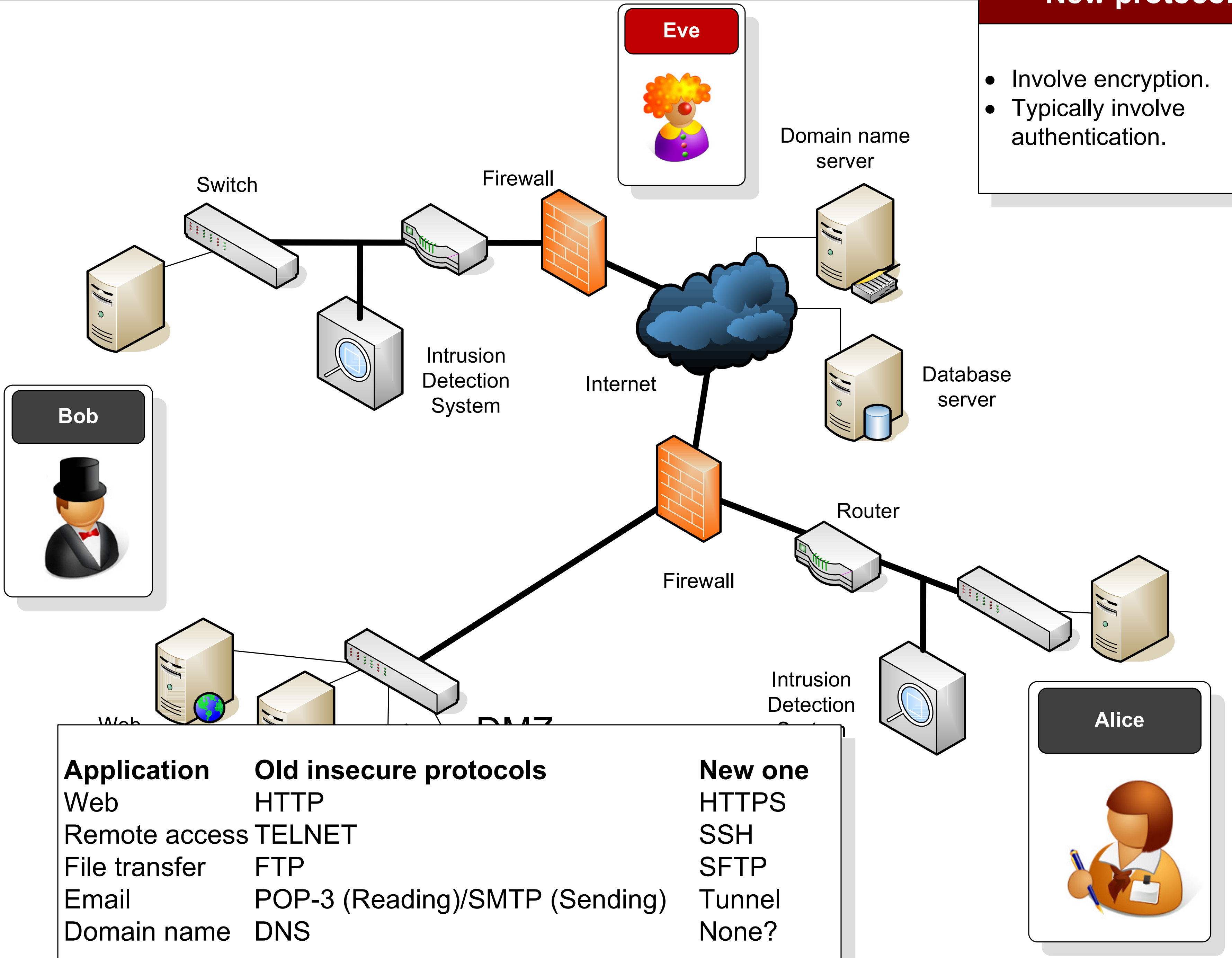
New protocols

- Involve encryption.
- Typically involve authentication.



Application	**Old insecure protocols**	**New one**
Web	HTTP	HTTPS
Remote access	TELNET	SSH
File transfer	FTP	SFTP
Email	POP-3 (Reading)/SMTP (Sending)	Tunnel
Domain name	DNS	None?

Hall of Frame

- Ron Rivest.
- Rivest, Shamir and Aldeman.
- Whitfield Diffie.
- Phil Zimmerman.

Whitfield Diffie

Key interchange

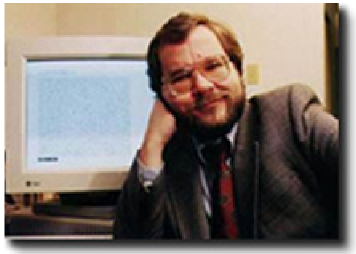
Rivest, Shamir & Aldeman

Public-key encryption

Ron Rivest

Hashing

Phil Zimmerman



PGP Encryption

Author: Prof Bill Buchanan

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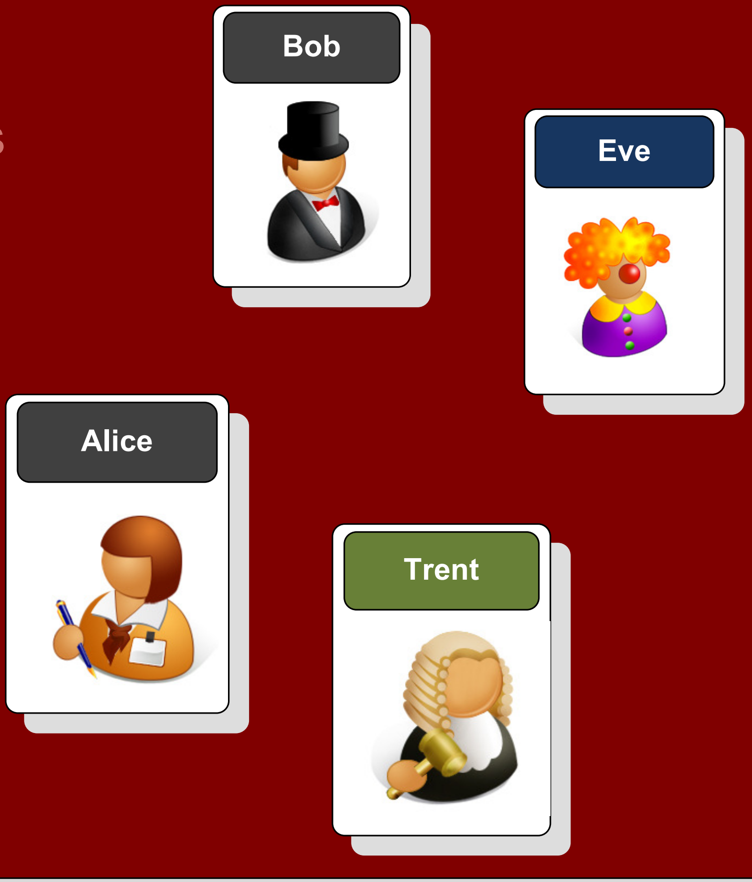
- PGP encryption



Before electronic communications

Secret Communications

- Quilts
- Carrier pigeon
- Smoke signals
- Etc...

Quilt patterns (used by slaves to escape)

Carrier pigeon

Smoke signals

Microfiche

Code talkers: Navajo words

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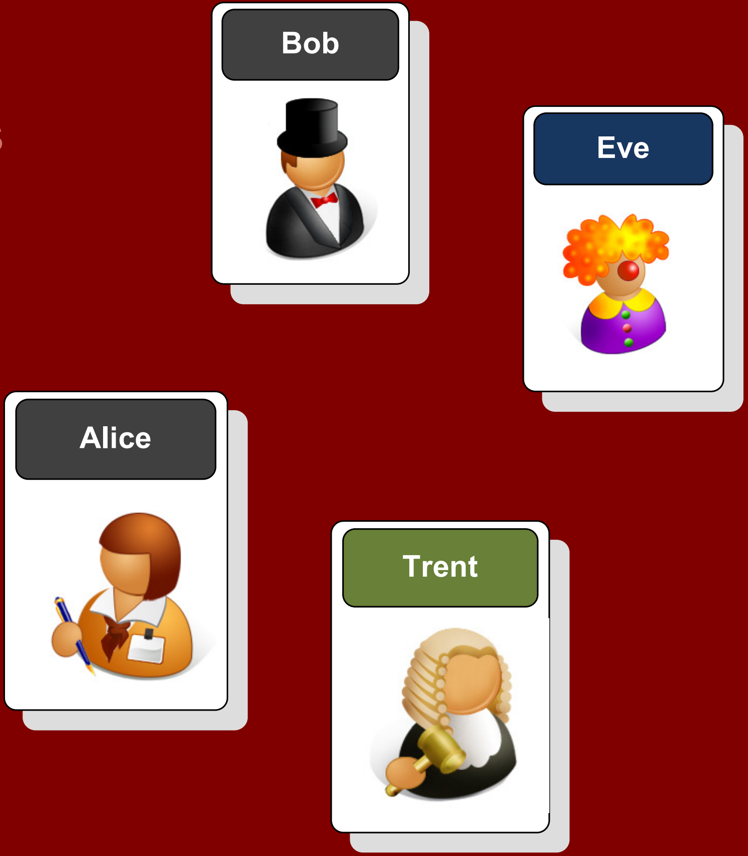
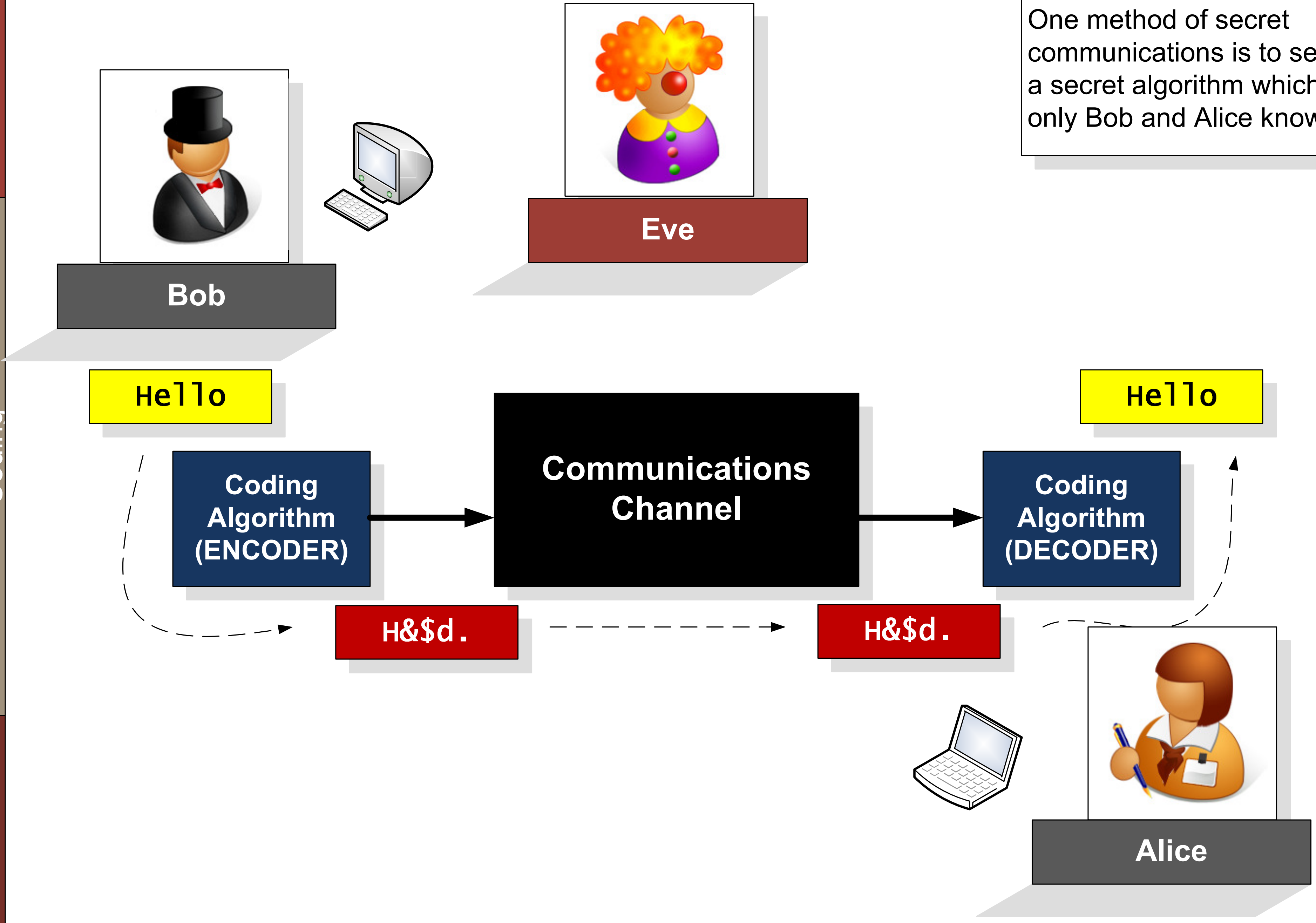


Codes

Secret Communications

One method of secret communications is to setup a secret algorithm which only Bob and Alice know



Eve

Bob

`Hello`

Coding Algorithm (ENCODER)

`H&$d.`

Communications Channel

`H&$d.`

Coding Algorithm (DECODER)

`Hello`

Alice

Author: Prof Bill Buchanan

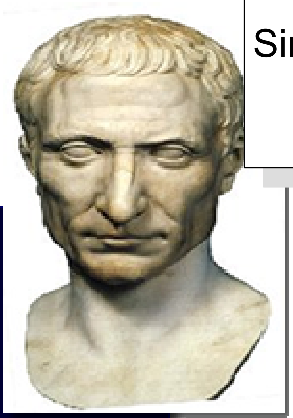
Caesar code

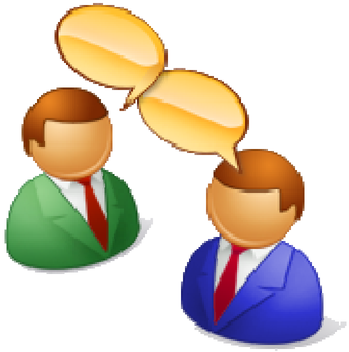
Simple alphabet shifting

Caesar code

```
abcdefghijklmnopqrstuvwxyz
YZABCDEFGHIJKLMNOPQRSTUVWX


RFC ZMW QRMMB ML RFC ZSPLGLE BCAI
```





25 code mappings

Code Mapping

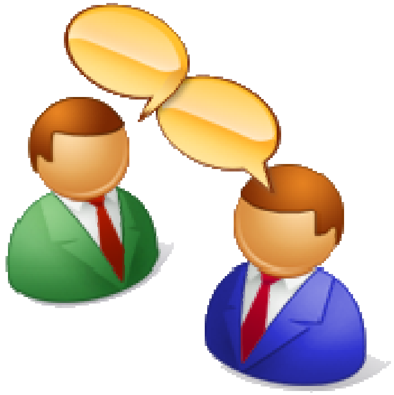
Code mapping scrambles the alphabet ..

403 million billion billion codes.

Code mapping

```
abcdefghijklmnopqrstuvwxyz
MGPOAFZBCDIEHXJKLNTQRWSUVY


QBCT CT MX AUMHKEA KCAPA JF QAUQ
```



4.03×10^{26} codes

Letters (%)	Digrams (%)	Trigrams (%)	Words (%)
E 13.05	TH 3.16	THE 4.72	THE 6.42
T 9.02	IN 1.54	ING 1.42	OF 4.02
O 8.21	ER 1.33	AND 1.13	AND 3.15
A 7.81	RE 1.30	ION 1.00	TO 2.36
N 7.28	AN 1.08	ENT 0.98	A 2.09
I 6.77	HE 1.08	FOR 0.76	IN 1.77
R 6.64	AR 1.02	TIO 0.75	THAT 1.25
S 6.46	EN 1.02	ERE 0.69	IS 1.03
H 5.85	TI 1.02	HER 0.68	I 0.94
D 4.11	TE 0.98	ATE 0.66	IT 0.93
L 3.60	AT 0.88	VER 0.63	FOR 0.77
C 2.93	ON 0.84	TER 0.62	AS 0.76
F 2.88	HA 0.84	THA 0.62	WITH 0.76
U 2.77	OU 0.72	ATI 0.59	WAS 0.72
M 2.62	IT 0.71	HAT 0.55	HIS 0.71
P 2.15	ES 0.69	ERS 0.54	HE 0.71
Y 1.51	ST 0.68	HIS 0.52	BE 0.63
W 1.49	OR 0.68	RES 0.50	NOT 0.61
G 1.39	NT 0.67	ILL 0.47	BY 0.57
B 1.28	HI 0.66	ARE 0.46	BUT 0.56
V 1.00	EA 0.64	CON 0.45	HAVE 0.55
K 0.42	VE 0.64	NCE 0.43	YOU 0.55
X 0.30	CO 0.59	ALL 0.44	WHICH 0.53
J 0.23	DE 0.55	EVE 0.44	ARE 0.50
Q 0.14	RA 0.55	ITH 0.44	ON 0.47
Z 0.09	RO 0.55	TED 0.44	OR 0.45

Code Mapping

Code mapping can typically be easily cracked by analysing the probability of the mapped letters.

Author: Prof Bill Buchanan

Vigenere code

Moves the mapping depending on a keyword (in this case “GREEN”)

Plain	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

Hello
GREEN

Vigenere code

Moves the mapping depending on a keyword (in this case “GREEN”)

Plain	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

```
Hello
GREEN
N
```

Vigenere code

Moves the mapping depending on a keyword (in this case “GREEN”)

Plain	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

Hello
GREEN
NV

Vigenere code

Moves the mapping depending on a keyword (in this case "GREEN")

Plain	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

Hello
GREEN
NVP

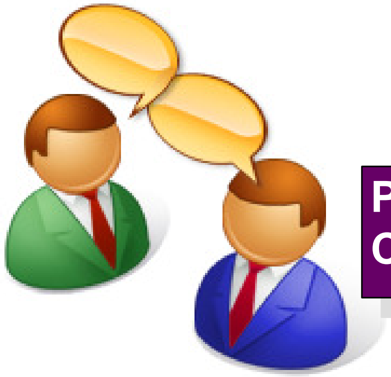
Author: Prof Bill Buchanan

Homophonic substitution code

Number of codes varies with the probability of the letter.

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
07	11	17	10	25	08	44	19	02	18	41	42	40	00	16	01	15	04	06	05	13	22	45	12	55	47
31	64	33	27	26	09	83	20	03			81	52	43	30	62		24	34	23	14		46		93	
50		49	51	28			21	29			86		80	61			39	56	35	36					
63			76	32			54	53			95		88	65			58	57	37						
66				48			70	68					89	91			71	59	38						
77				67			87	73						94			00	90	60						
84				69										96					74						
				72															78						
				75															92						
				79																					
				82																					
				85																					

Coding



Plaintext	h	e	l	l	o	e	v	e	r	y	o	n	e
Ciphertext:	19	25	42	81	16	26	22	28	04	55	30	00	32

Encryption

Author: Prof Bill Buchanan

Encryption

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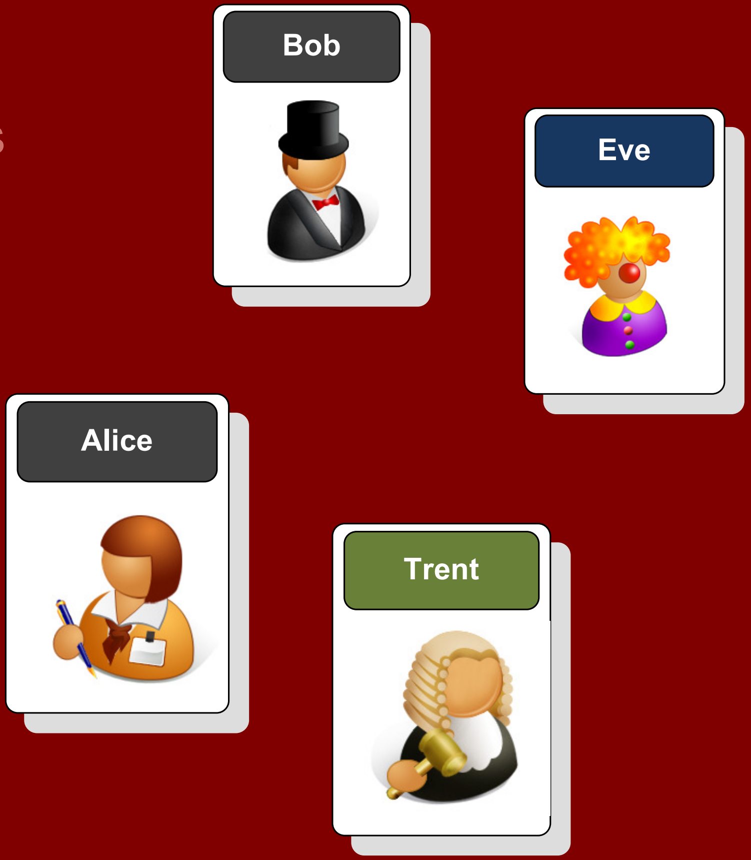
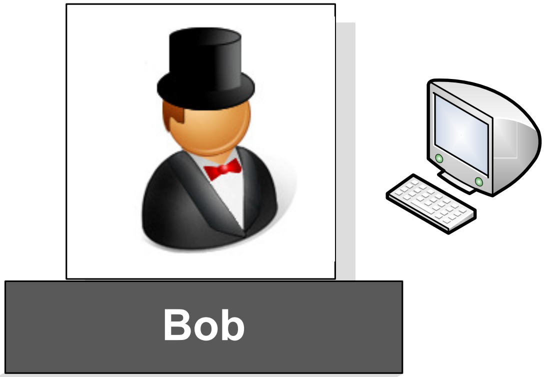
PGP encryption

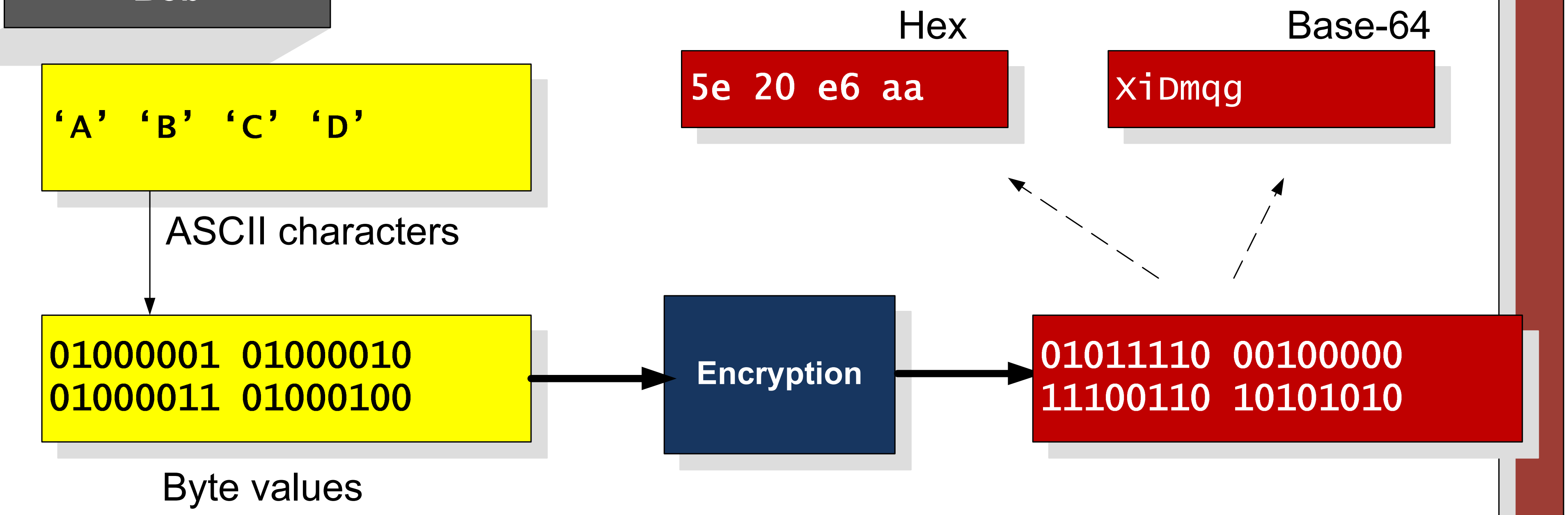


A few fundamentals

Viewing binary

Binary values are difficult to view/edit, thus encrypted values are typically converted to hex or Base-64.





‘A’ ‘B’ ‘C’ ‘D’

ASCII characters

01000001 01000010
01000011 01000100

Byte values

Encryption

01011110 00100000
11100110 10101010

Hex

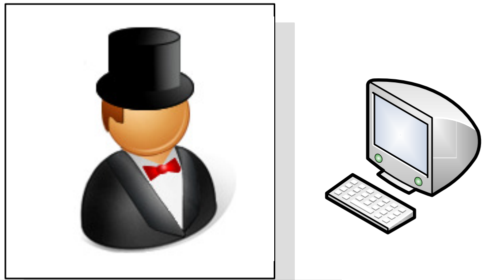
5e 20 e6 aa

Base-64

XiDmqg

Viewing binary

With hexadecimal, the bit stream is split into groups of four, and converted into hex values (0-9,A-F)



Bob

0101 1110 0010 0000 1110 0110 1010 1010

Bit stream

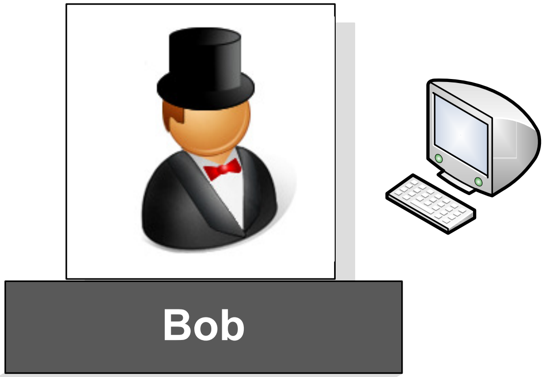
5 e 2 0 e 6 a a

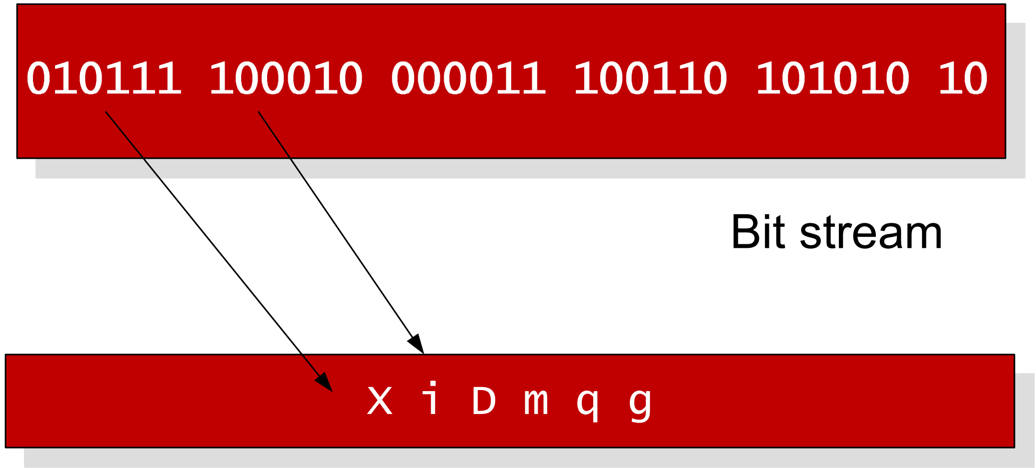
Hex

Decimal	Binary	Hex
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Viewing binary

With Base-64, the bits are split into groups of six, and then converted. Base-64 is used extensively on the Internet (such as in email).





010111 100010 000011 100110 101010 10

Bit stream

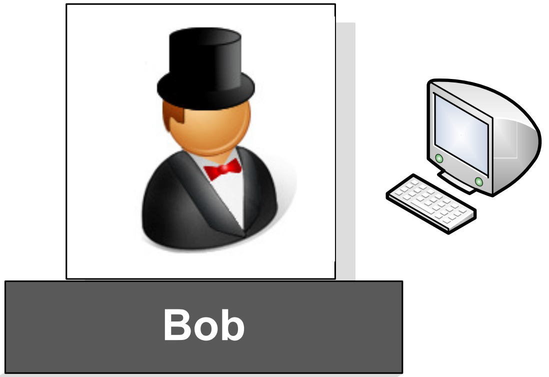
X i D m q g

Base-64

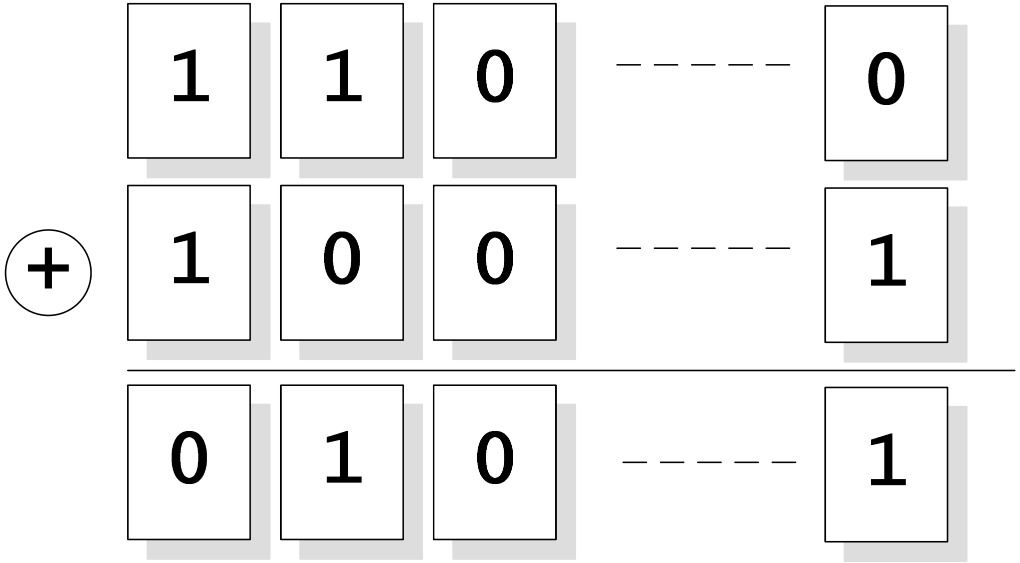
Val	Enc	Val	Enc	Val	Enc	Val	Enc
0	A	16	Q	32	g	48	w
1	B	17	R	33	h	49	x
2	C	18	S	34	i	50	y
3	D	19	T	35	j	51	z
4	E	20	U	36	k	52	0
5	F	21	V	37	l	53	1
6	G	22	W	38	m	54	2
7	H	23	X	39	n	55	3
8	I	24	Y	40	o	56	4
9	J	25	Z	41	p	57	5
10	K	26	a	42	q	58	6
11	L	27	b	43	r	59	7
12	M	28	c	44	s	60	8
13	N	29	d	45	t	61	9
14	O	30	e	46	u	62	+
15	P	31	f	47	v	63	/

Encryption operators

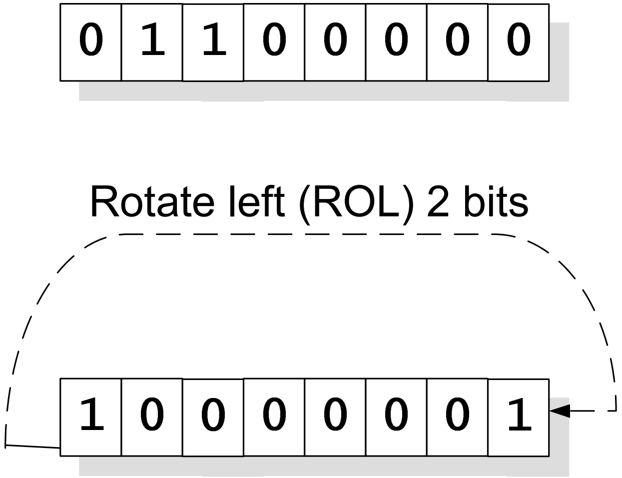
The two main operators used in encryption are Ex-OR and ROL/ROR, as they are fast, and preserve info.



The two main operators used in encryption are Ex-OR and ROR/ROL



+ Exclusive-OR operation



Rotate left (ROL)

Rotate right (ROR)

Author: Prof Bill Buchanan

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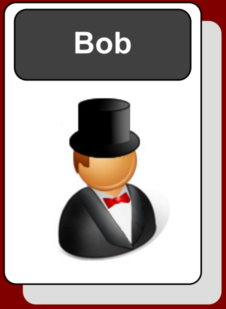
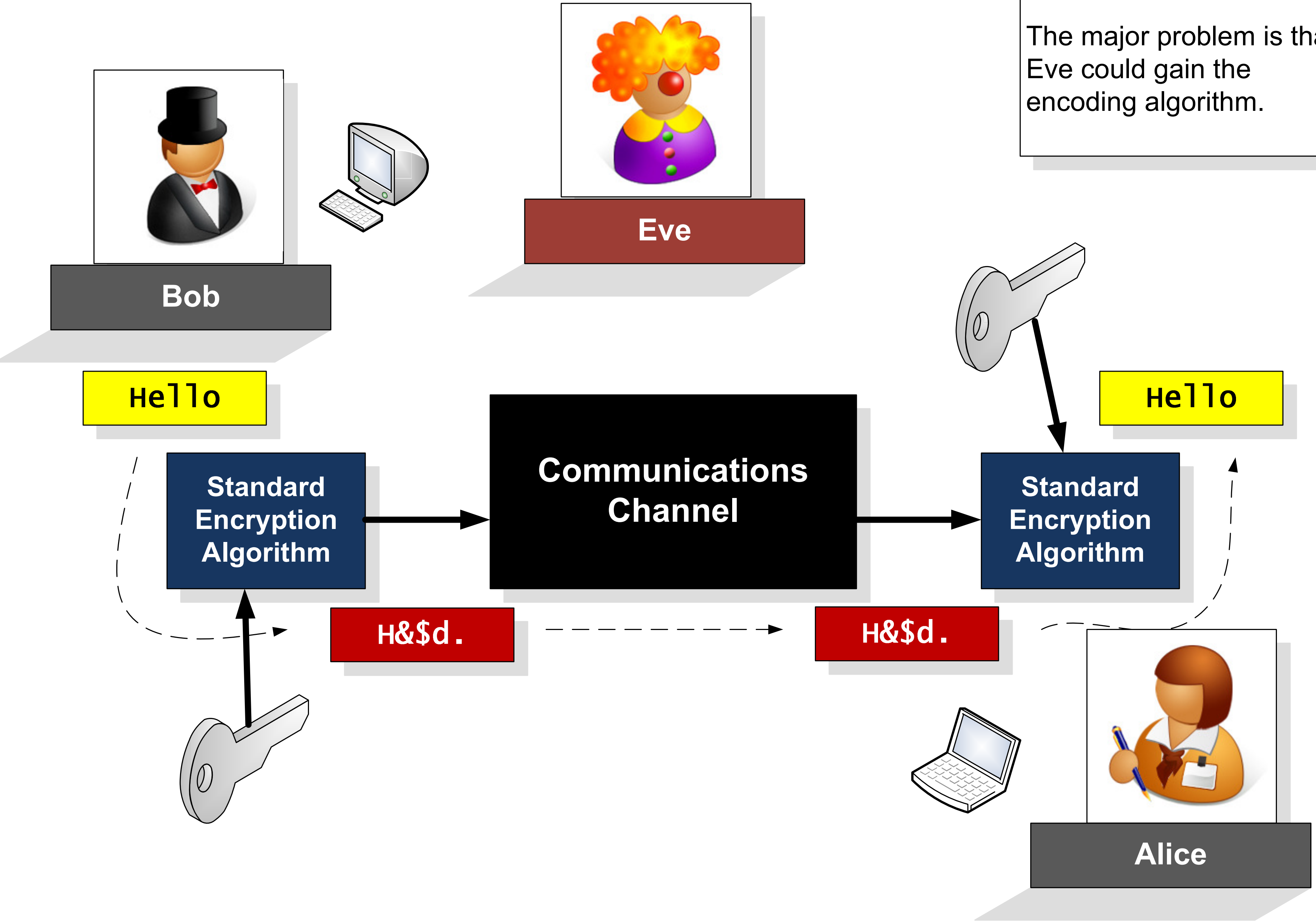


Key-based encryption

Key-encryption

The major problem is that Eve could gain the encoding algorithm.



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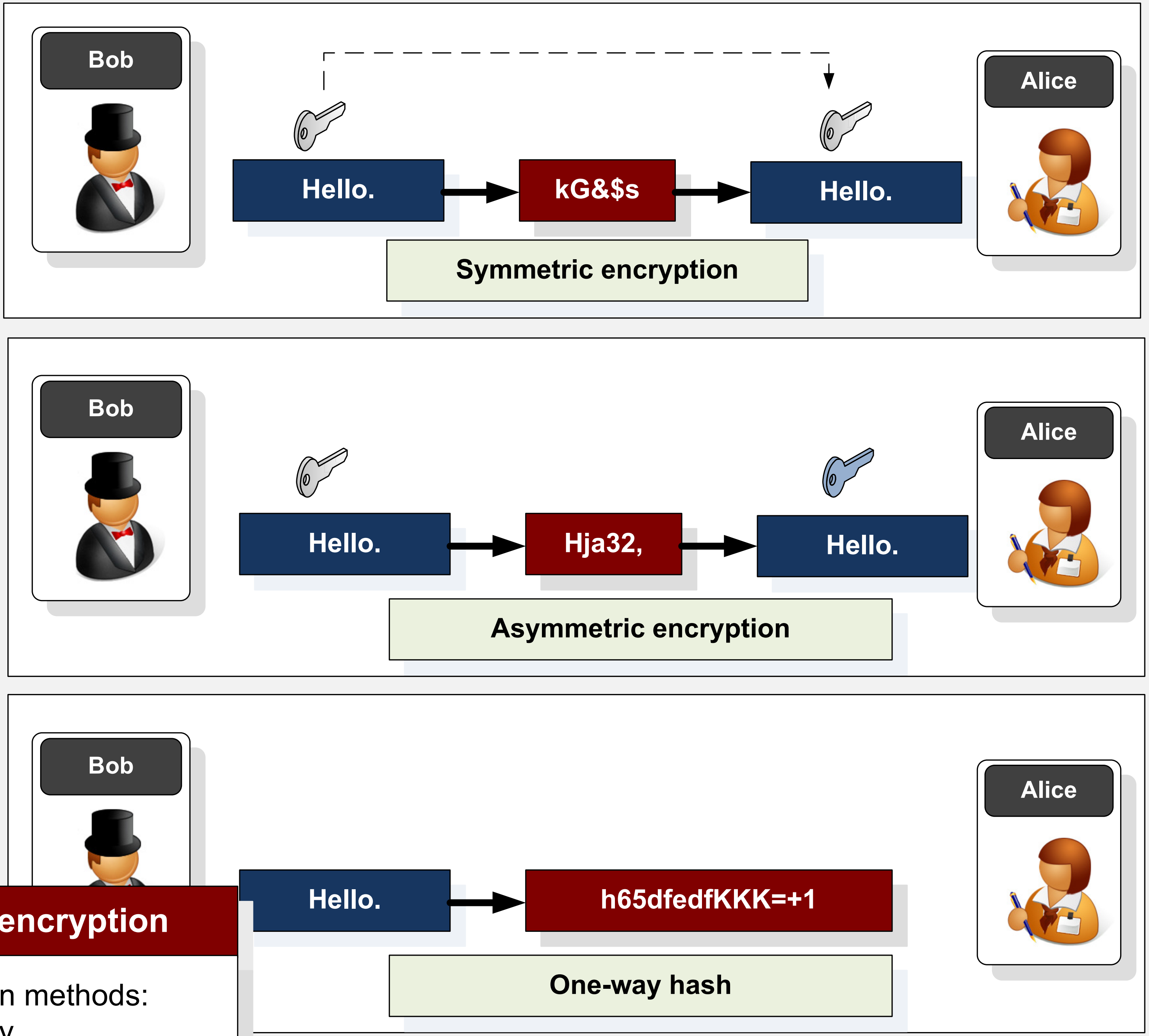
Key-based Encryption



Bob

Hello. → kG&$s → Hello.

Alice

Symmetric encryption

Bob

Hello. → Hja32, → Hello.

Alice

Asymmetric encryption

Bob

Hello. → h65dfedfKKK=+1

Alice

One-way hash

Private-key:
RC2, RC4,
DES, 3DES,
AES

Public-key:
RSA, DSA
(factoring prime
numbers)
FIPS 186-2,
ElGamal
(Elliptic curve)

Hashing:
MD5, SHA-1

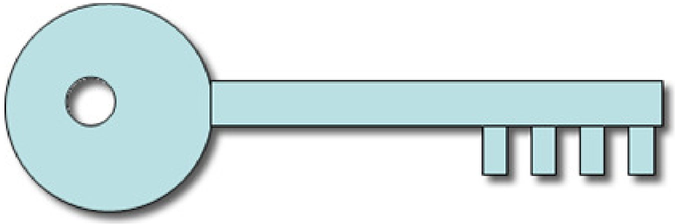
Strength: 80-bit DES -> 1024 RSA -> 160 bit Elliptic

Key-encryption

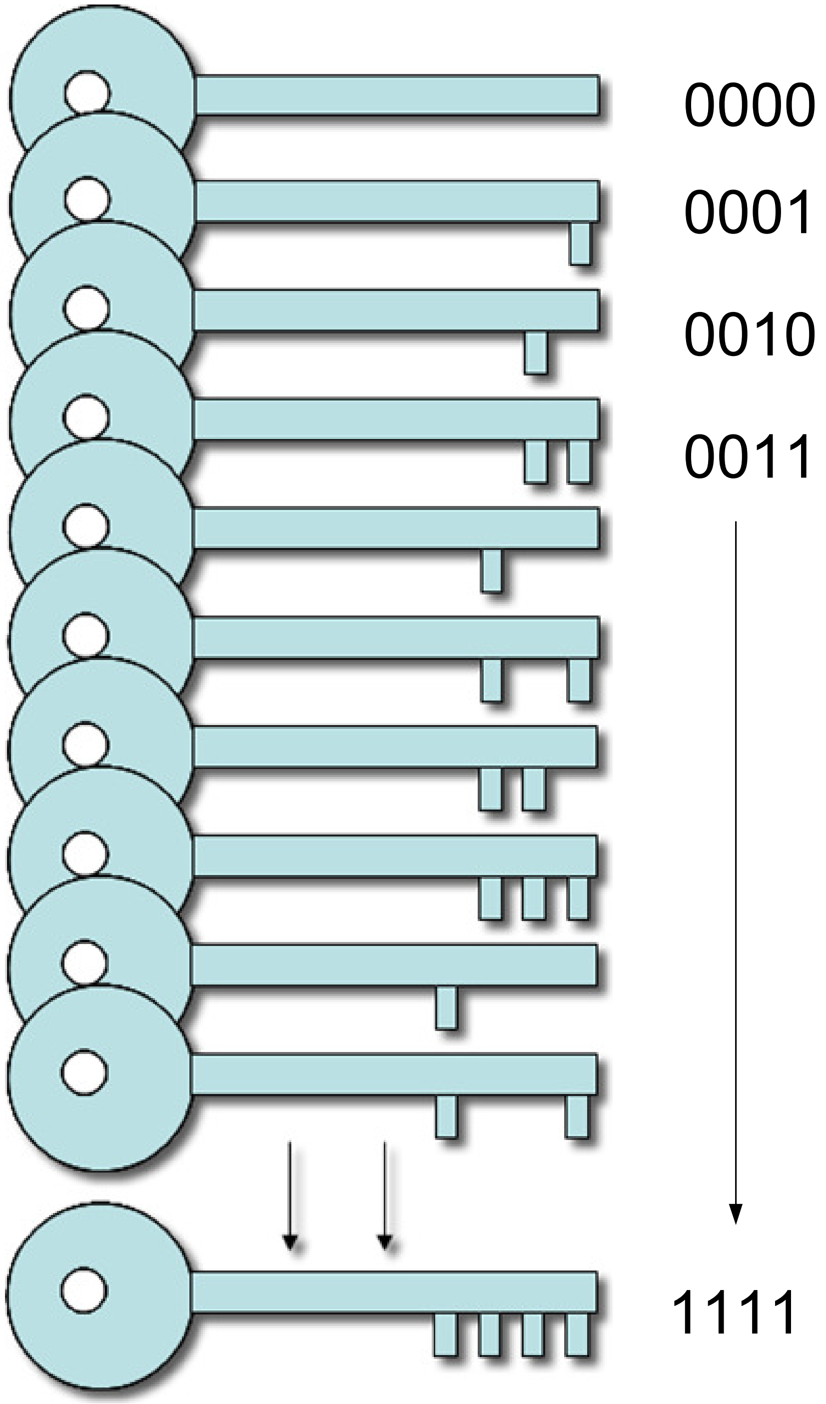
Three main methods:
Private-key.
Public-key.
One-way hash.

How safe is the key?
- the more keys … the less likely it is to find the key.

For example, if we have a key with four notches … each which can exist or not … how many keys can we have?

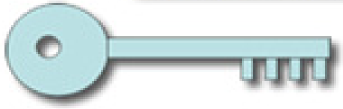


16 key combinations
2 to the power of 4 (2^4)



Width of Napier (100m)

Width of Edinburgh (6 miles)

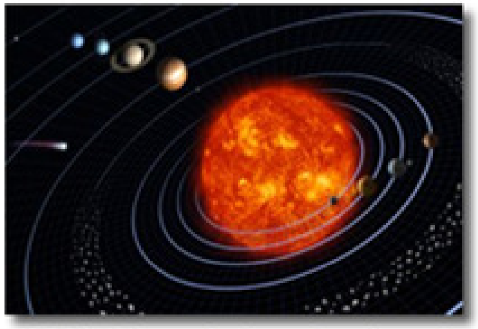


If each key was 1mm, and each key was laid end-on-end, what is the distance spanned for all the possible 64-bit electronic keys?

Earth to the Moon

93,000,000 miles

Width of the Milky Way
90,000 light years across



Width of the Solar System

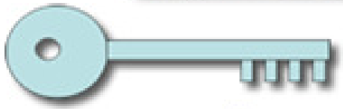
3,666,000,000 miles

Secret Communications

- Size would be somewhere between the Milky Way and the Universe

Width of Napier (100m)

Width of Edinburgh (6 miles)

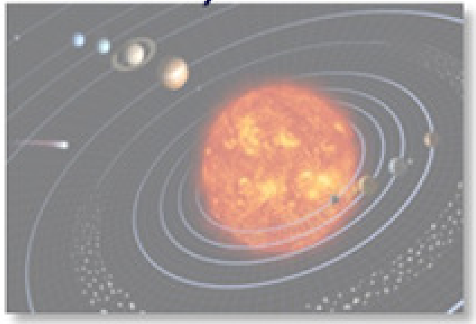


If each key was 1mm, and each key was laid end-on-end, what is the distance spanned for all the possible 64-bit electronic keys? (1,300,000,000,000,000 miles)

Earth to the Moon

93,000,000 miles

Width of the Milky Way
90,000 light years across



Width of the Solar System

3,666,000,000 miles

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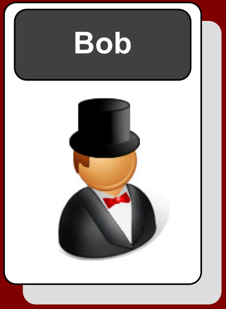
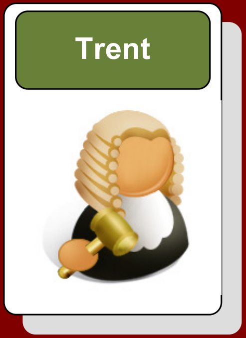
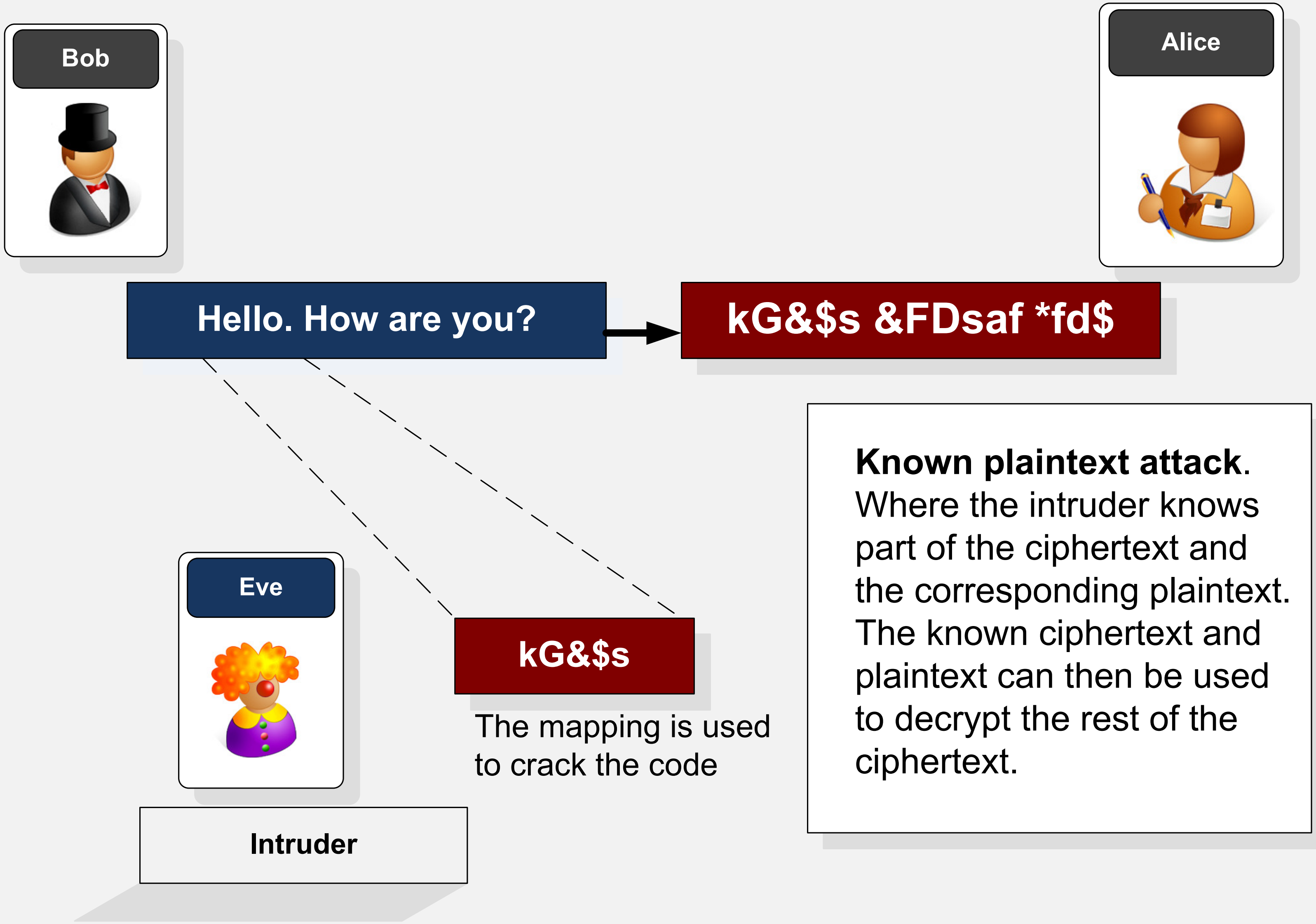




Cracking the code



Bob

Alice

Hello. How are you?

kG&$s &FDsaf *fd$

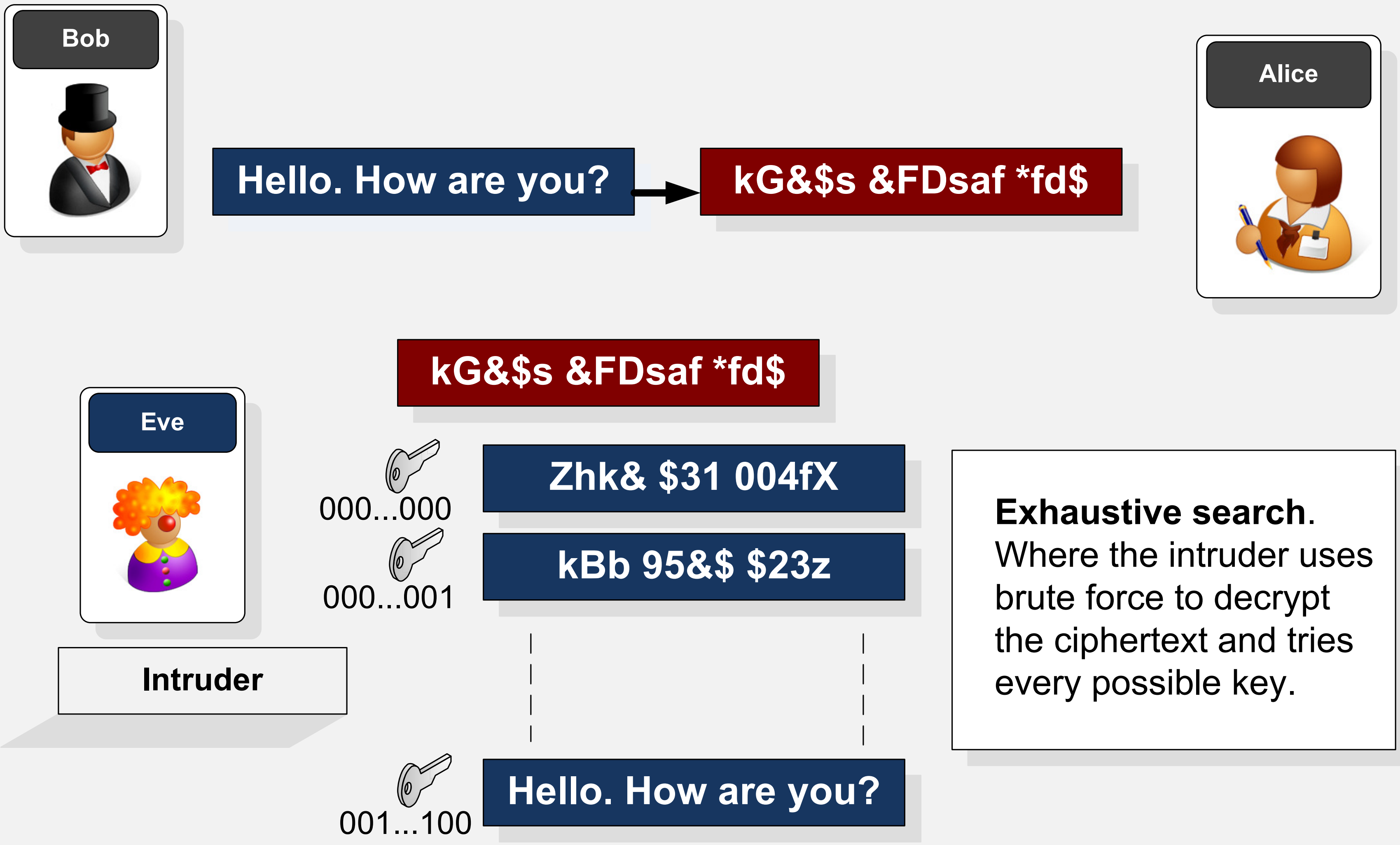
Eve

kG&$s

The mapping is used to crack the code

Intruder

Known plaintext attack. Where the intruder knows part of the ciphertext and the corresponding plaintext. The known ciphertext and plaintext can then be used to decrypt the rest of the ciphertext.



Bob

Hello. How are you?

kG&$s &FDsaf *fd$

Alice

kG&$s &FDsaf *fd$

Eve

Intruder

000...000

Zhk& $31 004fX

000...001

kBb 95&$ $23z

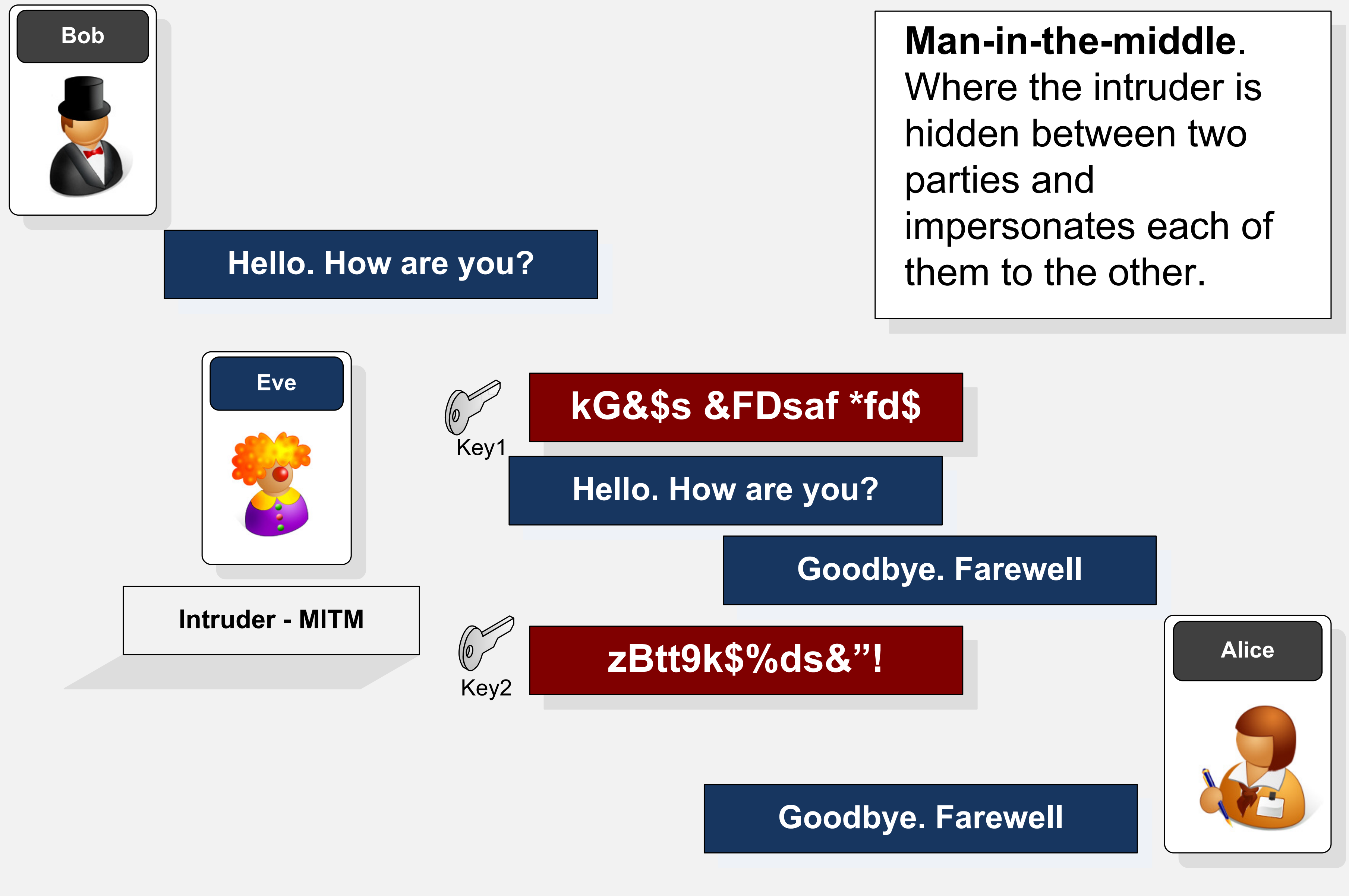
001...100

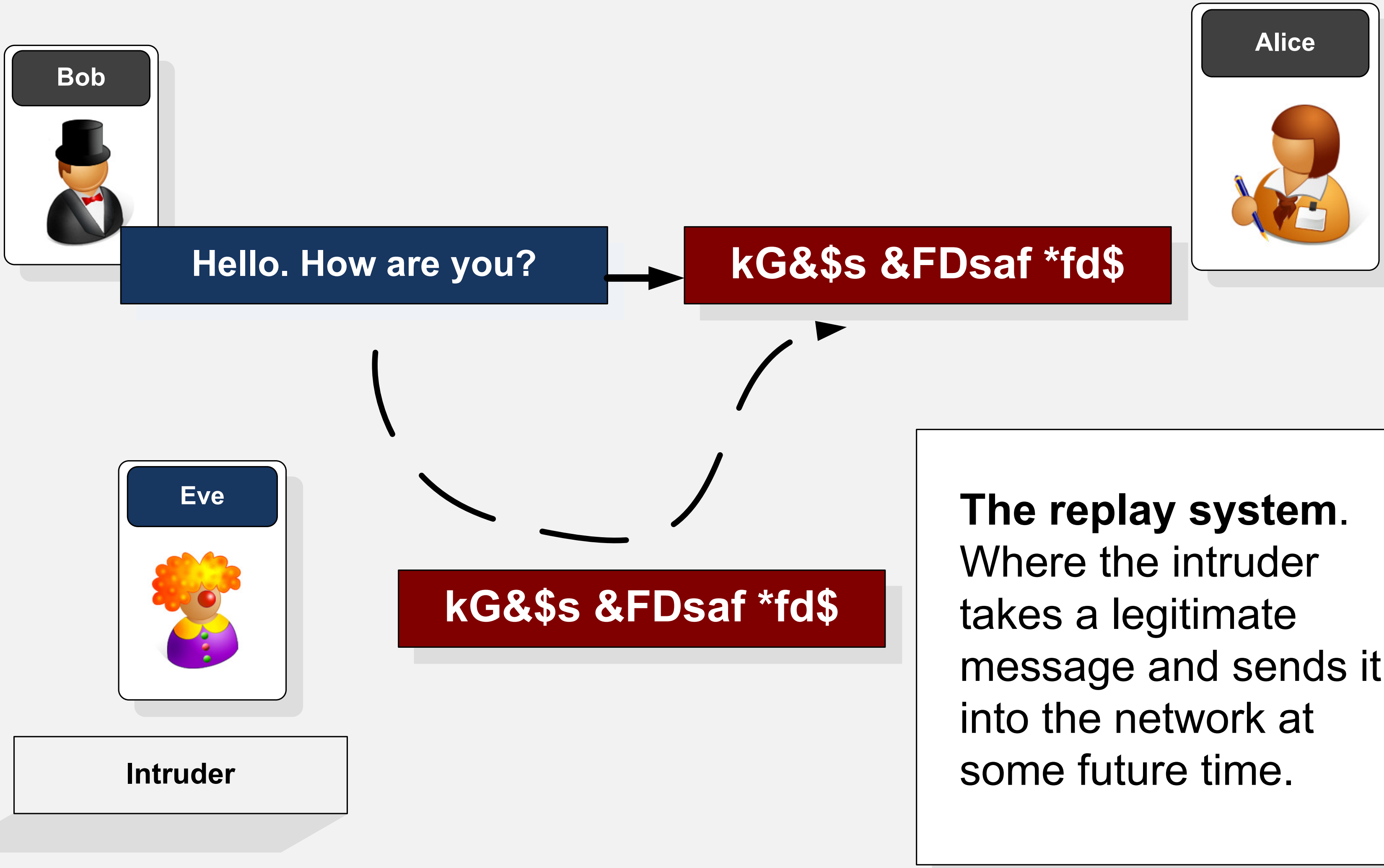
Hello. How are you?

Exhaustive search. Where the intruder uses brute force to decrypt the ciphertext and tries every possible key.

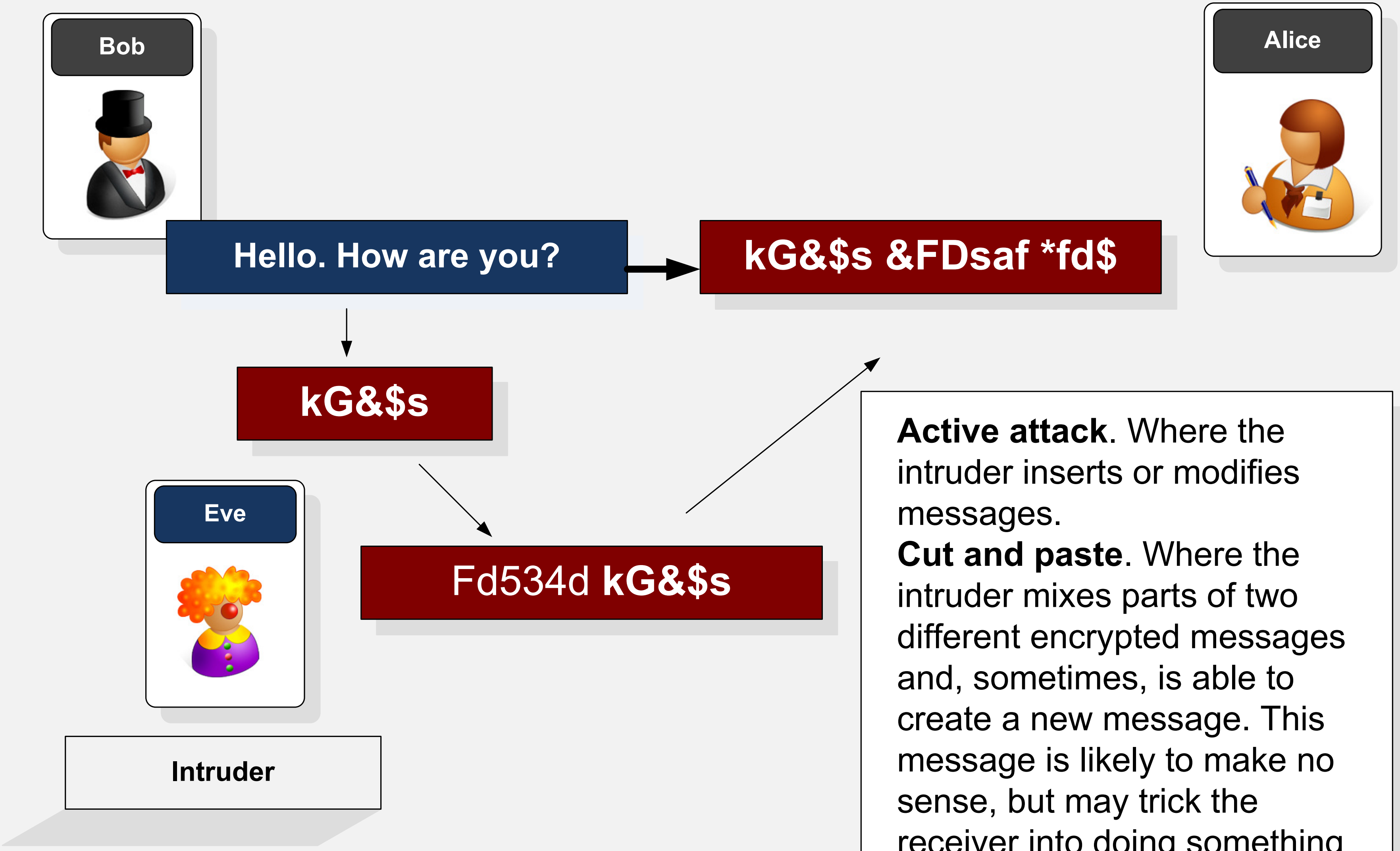
Author: Prof Bill Buchanan

Man-in-the-middle. Where the intruder is hidden between two parties and impersonates each of them to the other.





The replay system. Where the intruder takes a legitimate message and sends it into the network at some future time.



Bob

Alice

Hello. How are you?

kG&$s &FDsaf *fd$

kG&$s

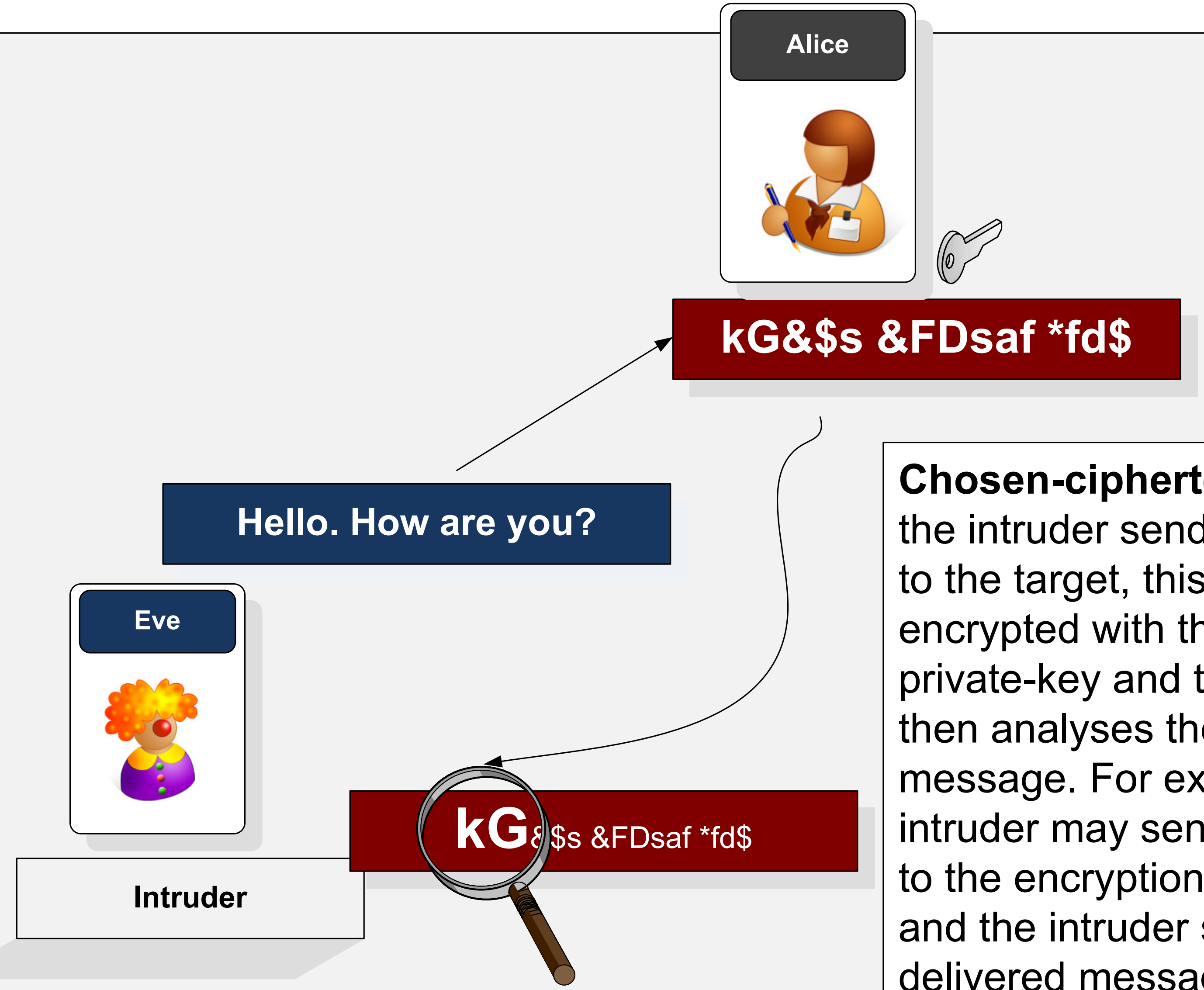
Eve

Fd534d **kG&$s**

Intruder

Active attack. Where the intruder inserts or modifies messages.

Cut and paste. Where the intruder mixes parts of two different encrypted messages and, sometimes, is able to create a new message. This message is likely to make no sense, but may trick the receiver into doing something that helps the intruder.



Alice

kG&$s &FDsaf *fd$

Hello. How are you?

Eve

Intruder

kG&$s &FDsaf *fd$

Chosen-ciphertext. Where the intruder sends a message to the target, this is then encrypted with the target's private-key and the intruder then analyses the encrypted message. For example, an intruder may send an e-mail to the encryption file server and the intruder spies on the delivered message.

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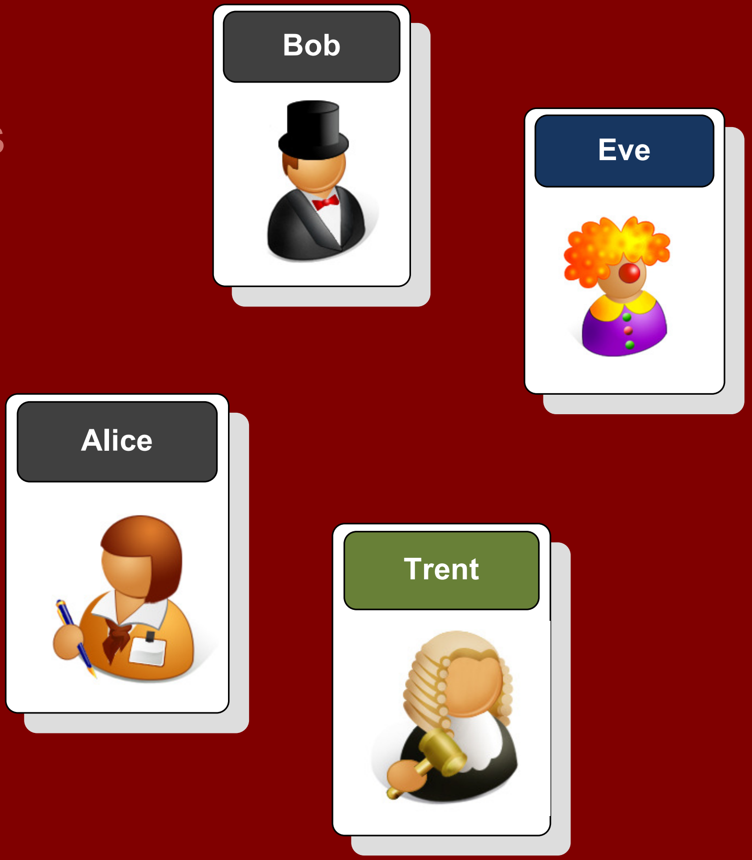


Brute force

Author: Prof Bill Buchanan

Bob

Alice

Trent

Eve

Number of keys

The larger the key, the greater the key space.

Code size	Number of keys	Code size	Number of keys	Code size	Number of keys
1	2	12	4,096	52	4.5×10^{15}
2	4	16	65,536	56	7.21×10^{16}
3	8	20	1,048,576	60	1.15×10^{18}
4	16	24	16,777,216	64	1.84×10^{19}
5	32	28	2.68×10^{8}	68	2.95×10^{20}
6	64	32	4.29×10^{9}	72	4.72×10^{21}
7	128	36	6.87×10^{10}	76	7.56×10^{22}
8	256	40	1.1×10^{12}	80	1.21×10^{24}
9	512	44	1.76×10^{13}	84	1.93×10^{25}
10	1024	48	2.81×10^{14}	88	3.09×10^{26}

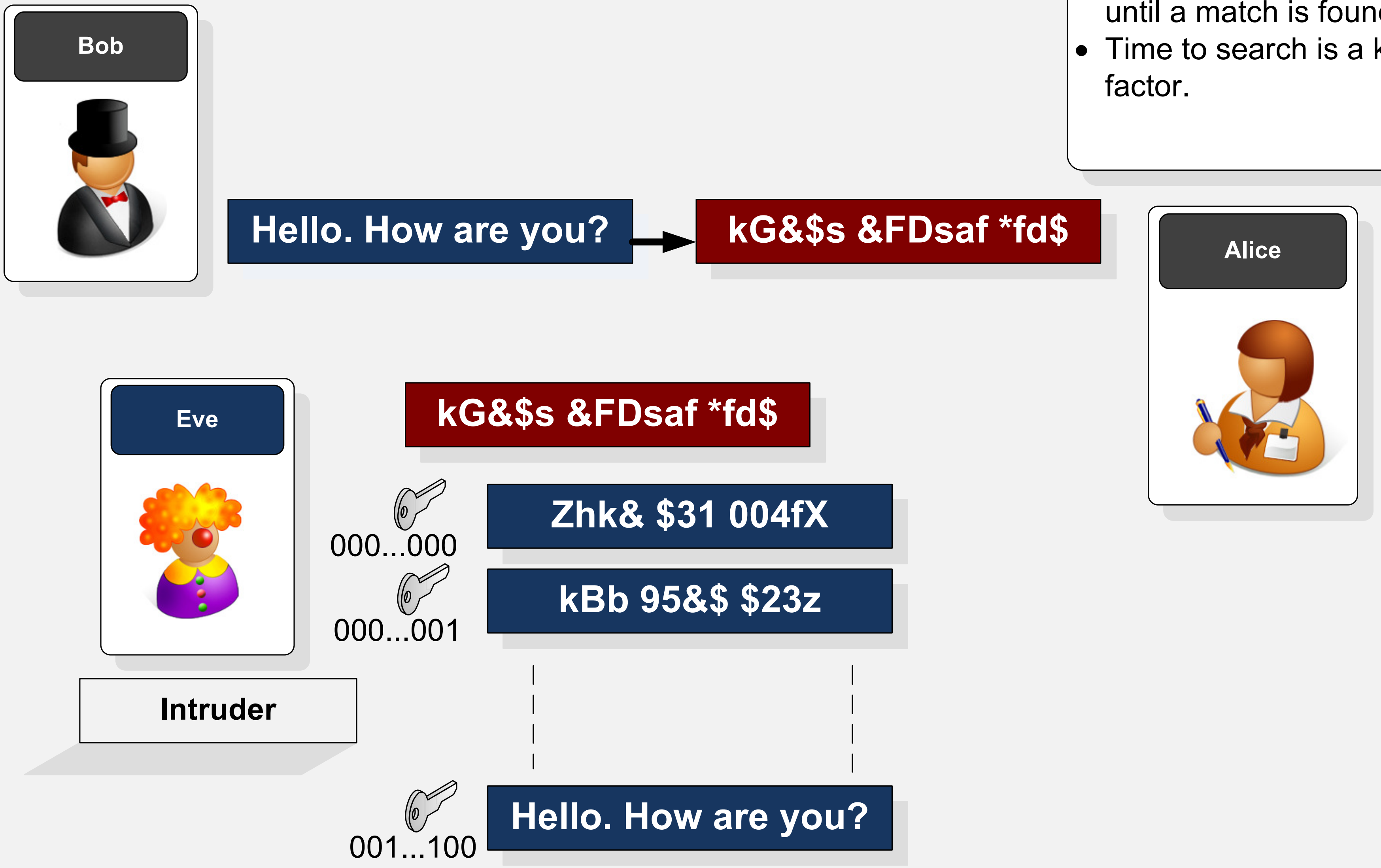
Brute force

Encryption

Author: Prof Bill Buchanan

Brute force

- Eve tries all the keys until a match is found.
- Time to search is a key factor.



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Time to crack

- It is important to understand the length of time that a message takes to crack as it may need to be secret for a certain time period.

Okay… we select a **64-bit key** …
which has 1.84×10^{19} combinations

18.4 million million million different keys
000000000000….0000000000000000000
To
111111111111….1111111111111111111

How long will it take to cracked It by brute-force (on average)?

Time to crack

- It is important to understand the length of time that a message takes to crack as it may need to be secret for a certain time period.

A 64-bit key has 1.84×10^{19} combinations and it could be cracked by brute-force in 0.9×10^{19} goes.

If we use a fast computer such as 1GHz clock (1ns), and say it takes one clock cycle to test a code, the time to crack the code will be:

9,000,000,000 seconds (150 million minutes) … **2.5 million hours** (285 years)

Time to crack

- It is important to understand the length of time that a message takes to crack as it may need to be secret for a certain time period.

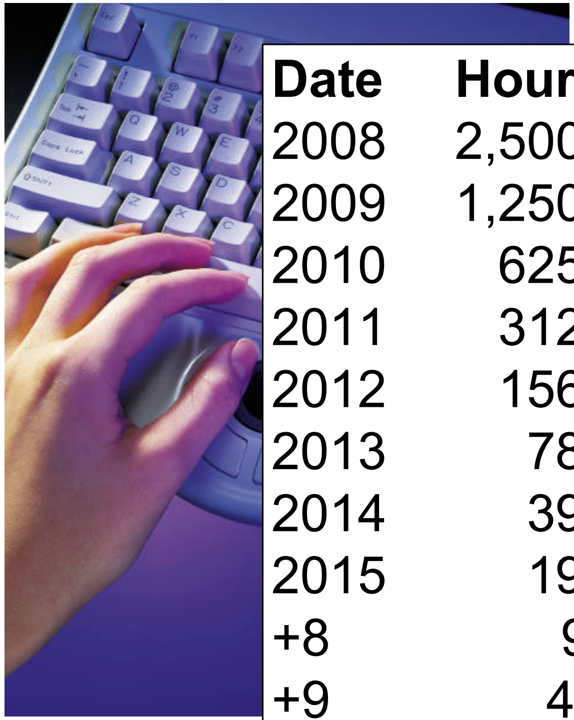
If it takes 2.5 million hours (285 years) to crack a code. How many years will it take to crack it within a day?

Computers typically improve their performance every year … so assume a **doubling** of performance each year.

Date	**Hours**	**Days**	**Years**
2008	2,500,000	104,167	285
2009	1,250,000	52,083	143

Time to crack

- From 285 years to 1 day, just by computers increasing their computing power.



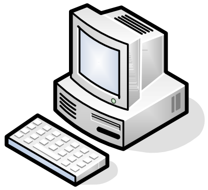
Date	Hours	Days	Years
2008	2,500,000	104,167	285
2009	1,250,000	52,083	143
2010	625,000	26,042	71
2011	312,500	13,021	36
2012	156,250	6,510	18
2013	78,125	3,255	9
2014	39,063	1,628	4
2015	19,532	814	2
+8	9,766	407	1
+9	4,883	203	1
+10	2,442	102	0.3
+11	1,221	51	0.1
+12	611	25	0.1
+13	306	13	0
+14	153	6	0
+15	77	3	0
+16	39	2	0
+17	**20**	**1**	**0**

56-bit DES:
Developed
1975
30 years ago!
… now easily
crackable

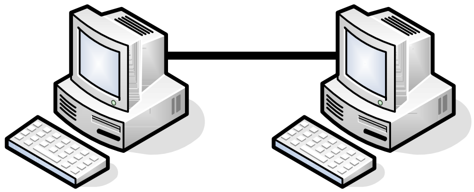
Author: Prof Bill Buchanan

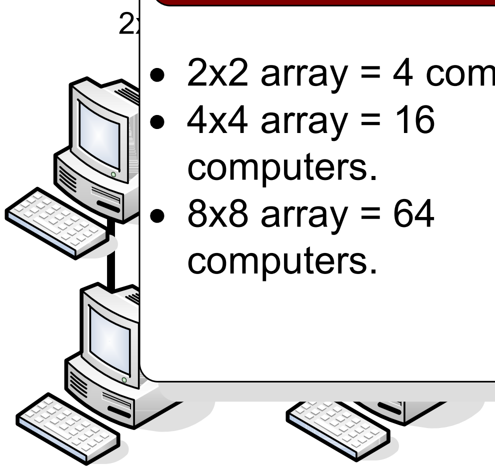
Parallel processing

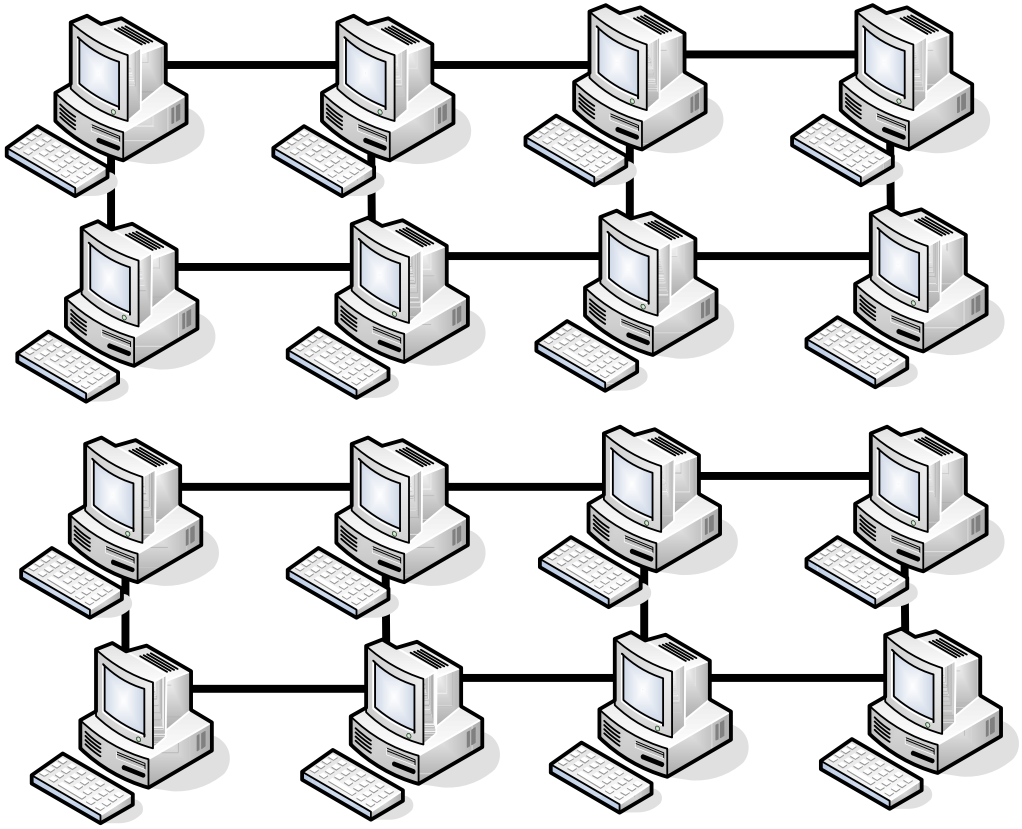
- 2x2 array = 4 computers.
- 4x4 array = 16 computers.
- 8x8 array = 64 computers.



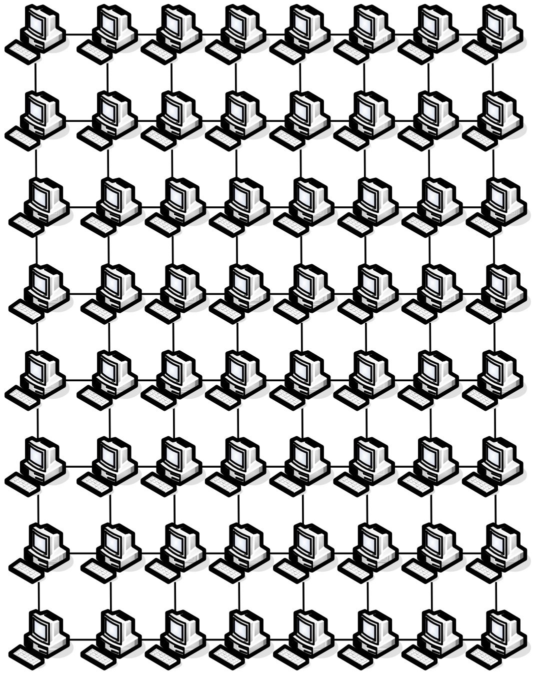
2x1 =2 element array







4x4 = 16 element array

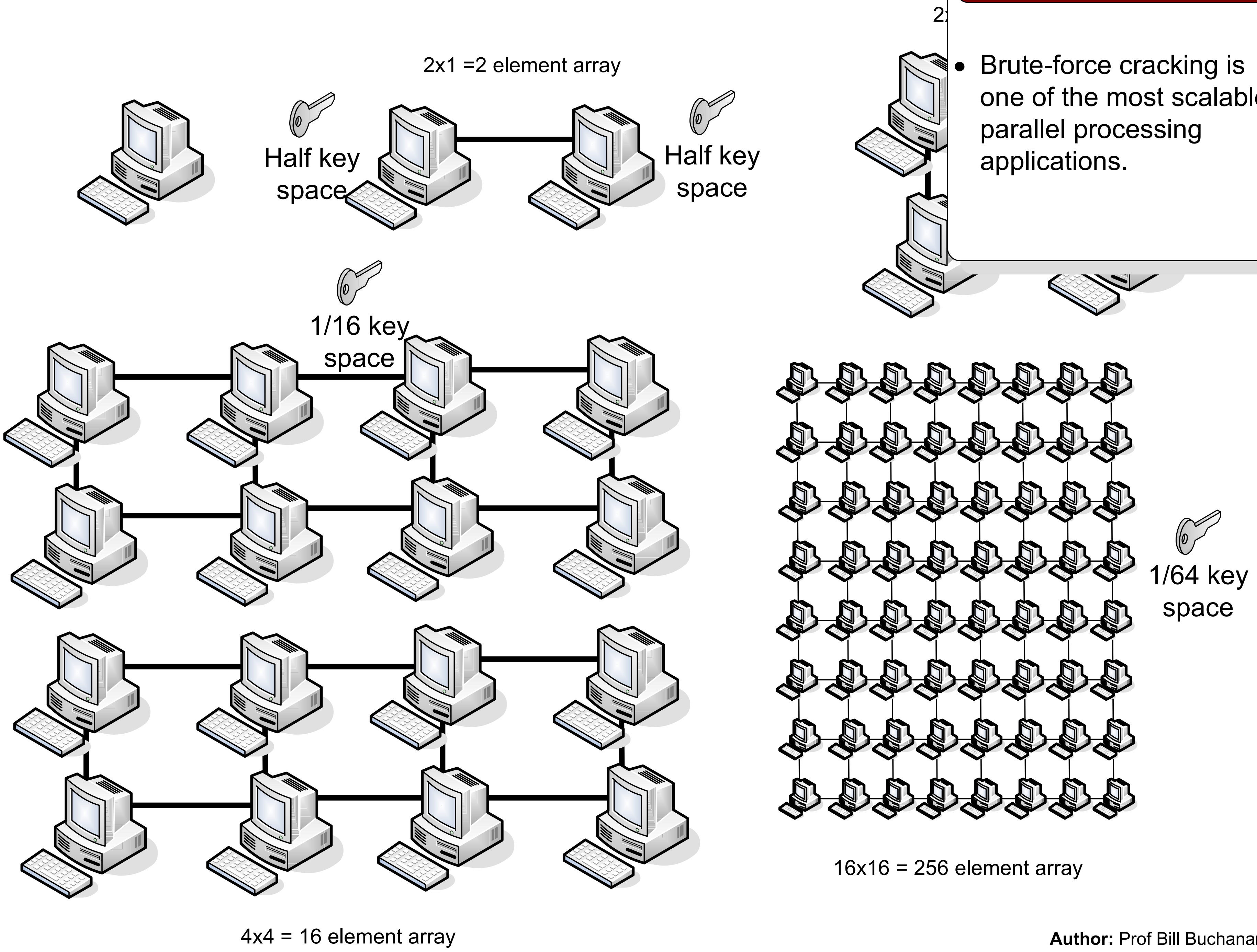


16x16 = 256 element array

Author: Prof Bill Buchanan

Parallel processing

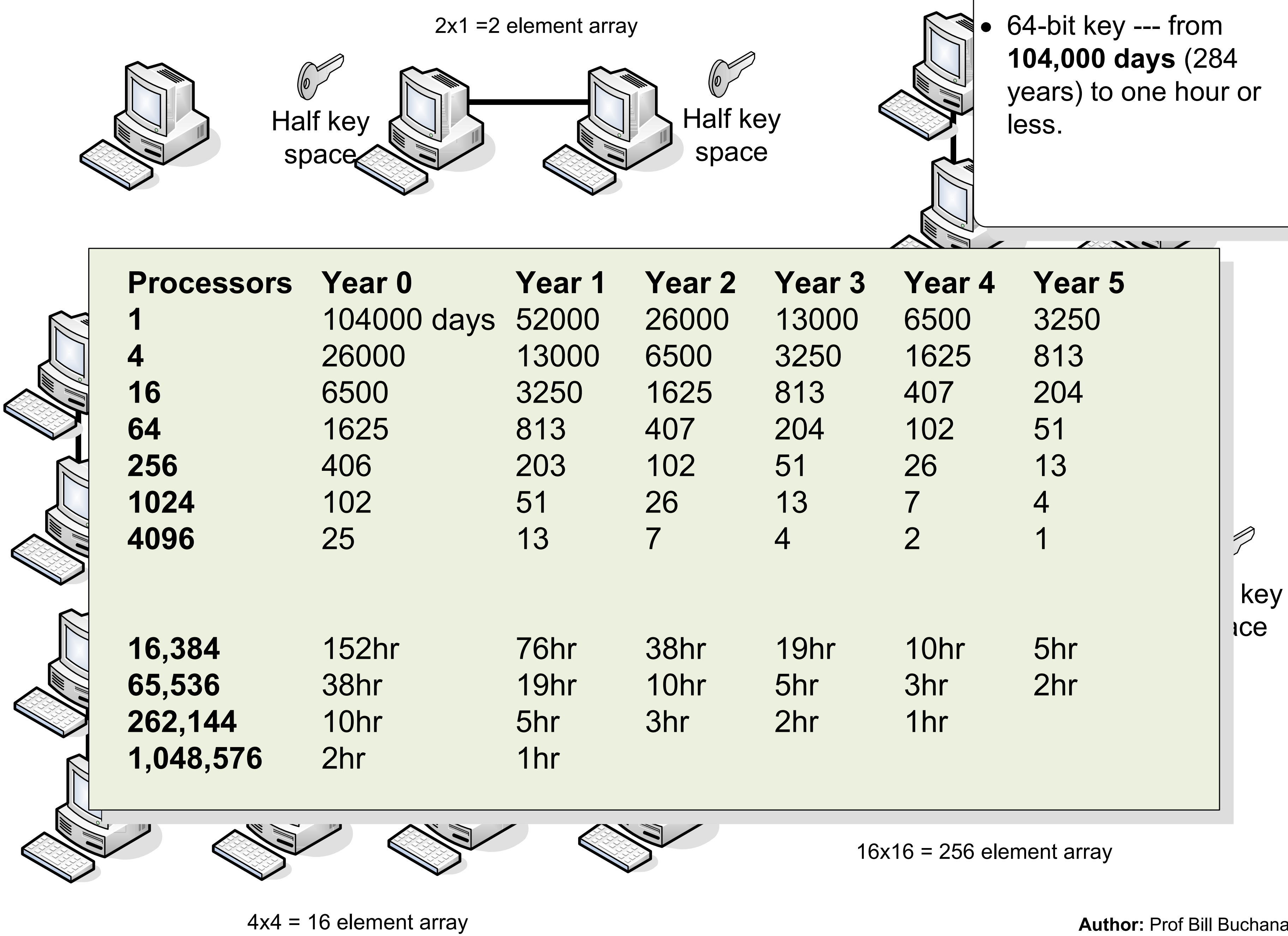
- Brute-force cracking is one of the most scalable parallel processing applications.



Author: Prof Bill Buchanan

Parallel processing

- 64-bit key --- from **104,000 days** (284 years) to one hour or less.



Processors	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
1	104000 days	52000	26000	13000	6500	3250
4	26000	13000	6500	3250	1625	813
16	6500	3250	1625	813	407	204
64	1625	813	407	204	102	51
256	406	203	102	51	26	13
1024	102	51	26	13	7	4
4096	25	13	7	4	2	1
16,384	152hr	76hr	38hr	19hr	10hr	5hr
65,536	38hr	19hr	10hr	5hr	3hr	2hr
262,144	10hr	5hr	3hr	2hr	1hr	
1,048,576	2hr	1hr				

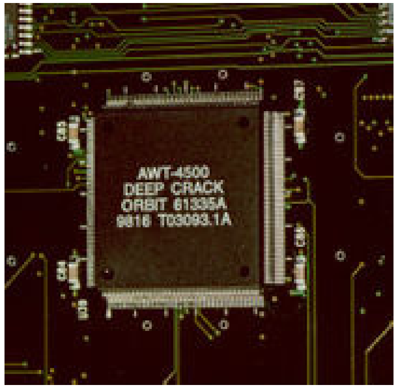
Brute-force

Encryption

Author: Prof Bill Buchanan

56-bit DES cracker

- 56-bit DES is seen as insecure as it can be cracked by enhanced processors.

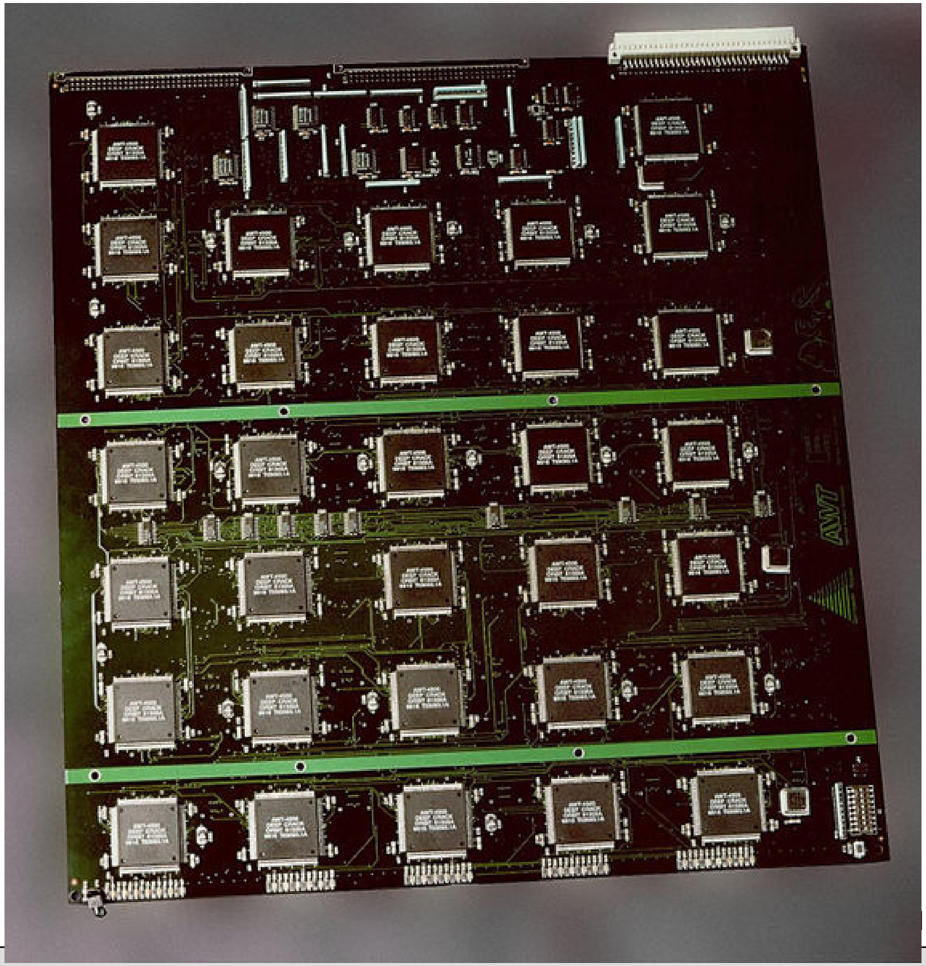


Year: 1998

Electronic Frontier Foundation - Cyberspace Civil Rights Group
90,000,000 keys per seconds

Array: 29 circuits of 64 chips
= 1856 elements

2.5 days



COPACOBANA

- Cracks 64-bit DES in less than nine days for less than $10,000

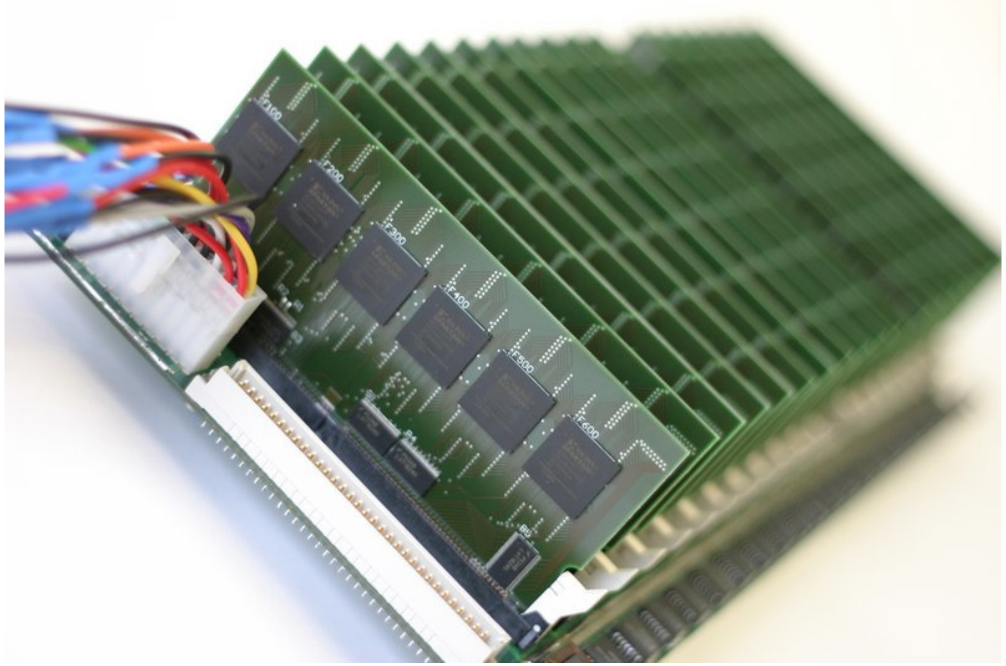
```
DES key search (version 0.6)
DES exhaustive key search

programming all FPGAs
type in plaintext (hex)
type in subspace (0...16383):
DES engine (0,1,2, or 3):
percentage (0...100):
plaintext : 1341343141343444
ciphertext: 36ca864f9359f49b
key       : 00000000e0400e00
expansion stage: 18 DIMM modules
DES key search started...

                FPGA 0
SLOT  1 | \ 1.42% (KS 0)
SLOT  2 | \ 1.42% (KS 6)
SLOT  3 | \ 1.42% (KS 12)
SLOT  4 | \ 1.42% (KS 18)
SLOT  5 | \ 1.42% (KS 24)
SLOT  6 | \ 1.42% (KS 30)
SLOT  7 | \ 1.42% (KS 36)
SLOT  8 | \ 1.42% (KS 42)
SLOT  9 | \ 1.42% (KS 48)
SLOT 10 | \ 1.42% (KS 54)
SLOT 11 | \ 1.42% (KS 60)
SLOT 12 | \ 1.41% (KS 66)
```

Now

System: **COPACOBANA** (Cost-Optimized Parallel COde Breaker)
Time to crack: Less than 9 days for DES (64-bit code).
Cost: Less than $10,000



Author: Prof Bill Buchanan

RSA Lab Challenge

- RSA Labs have a number of challenges, each of which have been solved. The present challenge is 72-bit RC5.

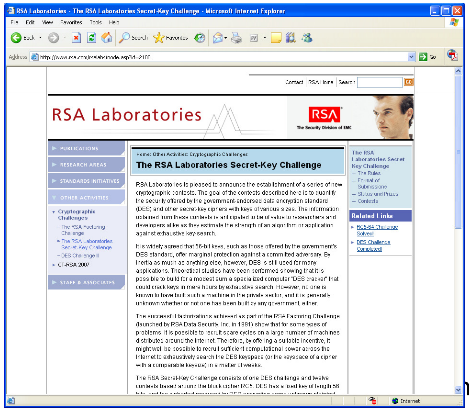
1997. RSA Lab's 56-bit RC5 Encryption Challenge - 250 days and 47% of the key space tested) – **distributed.net**

1998. RSA Lab's 56-bit DES II-1 Encryption Challenge - 39 days.
1998. RSA Lab's 56-bit DES II-2 Encryption Challenge - 2.5 days.

1999. RSA Lab's 56-bit DES-III Encryption Challenge - after 22.5 hours using EFF's Deep Crack custom DES cracker.

2002. RSA Lab's 64-bit RC5 Encryption Challenge — Completed 14 July 2002 – 1,757 days and 83% of the key space tested.

RSA Lab's 72-bit RC5 Encryption Challenge - In progress.



http://www.rsa.com/rsalabs/node.asp?id=2100

Home: Other Activities: Cryptographic Challenges

The RSA Laboratories Secret-Key Challenge

RSA Laboratories is pleased to announce the establishment of a series of new cryptographic contests. The goal of the contests described here is to quantify the security offered by the government-endorsed data encryption standard (DES) and other secret-key ciphers with keys of various sizes. The information obtained from these contests is anticipated to be of value to researchers and developers alike as they estimate the strength of an algorithm or application against exhaustive key-search.

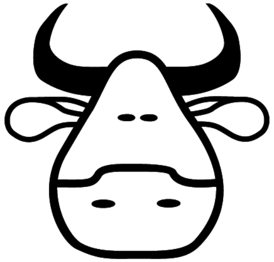
It is widely agreed that 56-bit keys, such as those offered by the government's DES standard, offer marginal protection against a committed adversary. By inertia as much as anything else, however, DES is still used for many applications. Theoretical studies have been performed showing that it is possible to build for a modest sum a specialized computer "DES cracker" that could crack keys in mere hours by exhaustive search. However, no one is known to have built such a machine in the private sector, and it is generally unknown whether or not one has been built by any government, either.

The successful factorizations achieved as part of the RSA Factoring Challenge (launched by RSA Data Security, Inc. in 1991) show that for some types of problems, it is possible to recruit spare cycles on a large number of machines distributed around the Internet. Therefore, by offering a suitable incentive, it might well be possible to recruit sufficient computational power across the Internet to exhaustively search the DES keyspace (or the keyspace of a cipher with a comparable keysize) in a matter of weeks.

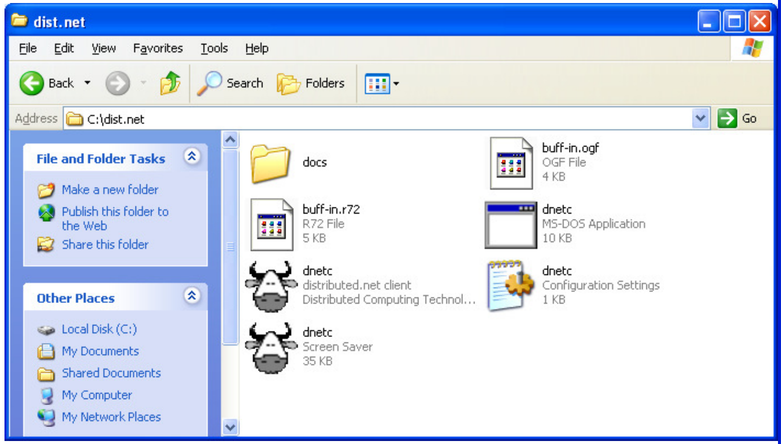
The RSA Secret-Key Challenge consists of one DES challenge and twelve contests based around the block cipher RC5. DES has a fixed key of length 56

distributed.net

- Tries to crack RSA Lab challenge by processing a range of possible keys while the screen save is on.
- Massive parallel processing system.



Distributed.net is starting and stopping (Max CPU when searching for possible keys)



docs

buff-in.ogf
OGF File
4 KB

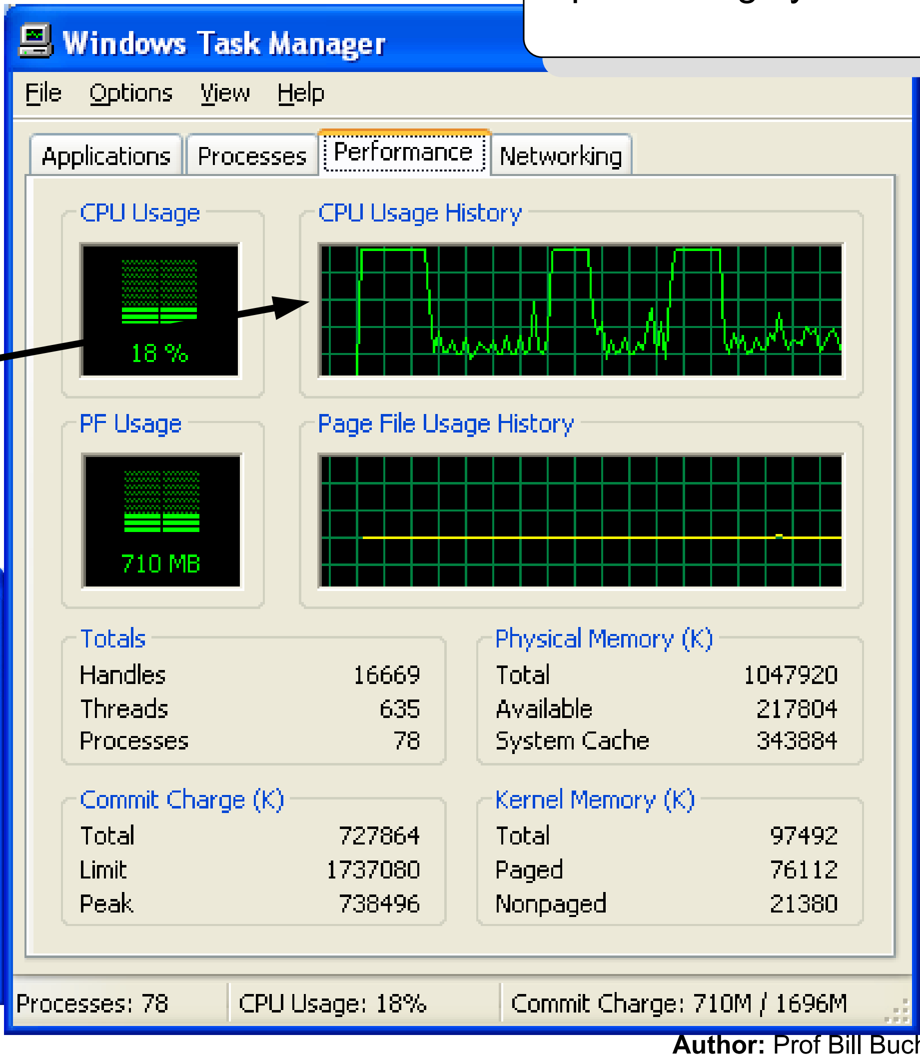
buff-in.r72
R72 File
5 KB

dnetc
MS-DOS Application
10 KB

dnetc
distributed.net client
Distributed Computing Technol...

dnetc
Configuration Settings
1 KB

dnetc
Screen Saver
35 KB



Totals	
Handles	16669
Threads	635
Processes	78

Physical Memory (K)	
Total	1047920
Available	217804
System Cache	343884

Commit Charge (K)	
Total	727864
Limit	1737080
Peak	738496

Kernel Memory (K)	
Total	97492
Paged	76112
Nonpaged	21380

Processes: 78 | CPU Usage: 18% | Commit Charge: 710M / 1696M

Super Computers

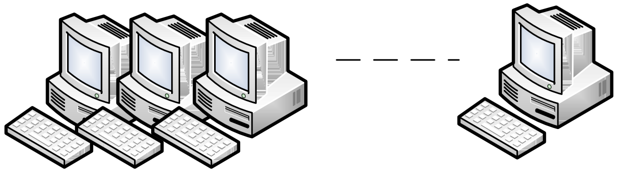
- BlueGene is 1.8million times more powerful than a standard PC.

BlueGene/L – eServer Blue Gene Solution
DOE/NNSA/LLNL, IBM
Department of Energy's (DOE) National Nuclear Security Administration's (NNSA).
131,072 processors
367,000 Gigaflop= 367,000,000 Mflops

Red Storm - Sandia/ Cray Red Storm
NNSA/Sandia National Laboratory United States, Opteron 2.4 GHz dual core Cray Inc.

26,544 processors
127,000 Gflops

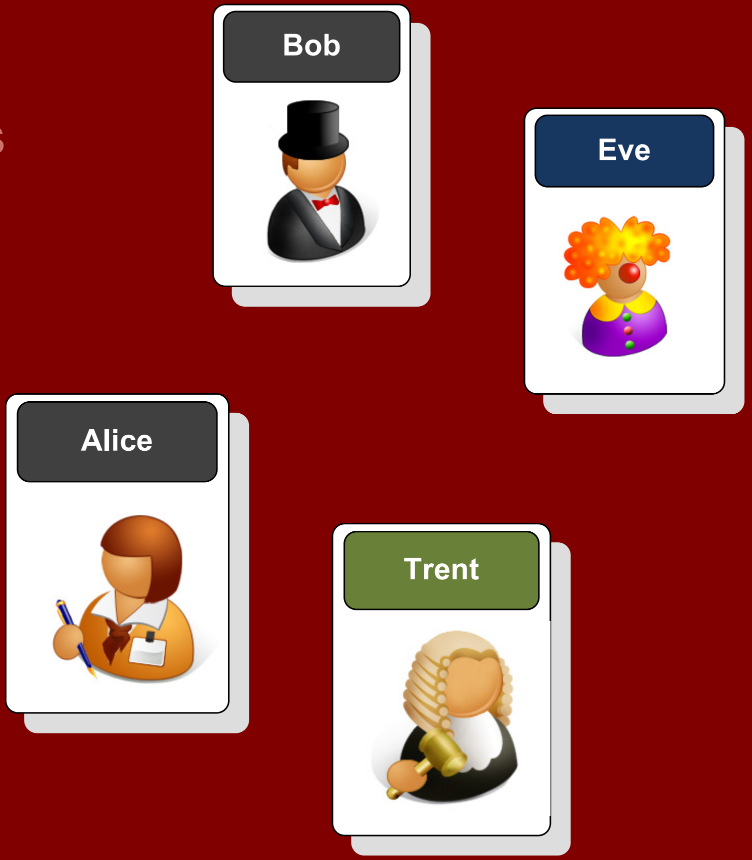
Typical PC: 200 Mflop … BlueGene is **1,835,000** times more powerful than a desktop.



Author: Prof Bill Buchanan

Encryption

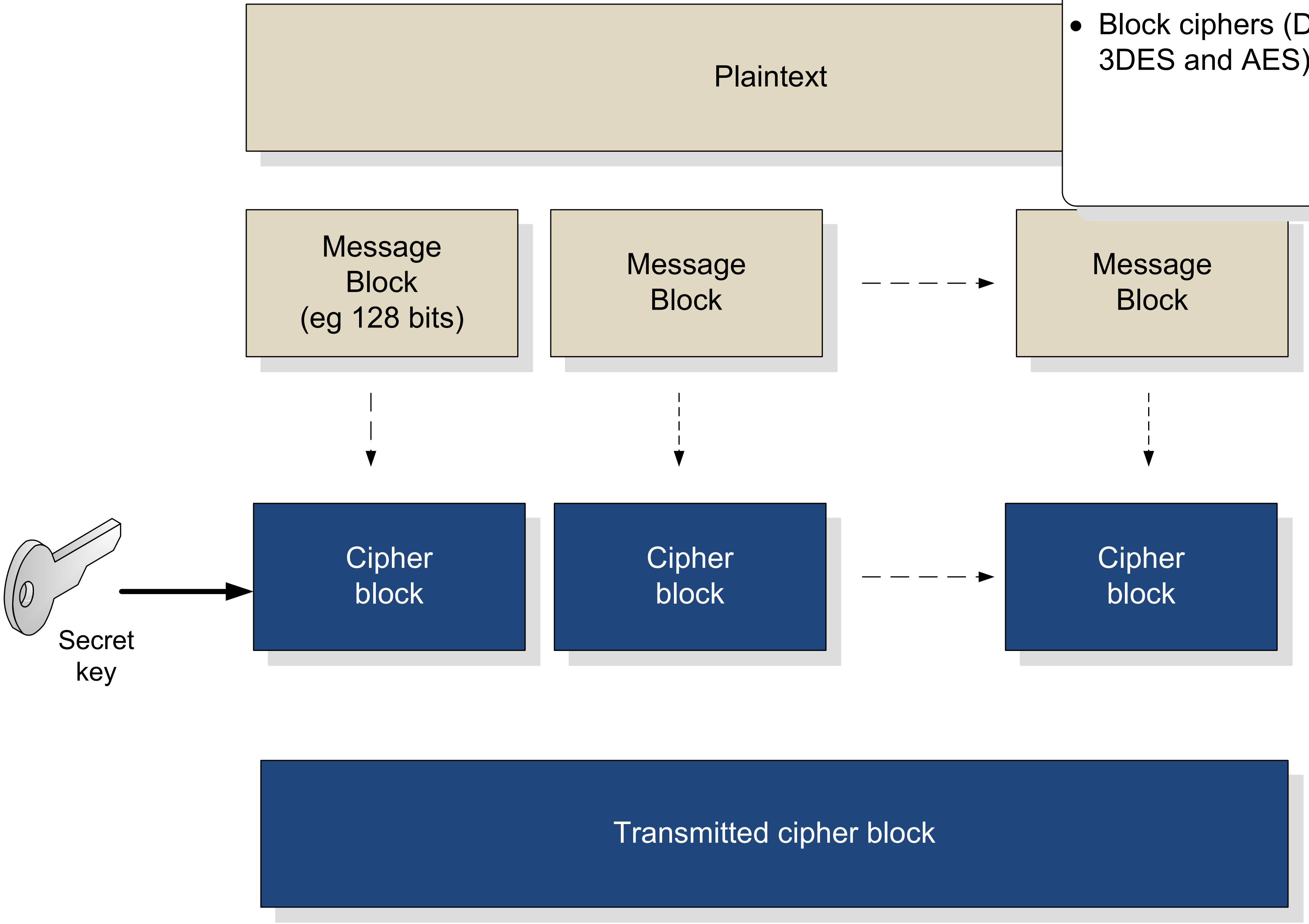
- Introduction
- Before electronic communications
- Codes
- A few fundamentals
- Key-based encryption
- Cracking the code
- Brute force
- Block or stream
- Private-key methods
- Encryption keys
- Passing keys
- Public-key encryption
- One-way hash
- Encrypting disks
- PGP encryption



Block or stream

Block cipher

- Block ciphers (DES, 3DES and AES)



Plaintext

Message Block (eg 128 bits)

Message Block

Message Block

Secret key

Cipher block

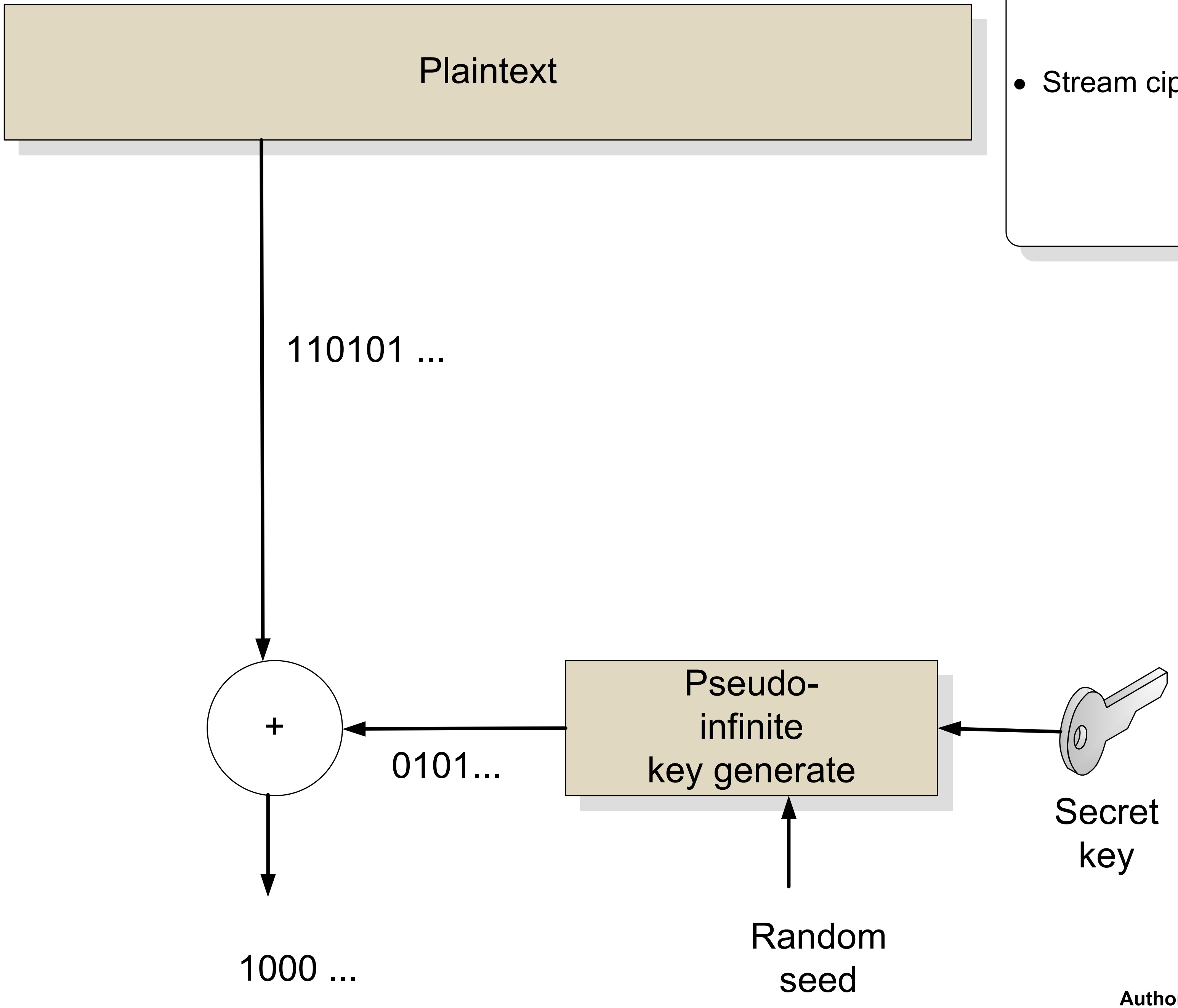
Cipher block

Cipher block

Transmitted cipher block

Stream cipher

- Stream cipher (RC4)



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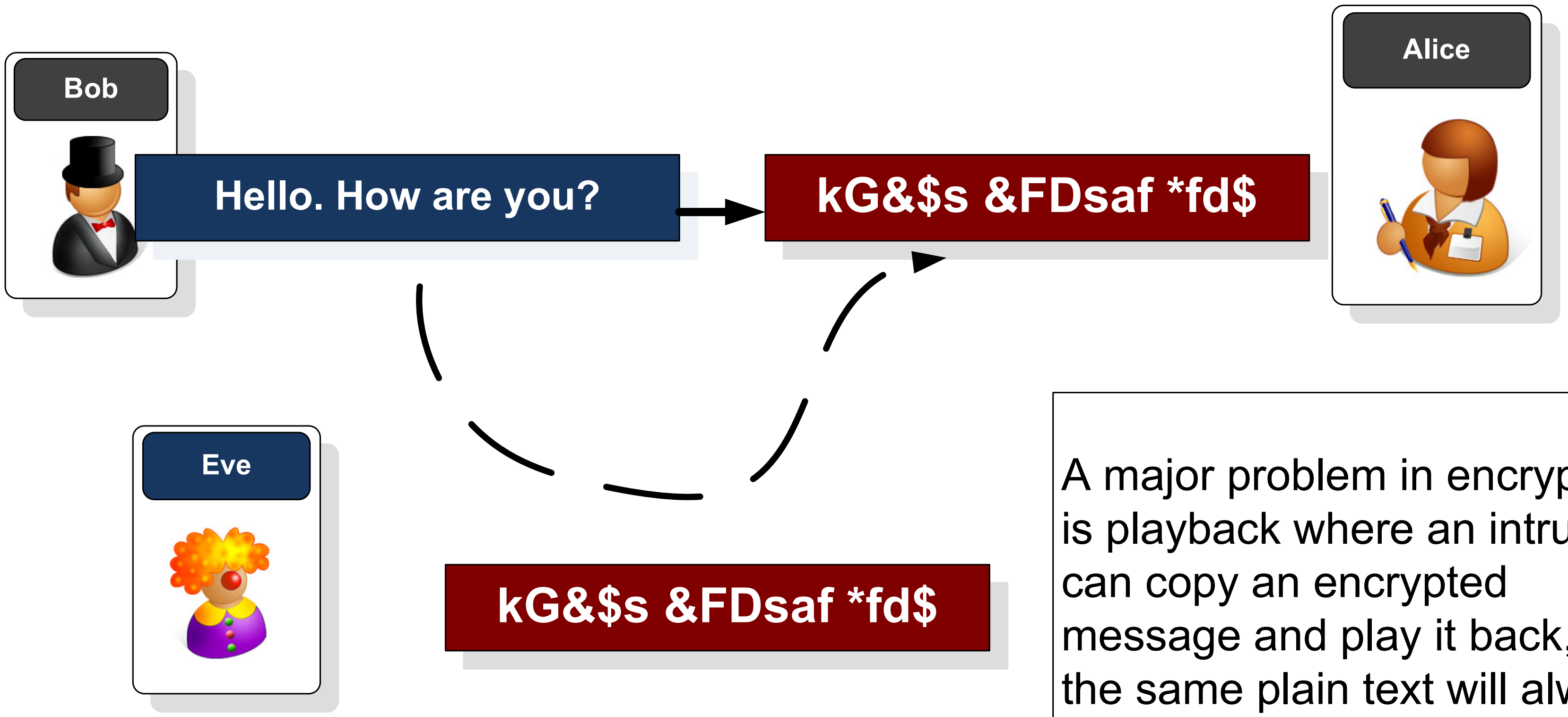
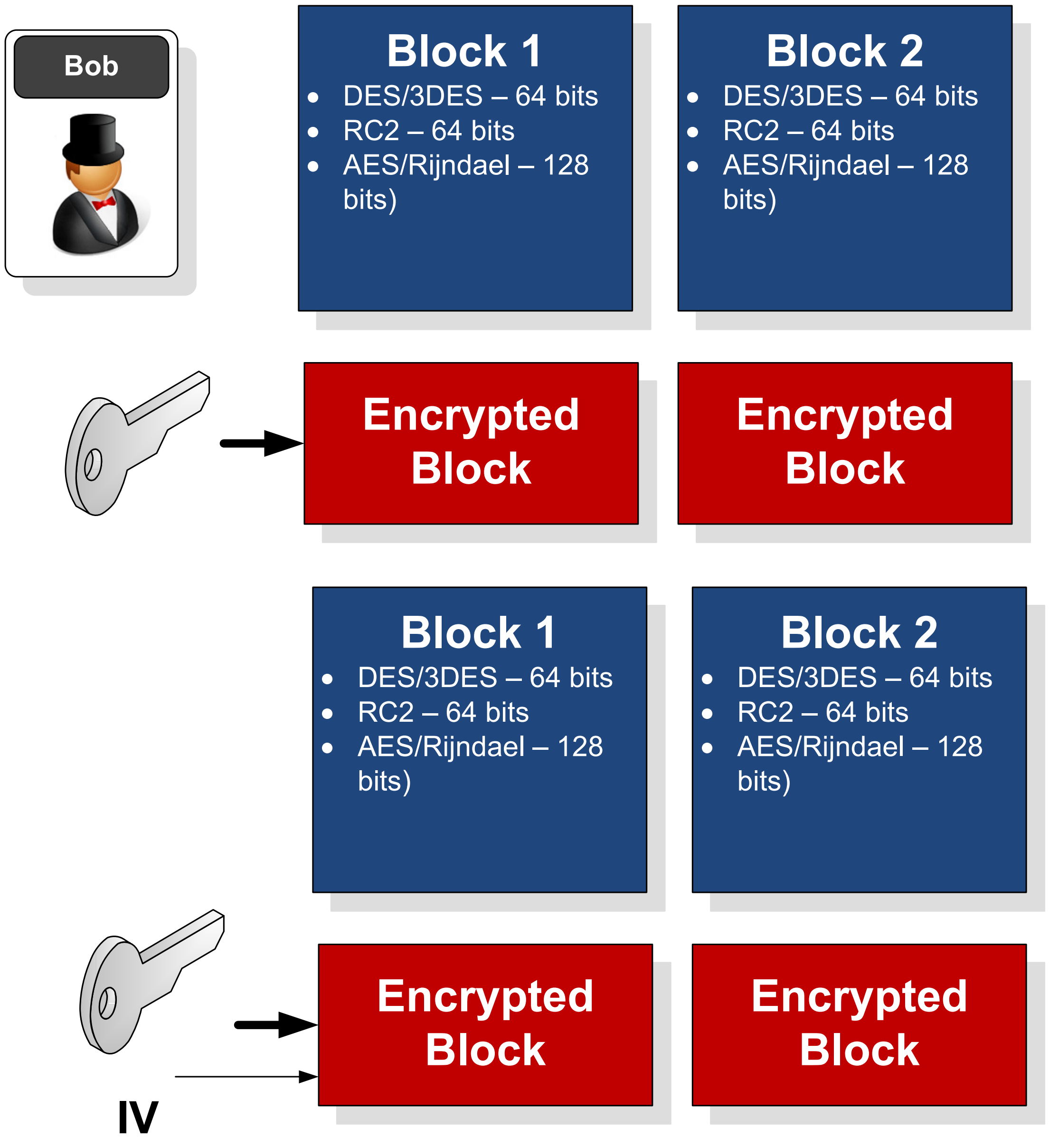
Private-key Methods



A major problem in encryption is playback where an intruder can copy an encrypted message and play it back, as the same plain text will always give the same cipher text.

The solution is to add **salt** to the encryption key, as that it changes its operation from block-to-block (for block encryption) or data frame-to-data frame (for stream encryption)



Block 1
- DES/3DES – 64 bits
- RC2 – 64 bits
- AES/Rijndael – 128 bits)

Block 2
- DES/3DES – 64 bits
- RC2 – 64 bits
- AES/Rijndael – 128 bits)

Encrypted Block

Encrypted Block

Electronic Code Book (ECB) method. This is weak, as the same cipher text appears for the same blocks.

Hello → 5ghd%43f=
Hello → 5ghd%43f=

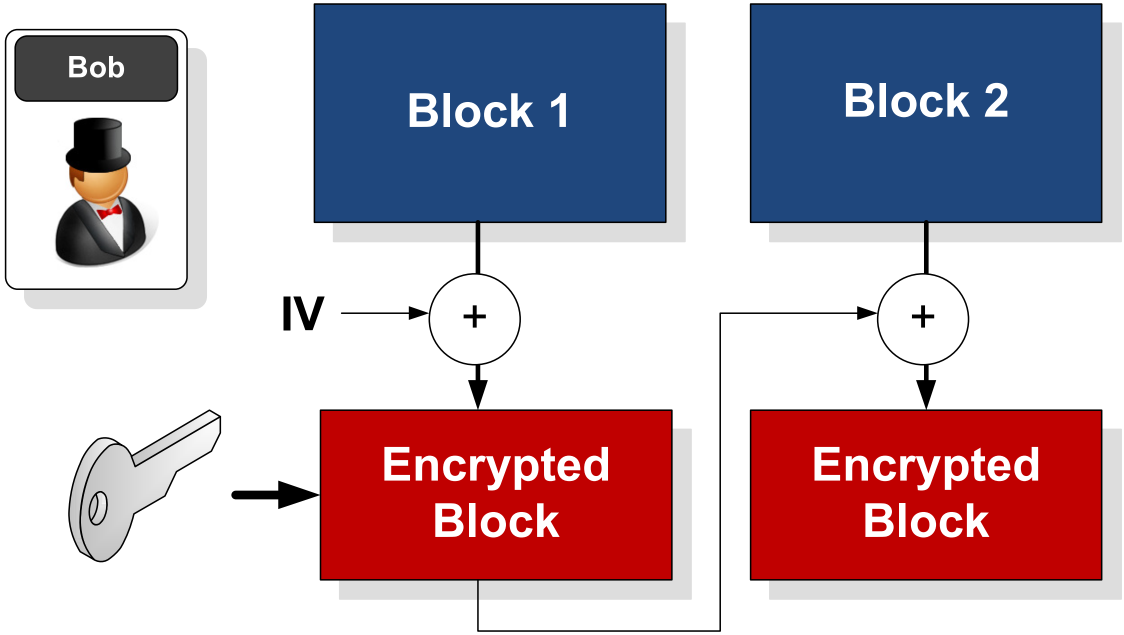
Block 1
- DES/3DES – 64 bits
- RC2 – 64 bits
- AES/Rijndael – 128 bits)

Block 2
- DES/3DES – 64 bits
- RC2 – 64 bits
- AES/Rijndael – 128 bits)

Encrypted Block

Encrypted Block

Adding salt. This is typically done with an IV (Initialisation Vector) which must be the same on both sides. In WEP, the IV is incremented for each data frame, so that the cipher text changes.



Cipher Block Chaining (CBC). This method uses the IV for the first block, and then the results from the previous block to encrypt the current block.

Original image

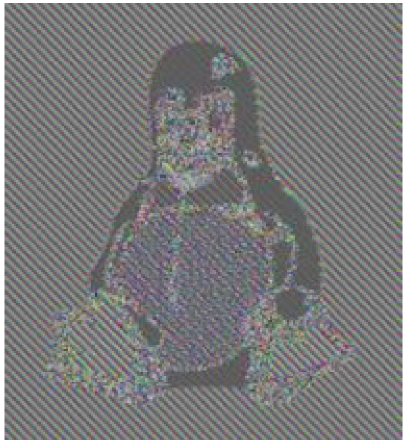


Image with AES using ECB

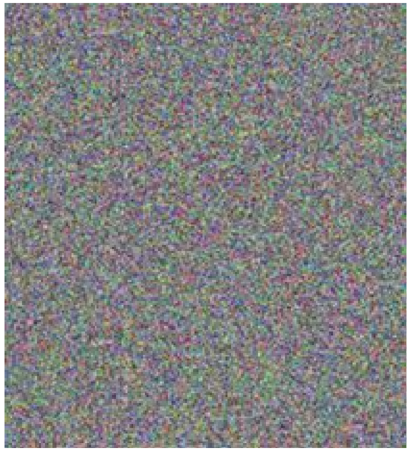


Image with AES using CBC

Image ref: http://en.wikipedia.org/wiki/Block_cipher_modes_of_operation

3-DES. The DES encryption algorithm uses a **64-bit block** and a 64-bit encryption key (of which only **56 bits** are actively used in the encryption process). Unfortunately DES has been around for a long time, and the 56-bit version is now easily crackable (in less than a day, on fairly modest equipment). An enhancement, and one which is still fairly compatible with DES, is the 3-DES algorithm. It has three phases, and splits the key into two. Overall the key size is typically **112 bits** (2x54 bits - with a combination of the three keys - of which two of the keys are typically the same). The algorithm is:

Encrypt$_{K3}$(Decrypt$_{K2}$(Encrypt$_{K1}$(message)))

http://buchananweb.co.uk/security07.aspx

where K1 and K3 are typically the same (to keep compatibility).

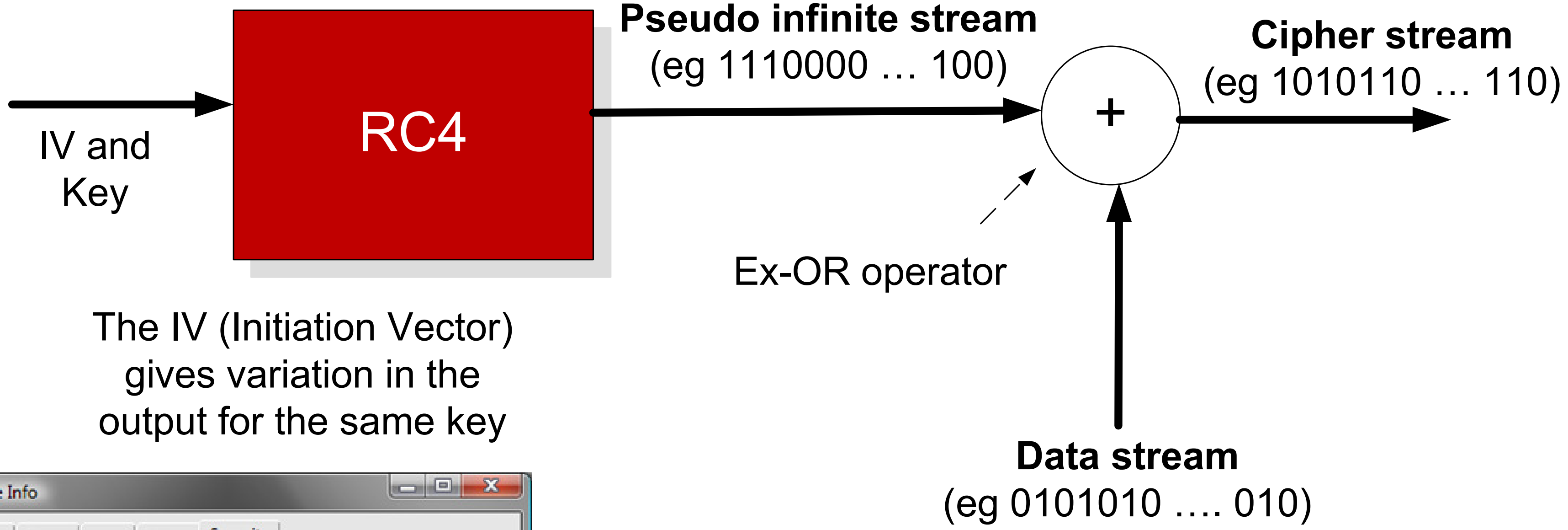
RC-2. RC2 ("Rivest Cipher") is seen as a replacement for DES. It was created by Ron Rivest in 1987, and is a **64-bit block code** and can have a key size from 40 bits to 128-bits (in increments of 8 bits). The 40-bit key version is seen as weak, as the encryption key is so small, but is favoured by governments for export purposes, as it can be easily cracked. In this case the key is created from a Key and an IV (Initialisation Vector). The key has 12 characters (96 bits), and the IV has 8 characters (64 bits), which go to make the overall key.

http://buchananweb.co.uk/security06.aspx

AES/Rijndael. AES (or Rijndael) is the new replacement for DES, and uses **128-bit blocks** with 128, 192 and 256 bit encryption keys. It was selected by NIST in 2001 (after a five year standardisation process). The name Rijndael comes from its Belgium creators: Joan Daemen and Vincent Rijmen.

http://buchananweb.co.uk/security15.aspx

RC4. This is a **stream** encryption algorithm, and is used in wireless communications (such as in WEP) and SSL (Secure Sockets).



IV and Key

RC4

Pseudo infinite stream
(eg 1110000 … 100)

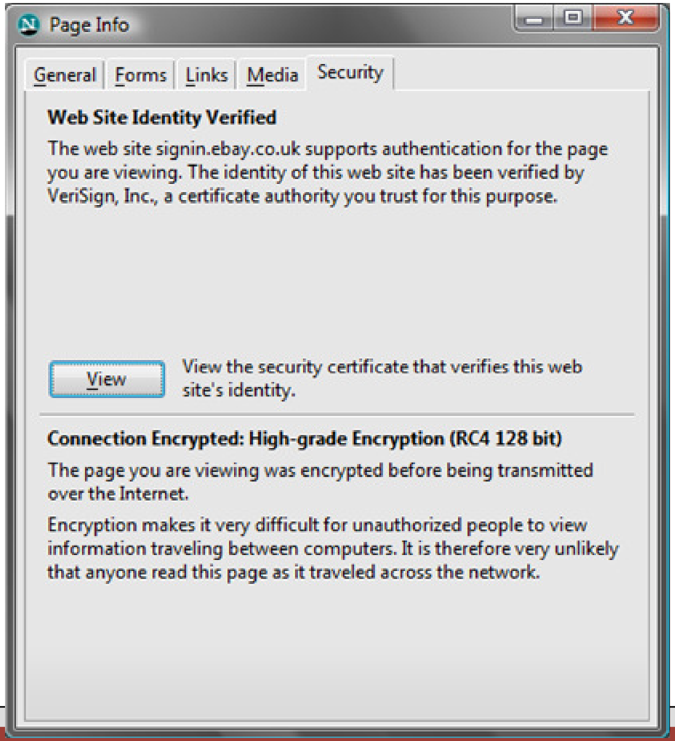
+

Cipher stream
(eg 1010110 … 110)

Ex-OR operator

Data stream
(eg 0101010 …. 010)

The IV (Initiation Vector) gives variation in the output for the same key



Web Site Identity Verified

The web site signin.ebay.co.uk supports authentication for the page you are viewing. The identity of this web site has been verified by VeriSign, Inc., a certificate authority you trust for this purpose.

View the security certificate that verifies this web site's identity.

Connection Encrypted: High-grade Encryption (RC4 128 bit)

The page you are viewing was encrypted before being transmitted over the Internet.

Encryption makes it very difficult for unauthorized people to view information traveling between computers. It is therefore very unlikely that anyone read this page as it traveled across the network.

Data stream	0101010 … 010	
Pseudo infinite stream	1110000 … 100	⊕
Cipher stream	1010110 … 110	

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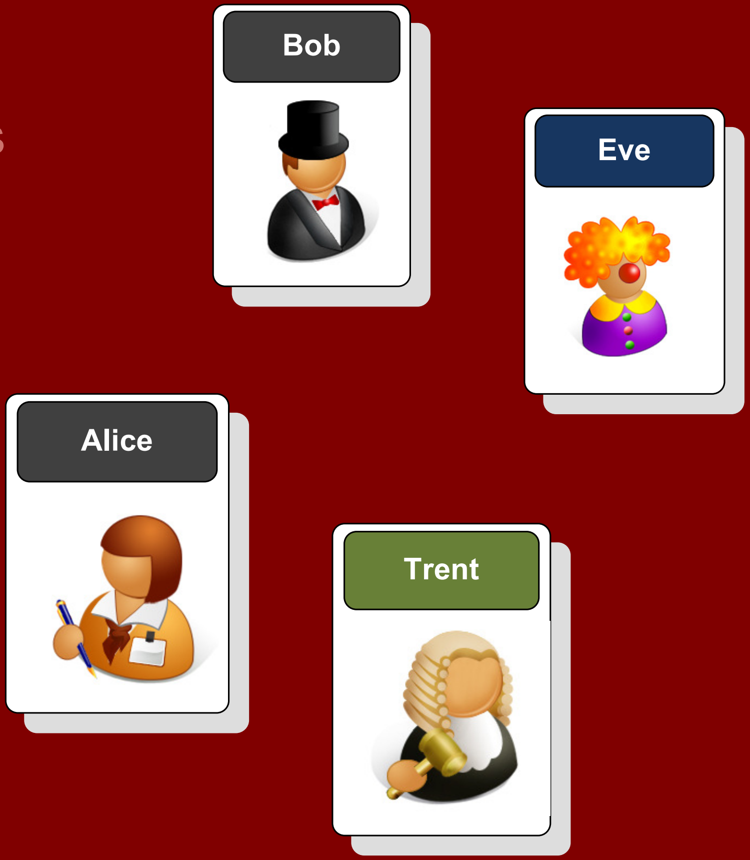

Encryption keys

Key entropy: Relates to the equivalent number of bits given the range of phases used.

For example: if there were eight pass phrases – this would be equivalent to a 3-bit key.

Standard English gives 1.3 bits per character. Thus an **8 character word** gives **10.4 bits** for the key entropy.

Key enthropy

- 256 phrases -> 8 bit equivalent key.
- 1024 phases -> 10 bit equivalent key.
- 1,048,576 phrases -> 20 equivalent key.

Key generator

Key generating method, such as a pass phrase

Generate key

Pass phrases might be: Napier, napier, napier1, napier11, napier123, and so on (the range of key will obviously be limited if the number of phrases are limited)

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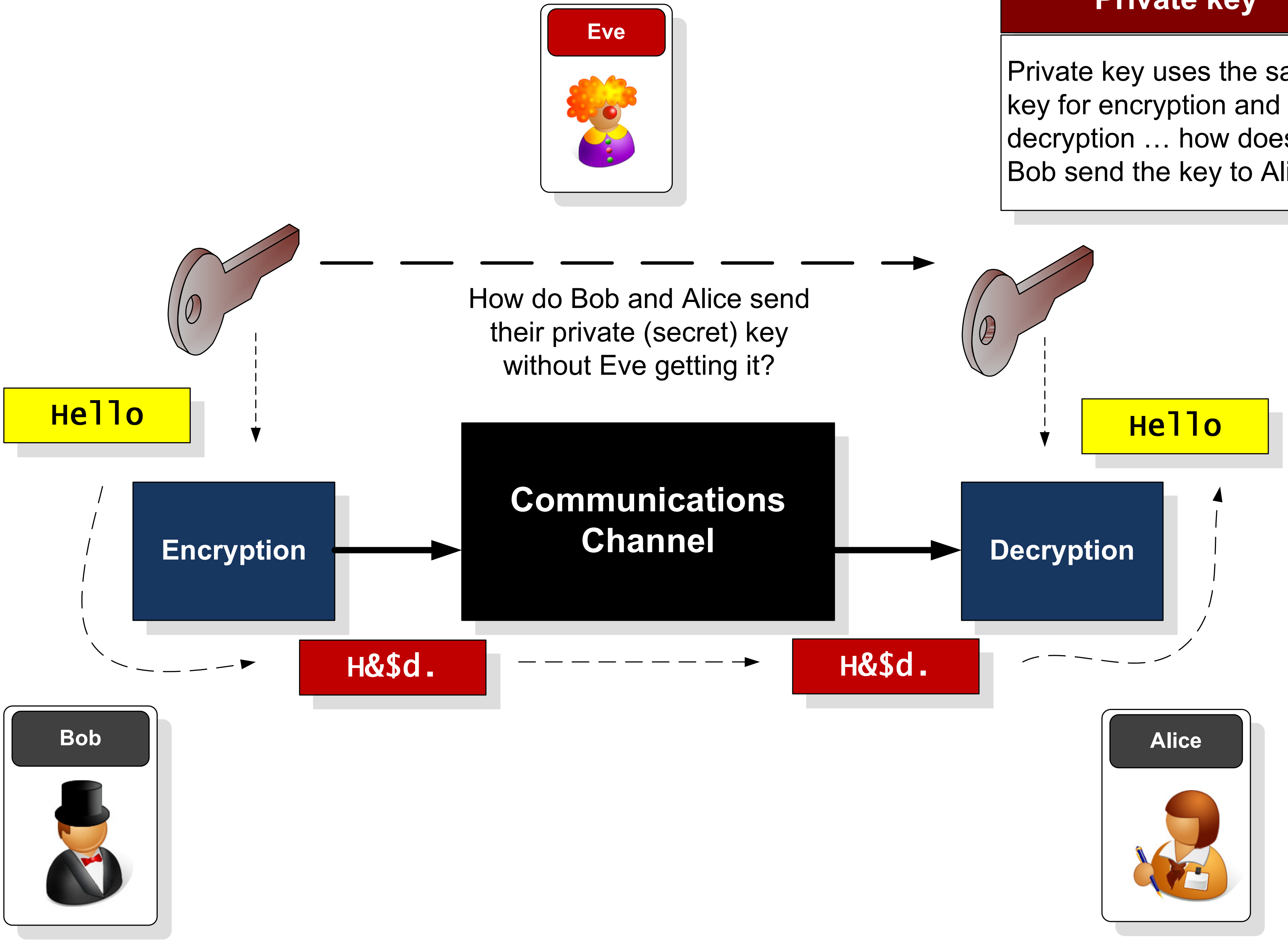
Passing keys

Private key

Private key uses the same key for encryption and decryption … how does Bob send the key to Alice?



How do Bob and Alice send their private (secret) key without Eve getting it?

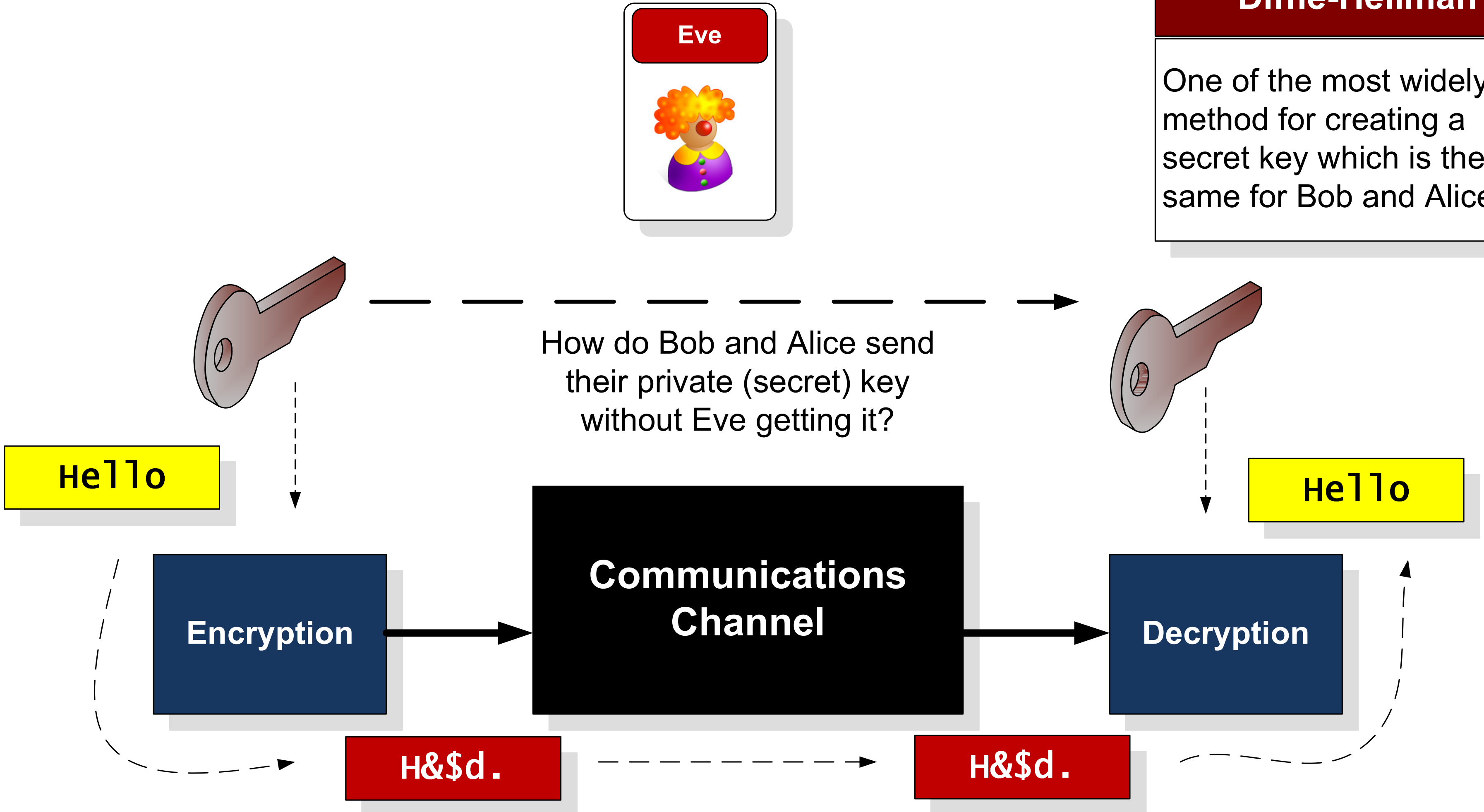
Passing keys

Encryption

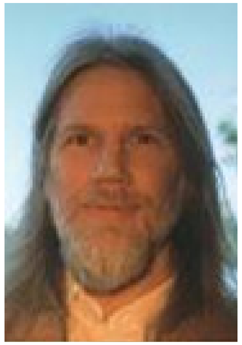
Author: Prof Bill Buchanan

Diffie-Hellman

One of the most widely method for creating a secret key which is the same for Bob and Alice



How do Bob and Alice send their private (secret) key without Eve getting it?

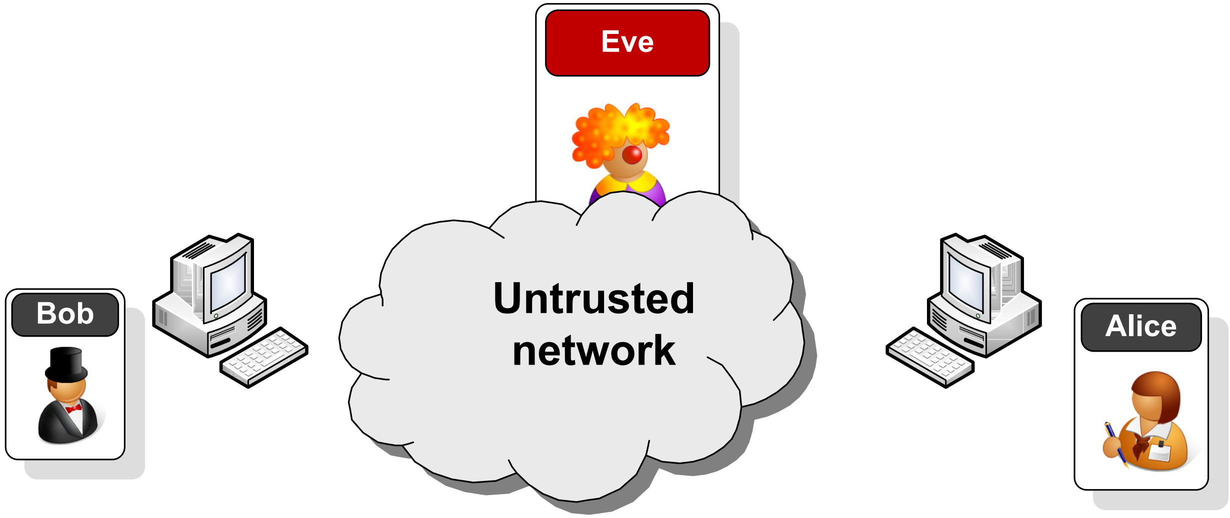


This problem was solved by Whitfield Diffie, who created the Diffie-Hellman algorithm, which is the most widely used method for passing secret keys

Author: Prof Bill Buchanan

Diffie-Hellman

Eve can listen to the values of A and B, but should not be able to determine the secret key



1. Both nodes agree on two values (G and *n*)

2. Generate a random value (*x*)

2. Generate a random value (y)

3. $A = G^x \bmod n$

3. $B = G^y \bmod n$

4. A and B values exchanged

5. $K1 = B^x \bmod n$

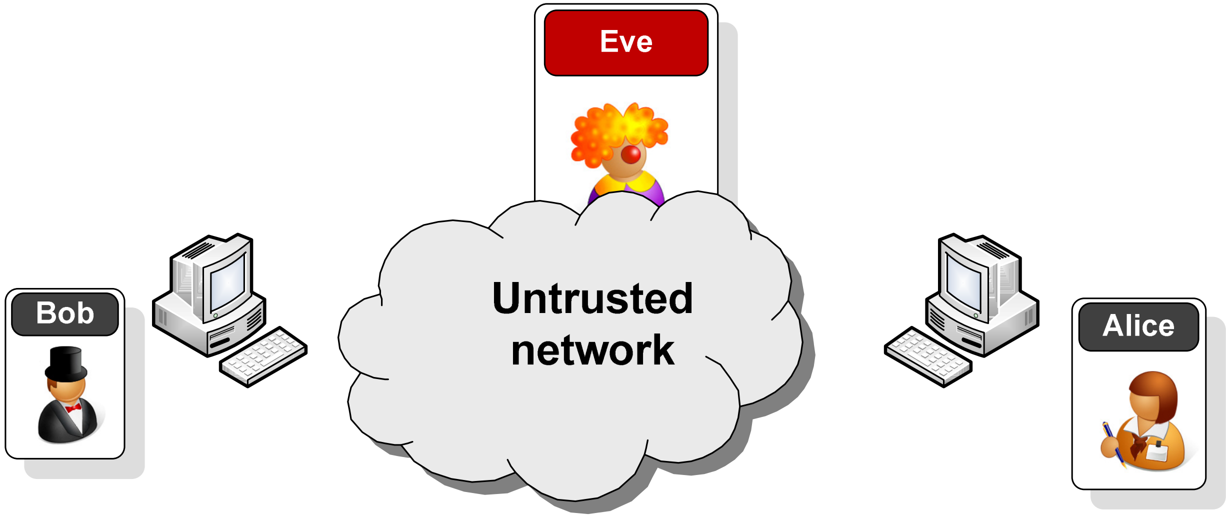
5. $K2 = A^y \bmod n$

K1 and *K2* should be the **same** and are the secret key

Author: Prof Bill Buchanan

Diffie-Hellman

Eve can listen to the values of A and B, but should not be able to determine the secret key



1. Both nodes agree on two values (5 and 4)

2. Generate a random value (3)

2. Generate a random value (4)

3. $A = 5^3 \bmod 4 = 5$

3. $B = 5^4 \bmod 4 = 1$

4. A and B values exchanged

5. $K1 = 1^5 \bmod 4 = 1$

5. $K2 = 5^4 \bmod 4 = 1$

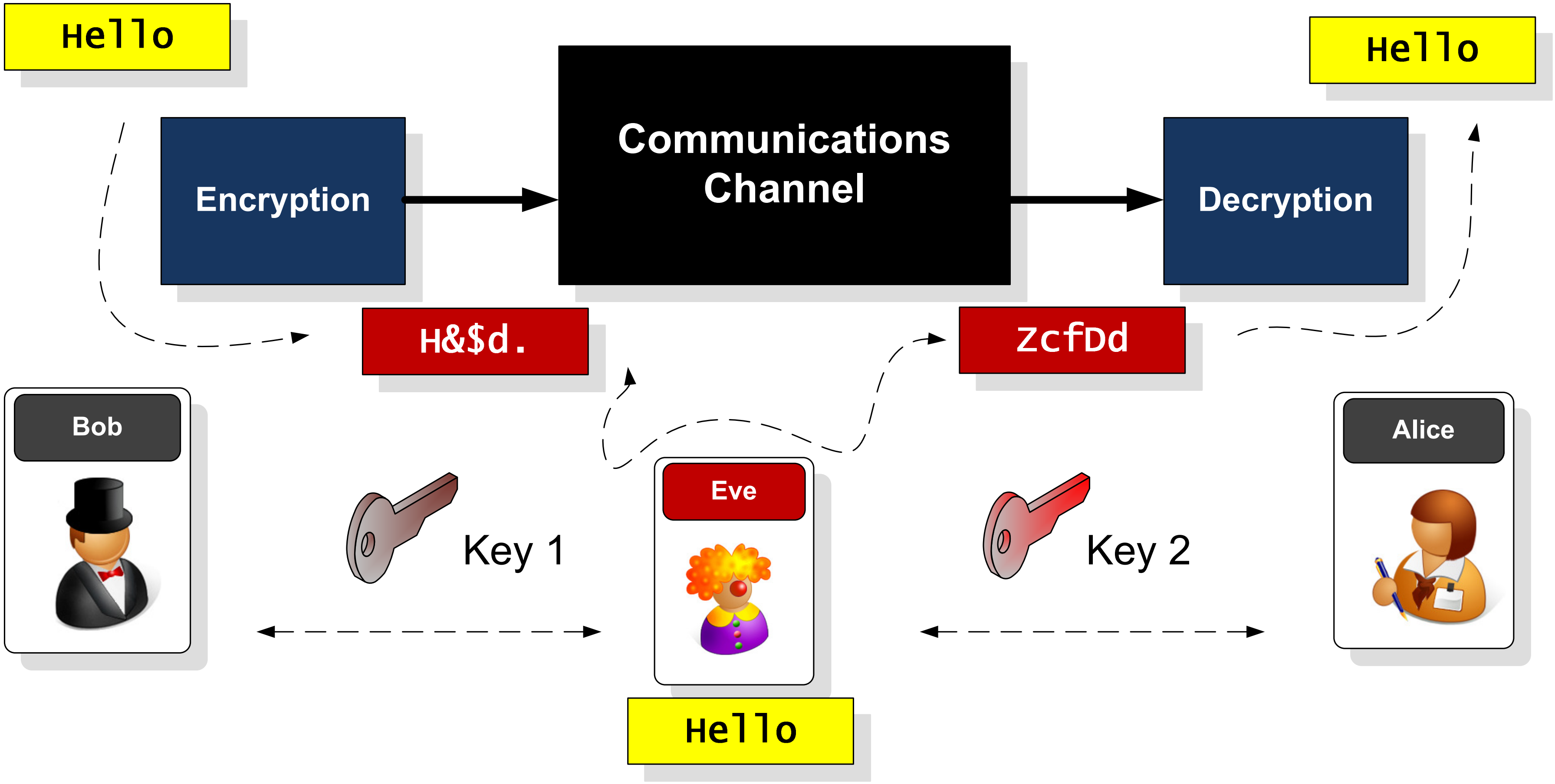
K1 and *K2* should be the **same** and are the secret key

Author: Prof Bill Buchanan

Man-in-the-middle

Diffie-Hellman suffers from Eve intercepting the key interchange, so that Bob thinks he’s talking to Alice for the key exchange.

Diffie-Hellman suffers from a man-in-the-middle attack, where Eve negotiates for each side, and creates two encryption channels



Hello

Encryption

Communications Channel

Decryption

Hello

H&$d.

ZcfDd

Bob

Key 1

Eve

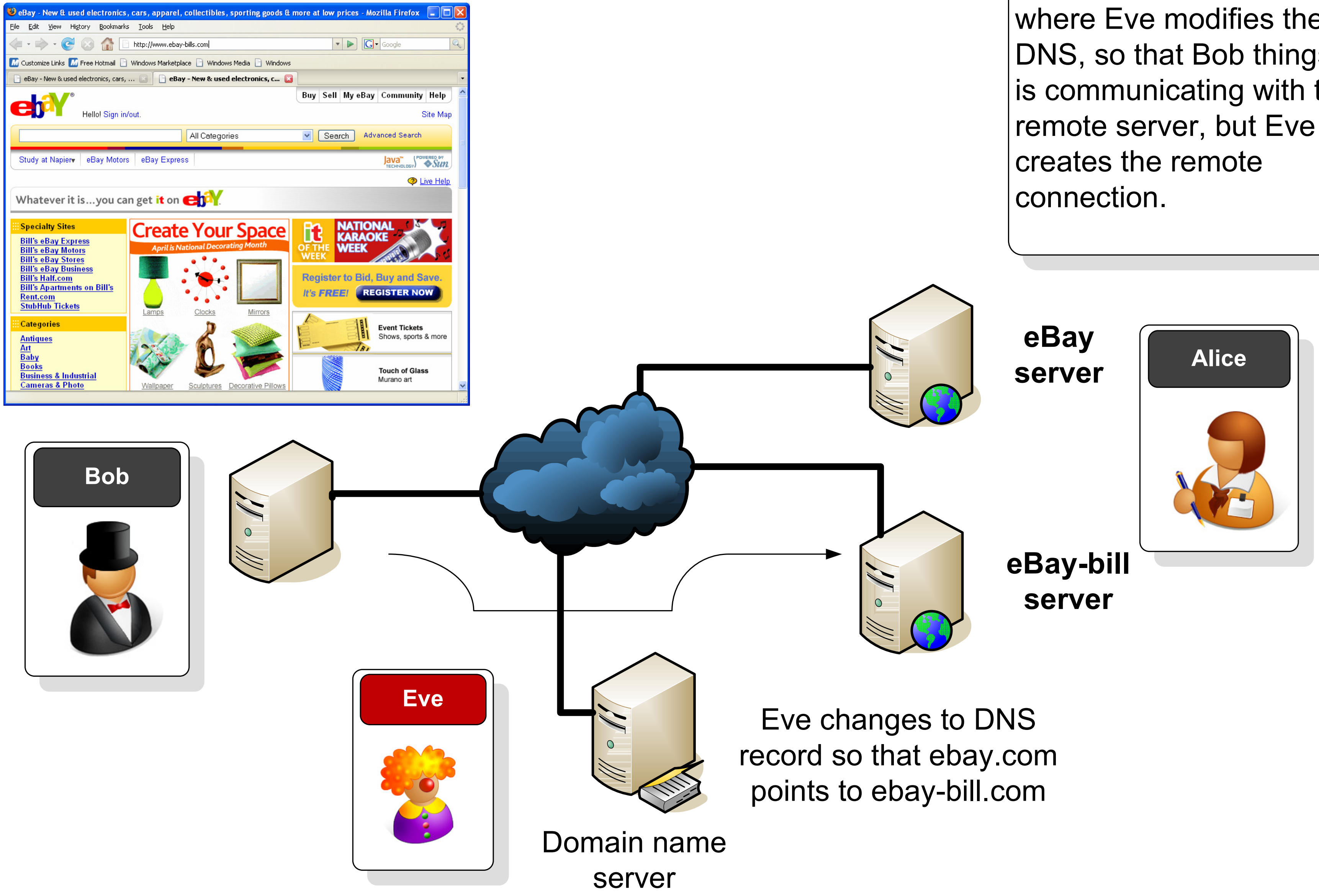
Key 2

Alice

Hello

DNS poisoning

A man-in-the-middle is where Eve modifies the DNS, so that Bob things he is communicating with the remote server, but Eve creates the remote connection.



eBay - New & used electronics, cars, apparel, collectibles, sporting goods & more at low prices - Mozilla Firefox

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- Bill's eBay Express
- Bill's eBay Motors
- Bill's eBay Stores
- Bill's eBay Business
- Bill's Half.com
- Bill's Apartments on Bill's Rent.com
- StubHub Tickets

Categories
- Antiques
- Art
- Baby
- Books
- Business & Industrial
- Cameras & Photo

Create Your Space

April is National Decorating Month

Lamps Clocks Mirrors

Wallpaper Sculptures Decorative Pillows

it OF THE WEEK NATIONAL KARAOKE WEEK

Register to Bid, Buy and Save.

It's FREE! REGISTER NOW

Event Tickets
Shows, sports & more

Touch of Glass
Murano art

Eve changes to DNS record so that ebay.com points to ebay-bill.com

Passing keys

Encryption

Author: Prof Bill Buchanan

Encryption

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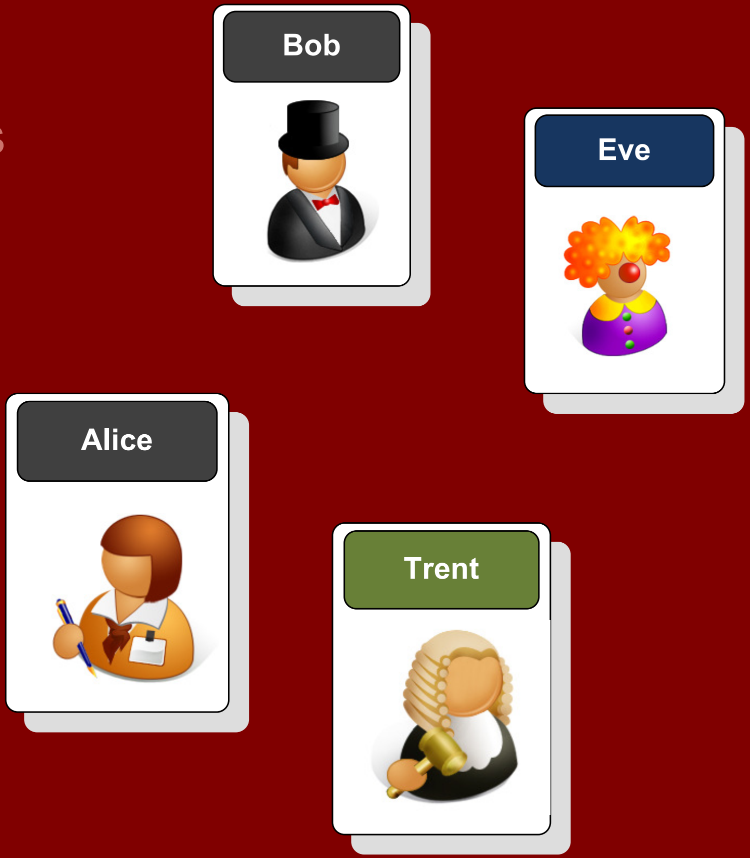
Block or stream
Private-key methods
Encryption keys
Passing keys
Public-key encryption
One-way hash
Encrypting disks
PGP encryption



Public-key encryption

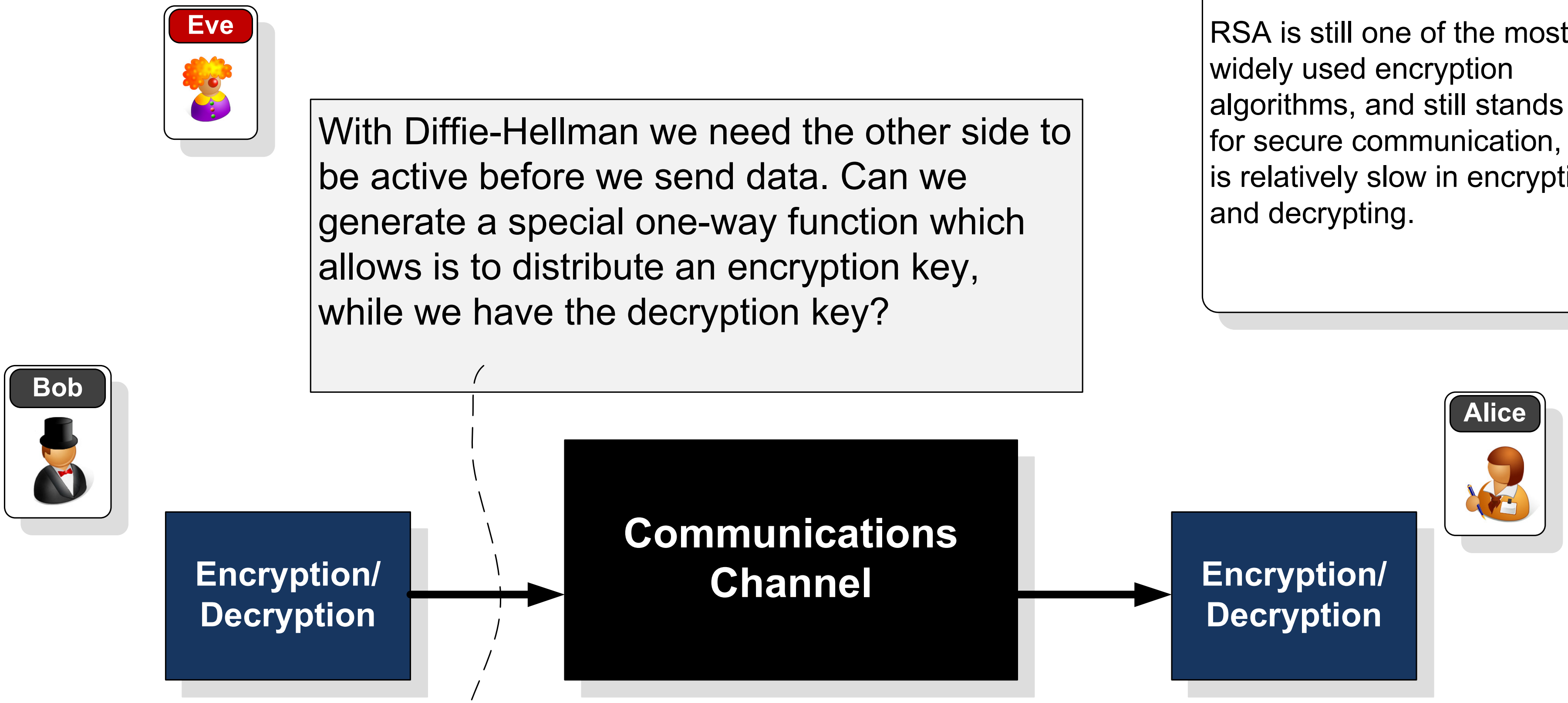
Author: Prof Bill Buchanan

Public-key encryption

Encryption

Public-key

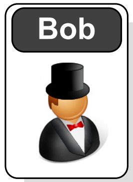
RSA is still one of the most widely used encryption algorithms, and still stands up for secure communication, but is relatively slow in encrypting and decrypting.



With Diffie-Hellman we need the other side to be active before we send data. Can we generate a special one-way function which allows is to distribute an encryption key, while we have the decryption key?

Solved in 1977, By Ron Rivest, Adi Shamir, and Len Aldeman created the RSA algorithm for public-key encryption.

Author: Prof Bill Buchanan



Select two prime numbers: **a** and **b**

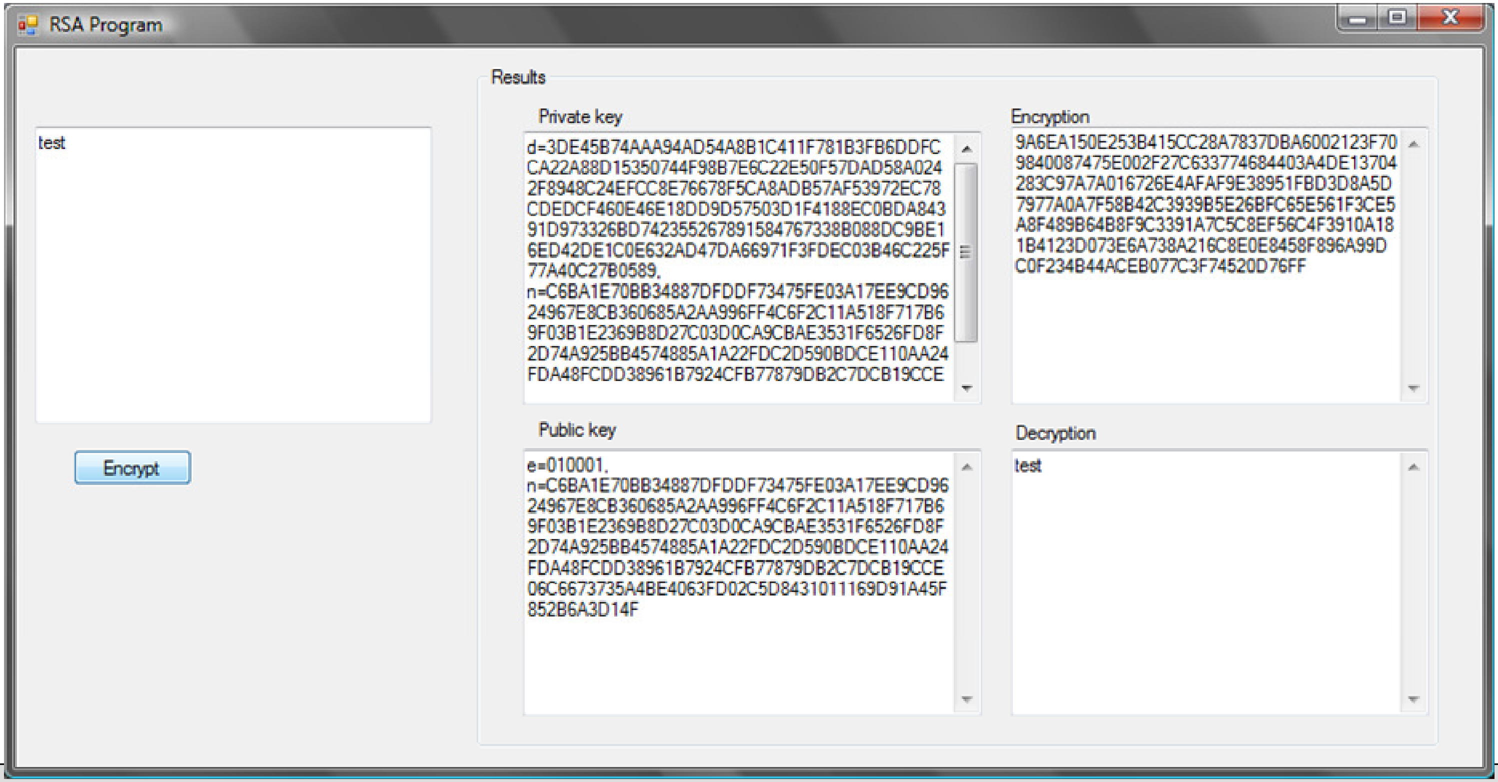
n = a x b

e is chosen so that **e** and **(a-1)x(b-1)** are relatively prime (no common factor greater than 1)

Public key is now: **<e,n>**

d = e-1 mod [(a-1)x(b-1)]

Private key is now: **<d,n>**



test

Private key

```
d=3DE45B74AAA94AD54A8B1C411F781B3FB6DDFC
CA22A88D15350744F98B7E6C22E50F57DAD58A024
2F8948C24EFCC8E76678F5CA8ADB57AF53972EC78
CDEDCF460E46E18DD9D57503D1F4188EC0BDA843
91D973326BD742355267891584767338B088DC9BE1
6ED42DE1C0E632AD47DA66971F3FDEC03B46C225F
77A40C27B0589,
n=C6BA1E70BB34887DFDDF73475FE03A17EE9CD96
24967E8CB360685A2AA996FF4C6F2C11A518F717B6
9F03B1E2369B8D27C03D0CA9CBAE3531F6526FD8F
2D74A925BB4574885A1A22FDC2D590BDCE110AA24
FDA48FCDD38961B7924CFB77879DB2C7DCB19CCE
```

Encryption

```
9A6EA150E253B415CC28A7837DBA6002123F70
9840087475E002F27C633774684403A4DE13704
283C97A7A016726E4AFAF9E38951FBD3D8A5D
7977A0A7F58B42C3939B5E26BFC65E561F3CE5
A8F489B64B8F9C3391A7C5C8EF56C4F3910A18
1B4123D073E6A738A216C8E0E8458F896A99D
C0F234B44ACEB077C3F74520D76FF
```

Public key

```
e=010001,
n=C6BA1E70BB34887DFDDF73475FE03A17EE9CD96
24967E8CB360685A2AA996FF4C6F2C11A518F717B6
9F03B1E2369B8D27C03D0CA9CBAE3531F6526FD8F
2D74A925BB4574885A1A22FDC2D590BDCE110AA24
FDA48FCDD38961B7924CFB77879DB2C7DCB19CCE
06C6673735A4BE4063FD02C5D8431011169D91A45F
852B6A3D14F
```

Decryption

test

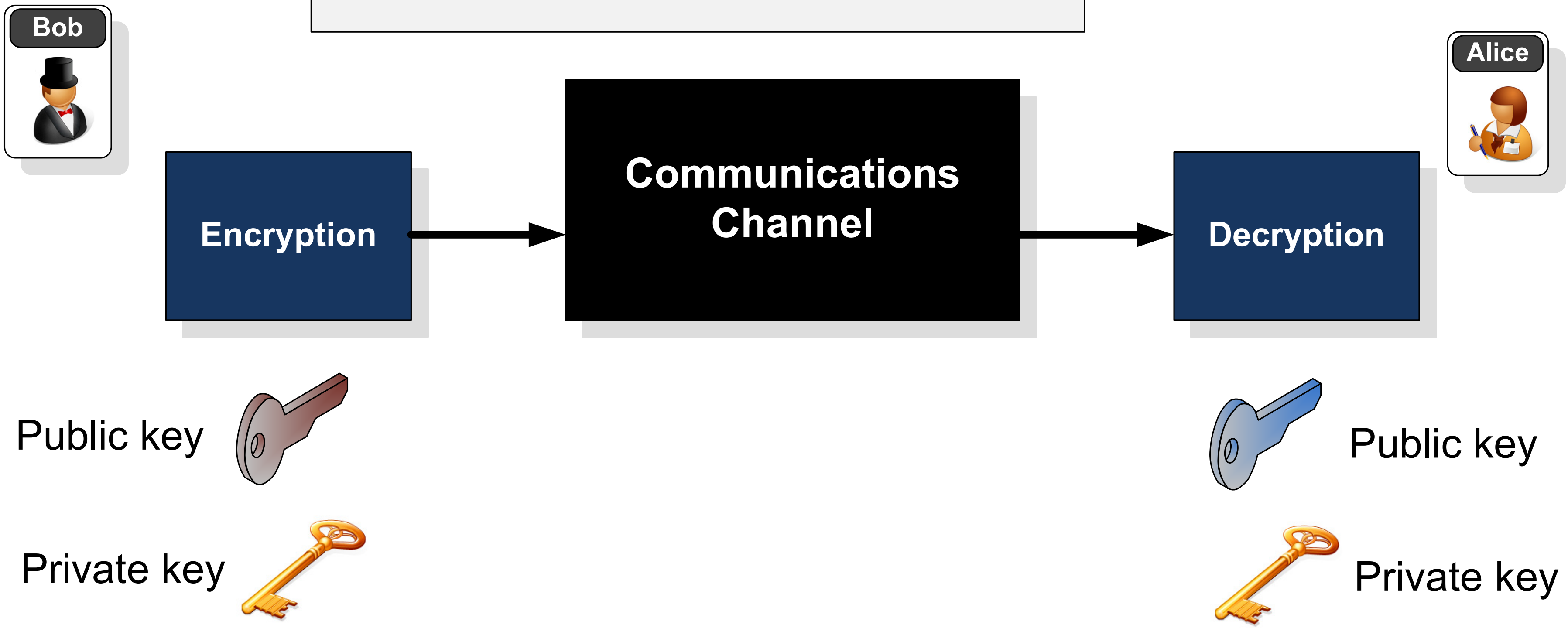
Author: Prof Bill Buchanan

Generating public and private keys

Public-key

Public key are keys which relate to extremely large prime numbers (as it is difficult to factorise large prime numbers). It is extremely difficult to determine a private key from a public key.

Public key generates two keys: A public key and a private one. These are special in that if one is applied to encrypt, the other can be used to decrypt



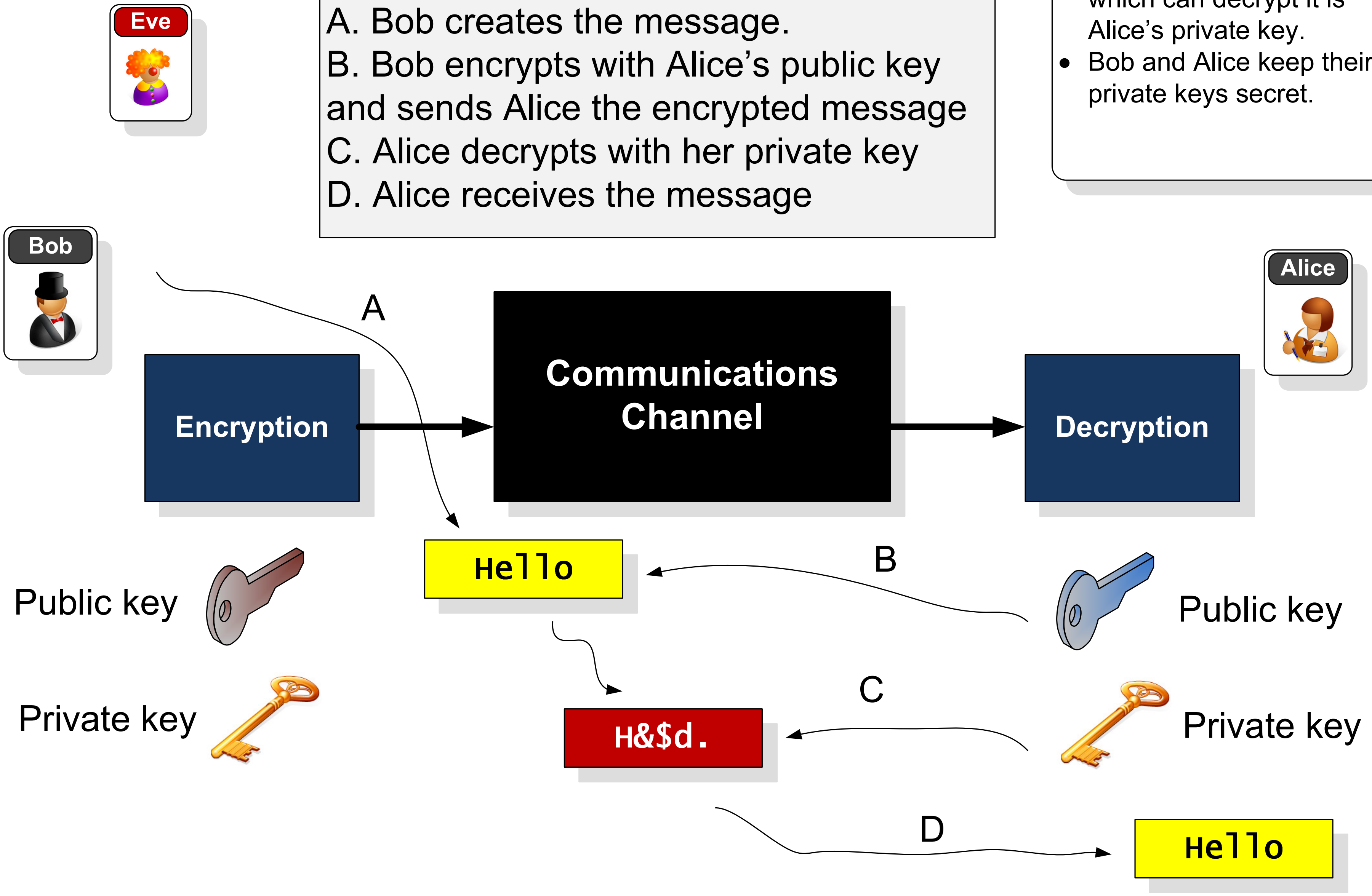
Public-key encryption

Encryption

Author: Prof Bill Buchanan

Public-key

- Once Bob encrypts the message, the only key which can decrypt it is Alice’s private key.
- Bob and Alice keep their private keys secret.



A. Bob creates the message.
B. Bob encrypts with Alice’s public key and sends Alice the encrypted message
C. Alice decrypts with her private key
D. Alice receives the message

Author: Prof Bill Buchanan

Encryption

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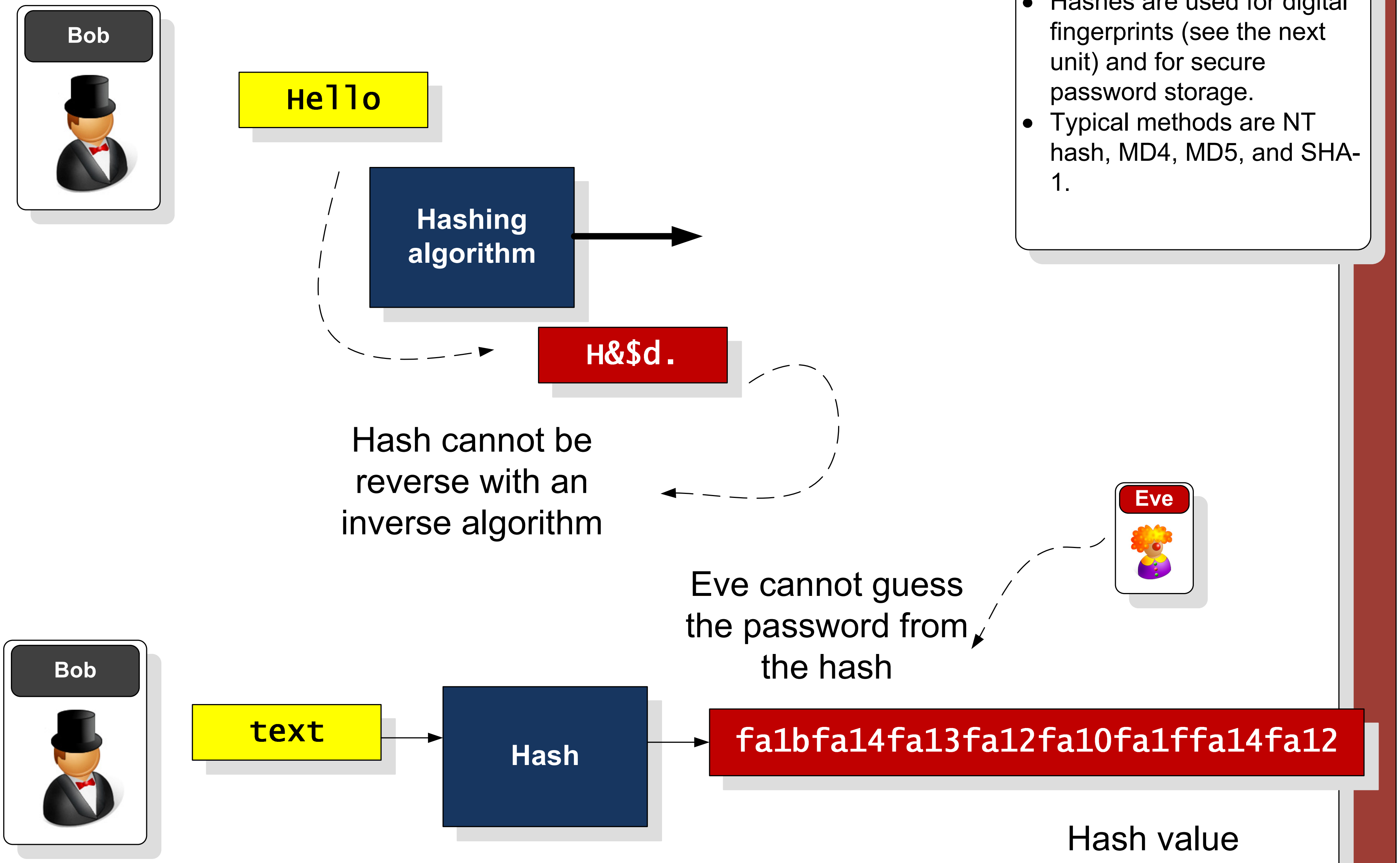
- Encrypting disks
- PGP encryption

One-way hash

One-way hash

- Hashes are used for digital fingerprints (see the next unit) and for secure password storage.
- Typical methods are NT hash, MD4, MD5, and SHA-1.



Hash cannot be reverse with an inverse algorithm

Eve cannot guess the password from the hash

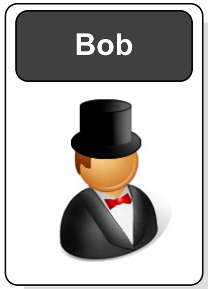
Hash value

Author: Prof Bill Buchanan

One-way hash

- Hashes are used for digital fingerprints (see the next unit) and for secure password storage.
- Typical methods are NT hash, MD4, MD5, and SHA-1.

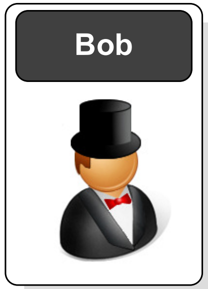
Windows login/ authentication



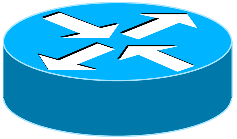
`mypass` → **NT hash (MD4)** → `fa1bfa14fa13fa12fa10fa1ffa14fa12`

NT-password hash for Windows NT, XP and Vista

Cisco password storage (MD5)



`mypass` →



```
# config t
(config)# enable secret test

Current configuration : 542 bytes
!
version 12.1
no service single-slot-reload-enable
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname Router
!
enable secret 5 $1$/Nwk$knsEQYxZVenGjWOGj/TGk0
```

MD5 encoded password →

One-way hash

Encryption

Windows login/ authentication

One-way hash

- Hashing suffers from dictionary attacks, thus it is important that any passwords are not standard words, such as to change **password** for **pA55wOrd**.

Bob

`mypass` → NT hash (MD4) → `fa1bfa14fa13fa12fa10fa1ffa14fa12`

NT-password hash for Windows NT, XP and Vista

Hashing suffers from **dictionary attacks** where the signatures of well know words are stored in a table, and the intruders does a lookup on this

mypast	effahd13fa12fa10fgffa1ffa14fa144
mypass	fa1bfa14fa13fa12fa10fa1ffa14fa12
mypose	ff1218904321095 4defff0123444512d

test1	aabbfce023215546dfeddd0101001cd

One-way hash

Encryption

A major factor with hash signatures is:

- **Collision.** This is where another match is found, no matter the similarity of the original message. This can be defined as a **Collision attack**.
- **Similar context**. This is where part of the message has some significance to the original, and generates the same hash signature. The can be defined as a Pre-image attack.
- **Full context**. This is where an alternative message is created with the same hash signature, and has a direct relation to the original message. This is an extension to a Pre-image attack.

In 2006 it was shown that MD5 can produce collision within less than a minute.

A 50% probability of a collision is:

$$\sqrt{N(signatures)} = \sqrt{2^n} = 2^{\frac{n}{2}}$$

where n is the number of bits in the signature. For example, for MD5 (128-bit) the number of operations that would be required for a better-than-50% chance of a collision is:

$$2^{64}$$

Note, in 2006, for SHA-1 the best time has been 18 hours

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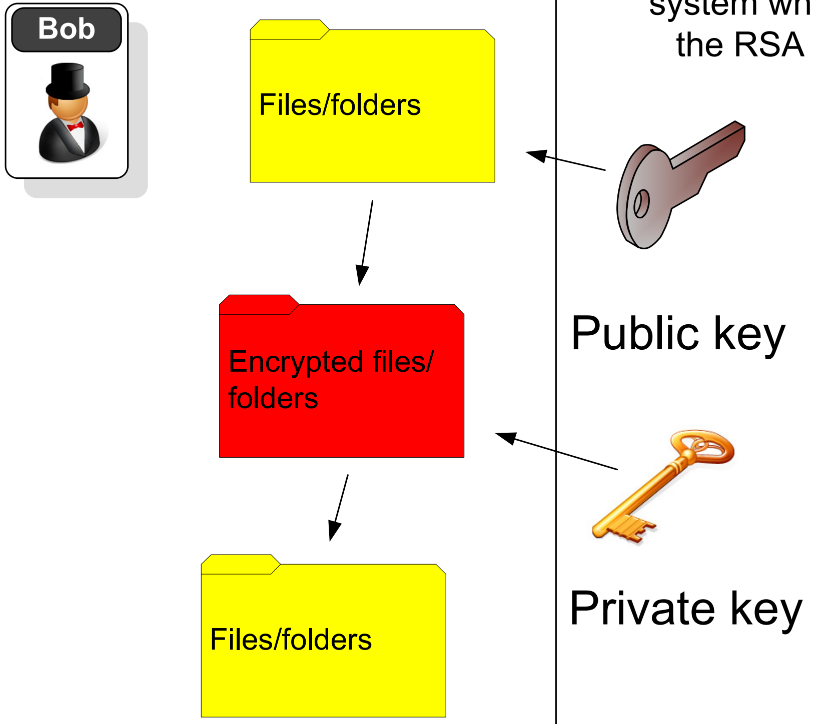
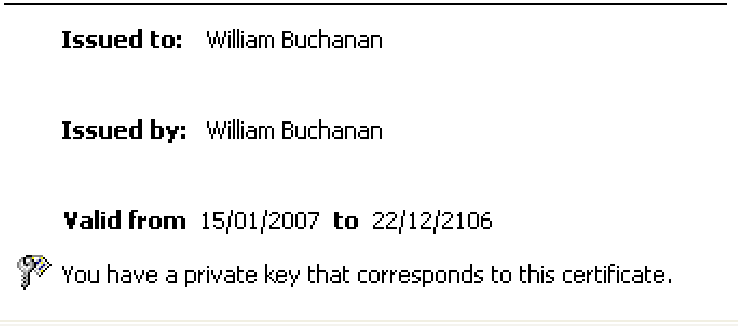
Encrypting disks

EFS

- The digital certificate contains both keys.
- If this certificate is deleted/ lost, the content cannot be decrypted.

A digital certificate is created on the system which has the RSA keys.



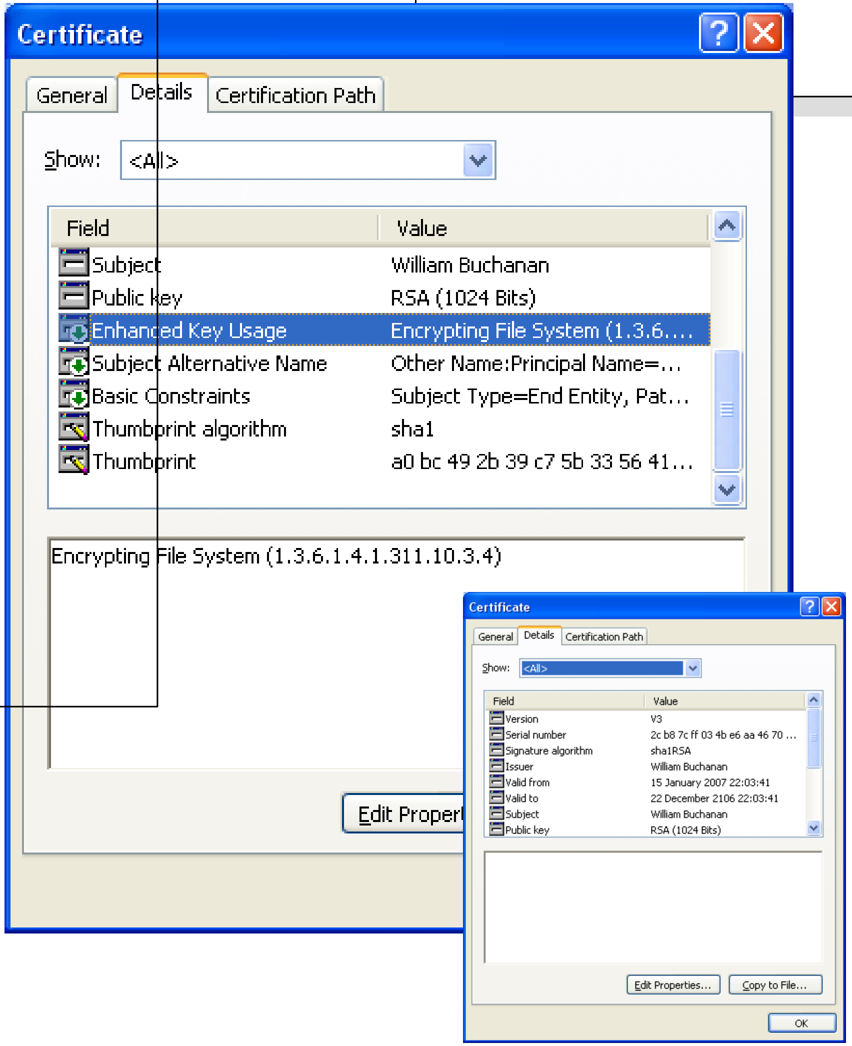


Issued to: William Buchanan

Issued by: William Buchanan

Valid from 15/01/2007 **to** 22/12/2106

You have a private key that corresponds to this certificate.



Field	Value
Subject	William Buchanan
Public key	RSA (1024 Bits)
Enhanced Key Usage	Encrypting File System (1.3.6....
Subject Alternative Name	Other Name:Principal Name=...
Basic Constraints	Subject Type=End Entity, Pat...
Thumbprint algorithm	sha1
Thumbprint	a0 bc 49 2b 39 c7 5b 33 56 41...

Encrypting File System (1.3.6.1.4.1.311.10.3.4)

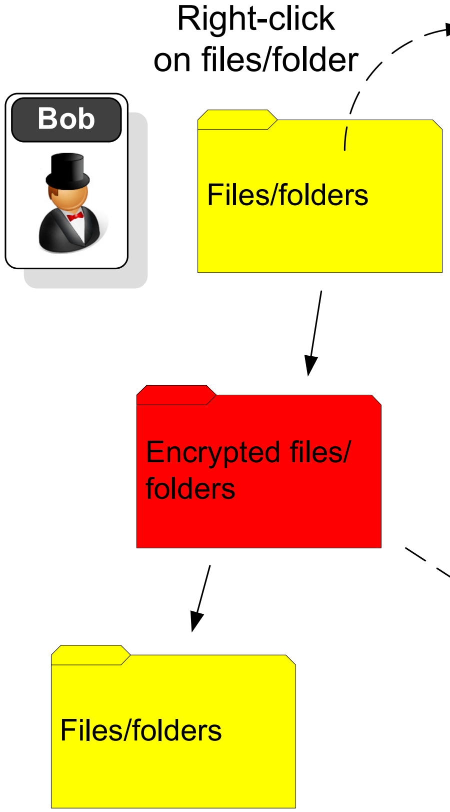
Field	Value
Version	V3
Serial number	2c b8 7c ff 03 4b e6 aa 46 70 ...
Signature algorithm	sha1RSA
Issuer	William Buchanan
Valid from	15 January 2007 22:03:41
Valid to	22 December 2106 22:03:41
Subject	William Buchanan
Public key	RSA (1024 Bits)

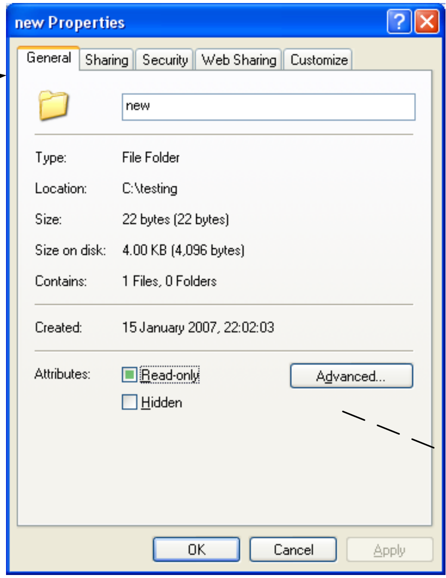
EFS

tificate
keys.
te is deleted/
nt cannot be

Public-key encryption

Encryption





new

Type: File Folder

Location: C:\testing

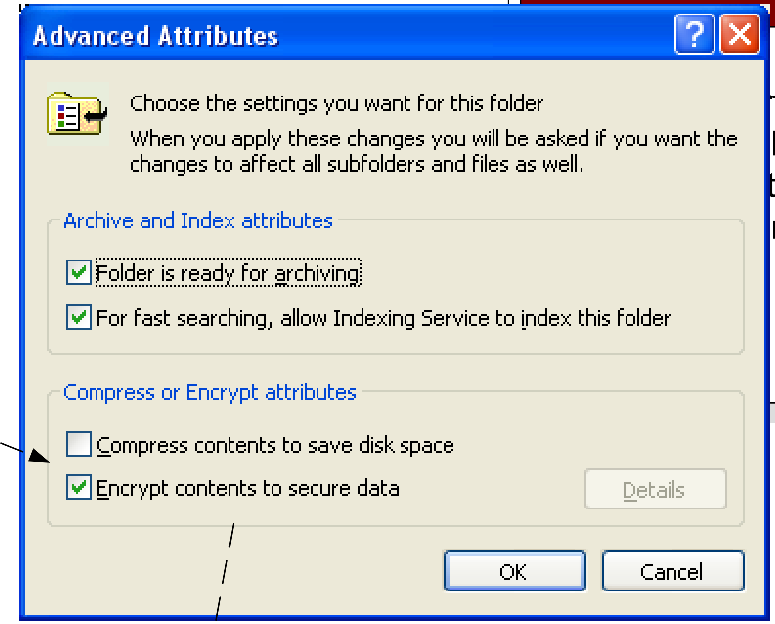
Size: 22 bytes (22 bytes)

Size on disk: 4.00 KB (4,096 bytes)

Contains: 1 Files, 0 Folders

Created: 15 January 2007, 22:02:03

Attributes: ☐ Read-only ☐ Hidden



Choose the settings you want for this folder

When you apply these changes you will be asked if you want the changes to affect all subfolders and files as well.

Archive and Index attributes

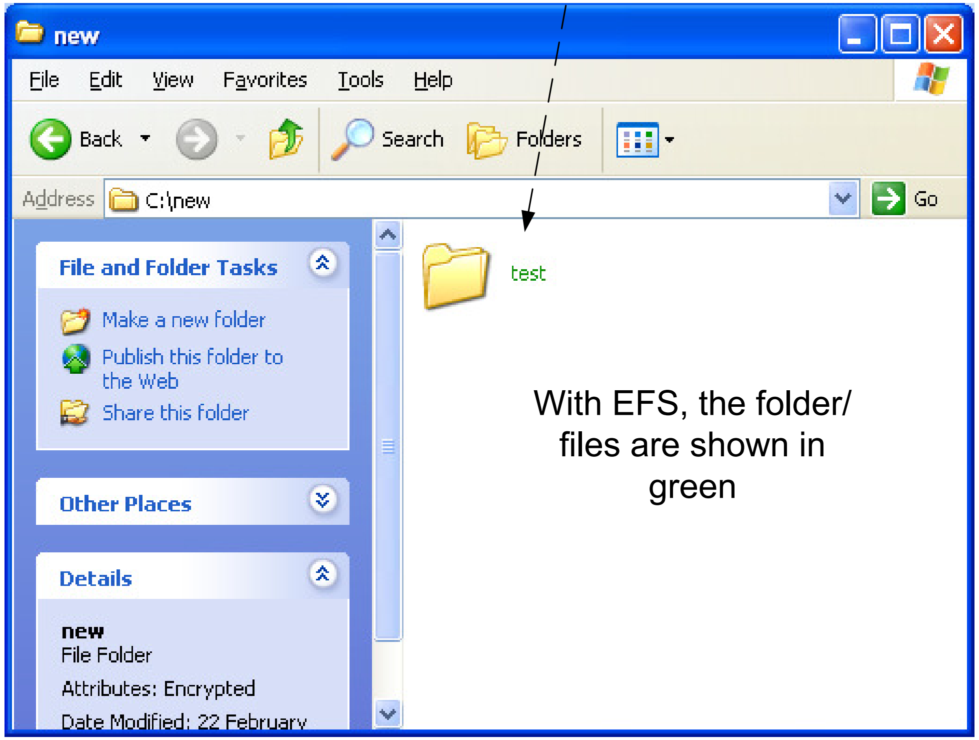
☑ Folder is ready for archiving

☑ For fast searching, allow Indexing Service to index this folder

Compress or Encrypt attributes

☐ Compress contents to save disk space

☑ Encrypt contents to secure data



Address: C:\new

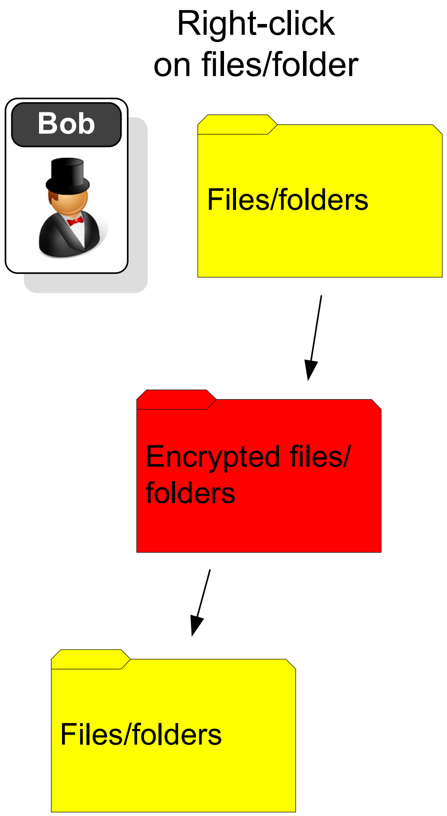
new
File Folder
Attributes: Encrypted
Date Modified: 22 February

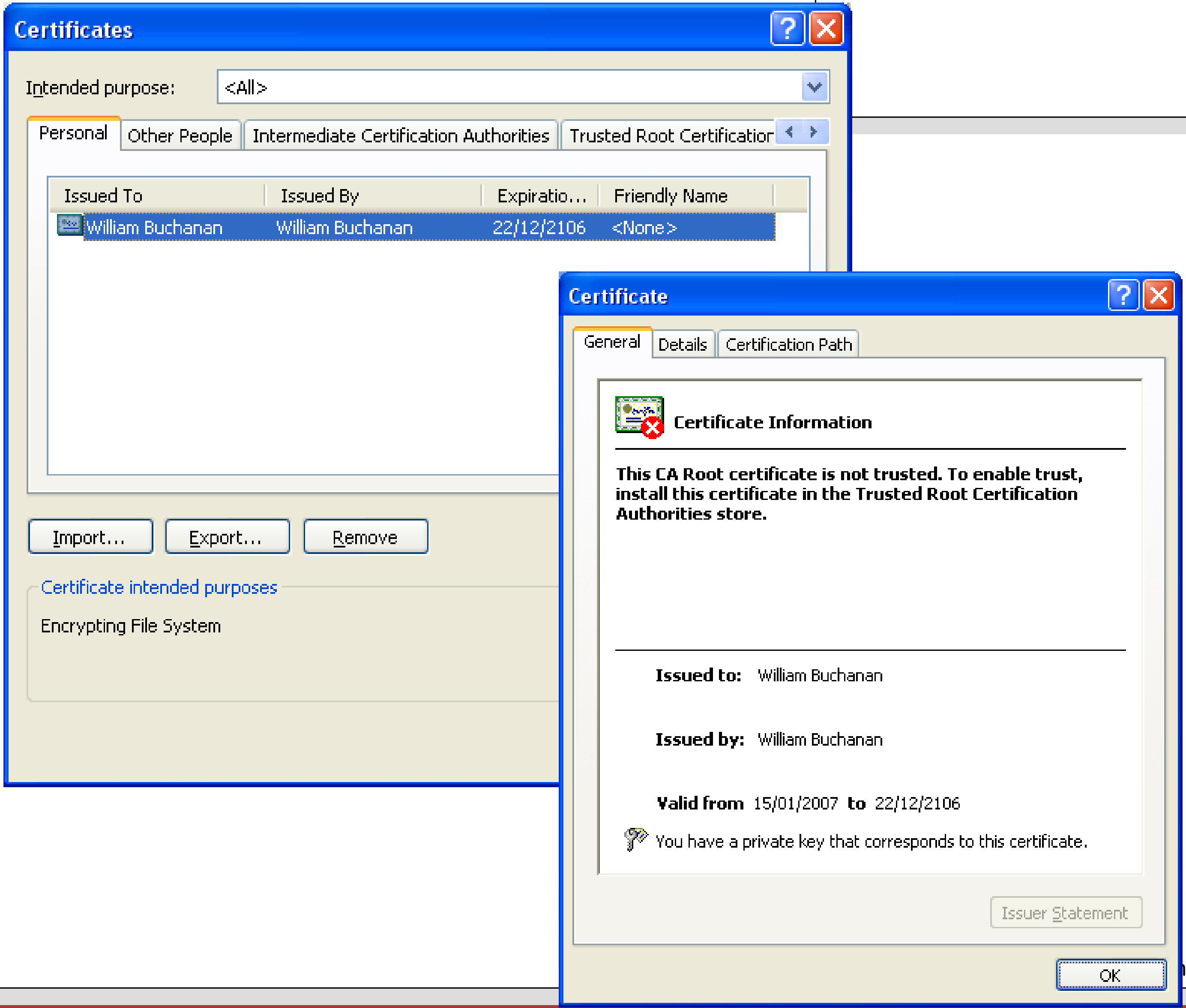
With EFS, the folder/ files are shown in green

Author: Prof Bill Buchanan

EFS

- EFS digital certificate is stored on the system in the Certificates store (to be covered in the next lecture).





Intended purpose: <All>

Issued To	Issued By	Expiratio...	Friendly Name
William Buchanan	William Buchanan	22/12/2106	<None>

Certificate intended purposes

Encrypting File System

Certificate Information

This CA Root certificate is not trusted. To enable trust, install this certificate in the Trusted Root Certification Authorities store.

Issued to: William Buchanan

Issued by: William Buchanan

Valid from 15/01/2007 **to** 22/12/2106

You have a private key that corresponds to this certificate.

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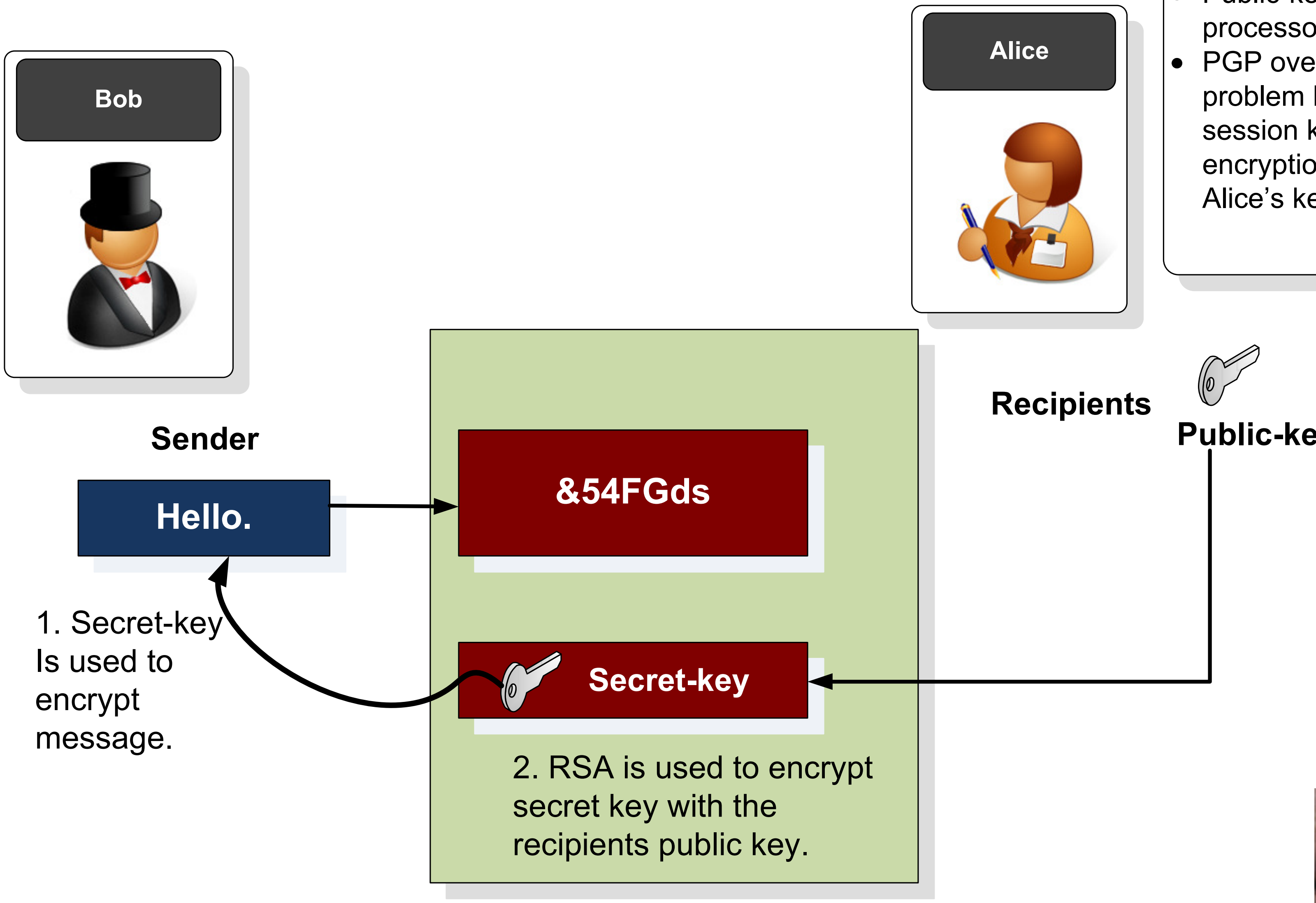
PGP encrypting

Encryption

PGP encryption

PGP

- Public-key is fairly processor intensive.
- PGP overcomes this problem by creating a session key for the encryption, and using Alice’s key to encrypt it.



Bob

Alice

Sender

Recipients

Public-key

Hello.

&54FGds

Secret-key

1. Secret-key Is used to encrypt message.

2. RSA is used to encrypt secret key with the recipients public key.

Author: Prof Bill Buchanan

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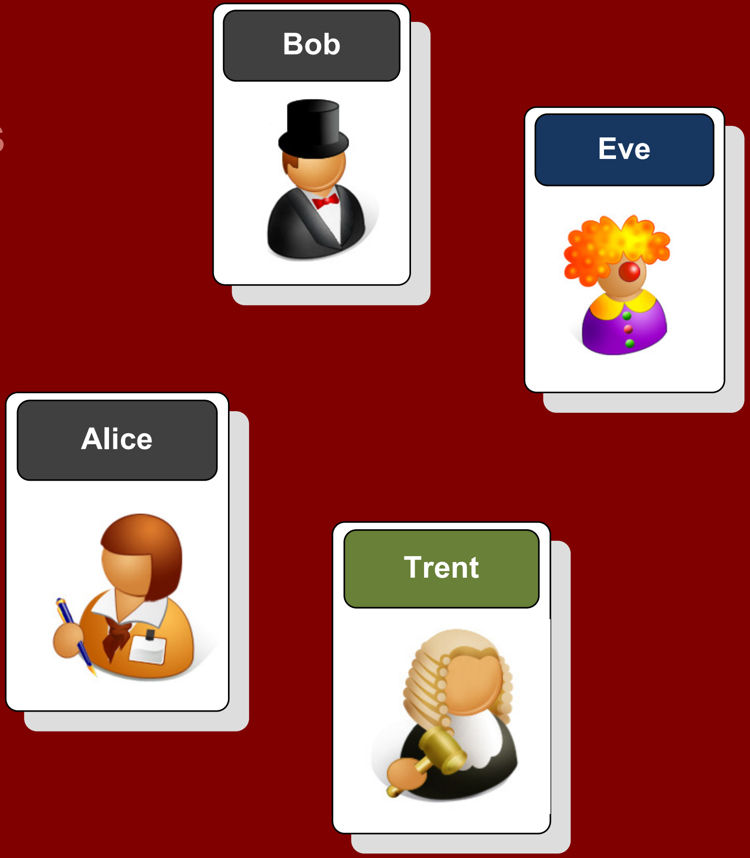
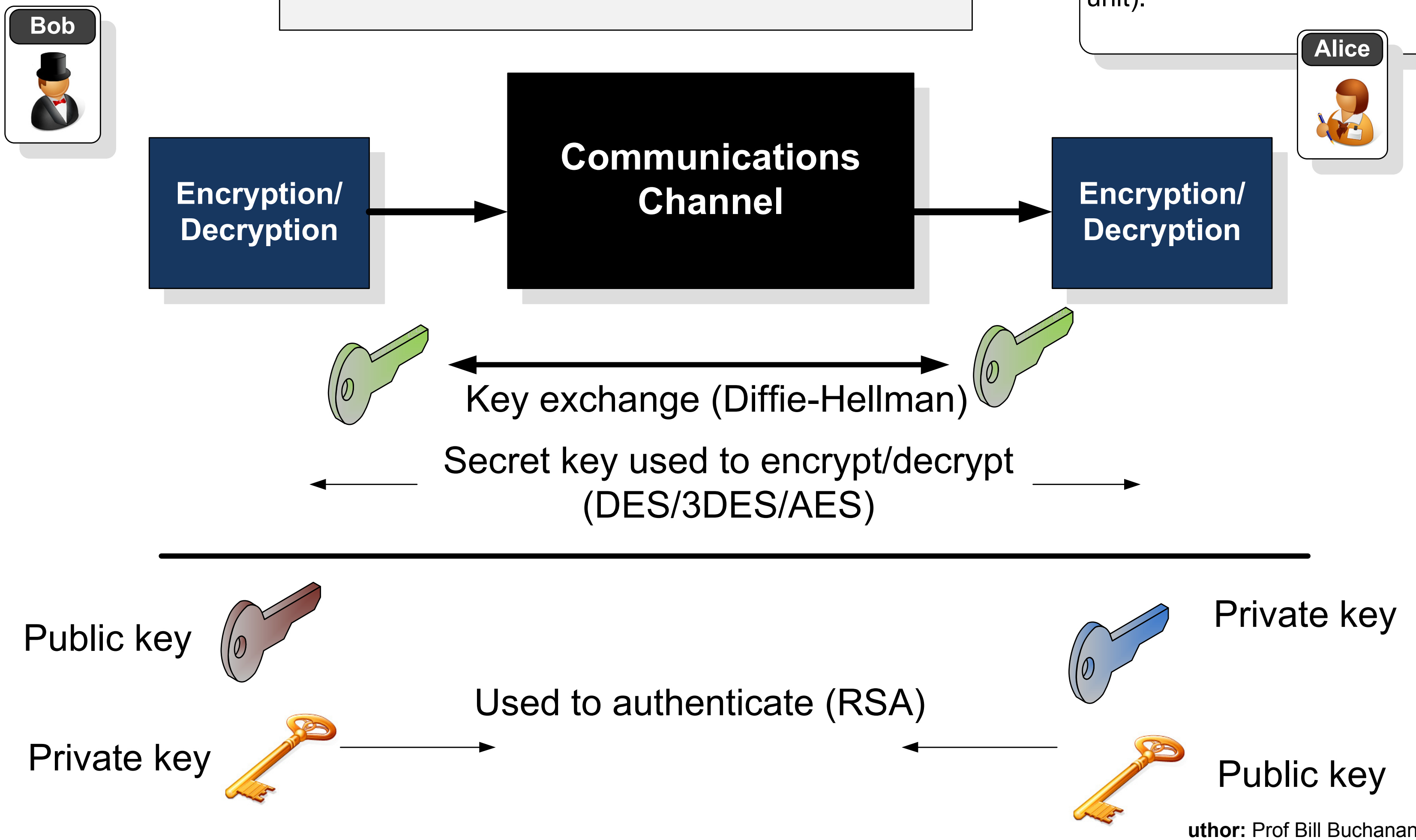


Conclusions

Typical application:
Diffie-Hellman used to generate private-key.
Public-key used for authentication.
Private-key used for encryption.

Typical application

For fast encryption/decryption, public key cannot be used. Thus, typically Diffie-Hellman is used in most application, with private key encryption. Public key is used for authentication (see the next unit).



Encryption/ Decryption

Communications Channel

Encryption/ Decryption

Key exchange (Diffie-Hellman)

Secret key used to encrypt/decrypt (DES/3DES/AES)

Public key

Private key

Used to authenticate (RSA)

Private key

Public key