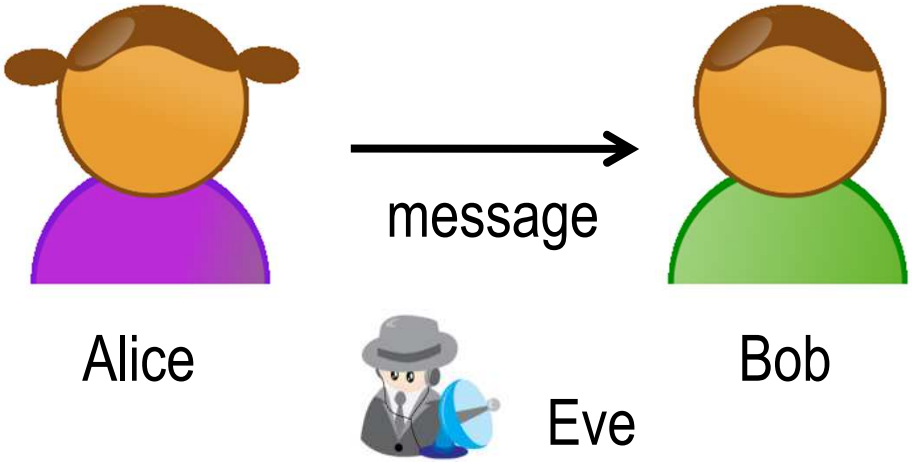
# Classical Cryptosystems

Cryptography and Protocols

Andrei Bulatov

# Notation




Plaintext
Ciphertext
Key

Protocol: (K, E, D)

- K – key generation algorithm
- E – encryption algorithm
- D – decryption algorithm

# Three Types of Cryptosystems

- Steganography

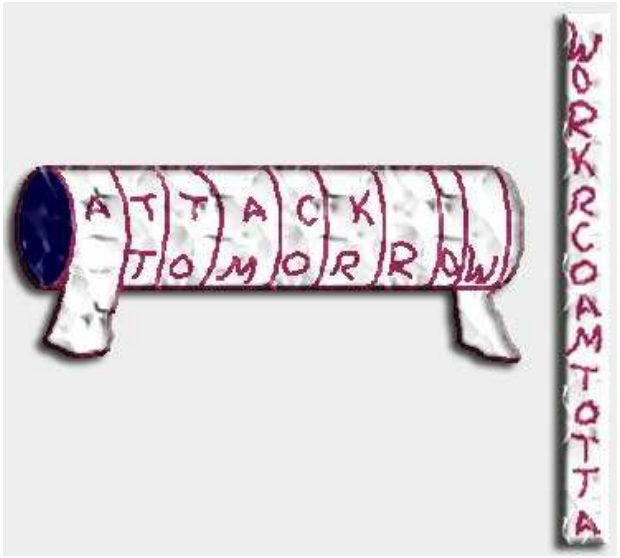
  `Security by obscurity'

- Transposition cryptosystems:

  E permutes (transposes) the letters of plaintext

  D applies the converse transposition

Example: Spartans Scytale



# Three Types of Cryptosystems (cntd)

- Substitution cryptosystems

  E substitutes each letter of the plaintext with another letter or symbol

  D applies the converse substitution

Example: Caesar cipher

He made messages secret by shifting each letter three letters forward.

Thus we can replace letters by integers from 0 to 25.

Then E adds 3 modulo 25 to every letter.

To decrypt a message, D subtracts 3 from each letter

# Caesar Cipher

- Encrypt `SEND MORE MEN AND AMUNITION'

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |

S E N D M O R E M E N A N D A M U N I T I O N

18 4 13 3 12 14 17 4 12 4 13 0 13 3 0 12 20 13 8 19 8 14 13

21 7 16 6 15 17 20 7 15 7 16 3 16 6 3 15 23 16 11 22 11 17 16

V H Q G P R U H P H Q D Q G D P X Q L W L R Q

# Drawbacks of Classical Cryptosystems

- Too few keys

  If the type of the cryptosystem is known it can be bruteforced

- Kerchoff's Principle:

  System should be secure even if algorithms are known,
  as long as key is secret

- Problem: How to increase the number of keys?

# Transposition: Railfence and Redefence Ciphers

- Railfence cipher:

  `SEND MORE MEN AND AMUNITION'

| S | | | | **M** | | | | **M** | | | | **N** | | | | **U** | | | | **I** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E | | D | | O | | E | | E | | A | | D | | M | | N | | T | | O | |
| | | N | | | | R | | | | N | | | | A | | | | I | | | | N |

  `SMMNUIEDOEEADMNTONRNAIN'

- Redefence Cipher

| 2 | S | | | | **M** | | | | **M** | | | | **N** | | | | **U** | | | | **I** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | E | | D | | O | | E | | E | | A | | D | | M | | N | | T | | O | |
| 3 | | | N | | | | R | | | | N | | | | A | | | | I | | | | N |

  `EDOEEADMNTOSMMNUINRNAIN'

# Substitution: Linear Cipher

- Similar to Caesar cipher, but instead of adding 3, computes a linear function on letters. Say,

$$E: \quad X \rightarrow 4X + 21 \pmod{26}$$

# Substitution: Playfair

- Keysquare:

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

- Encryption

`SEND MORE MEN AND AMUNITION'

SE ND MO RE ME NA ND AM UN IT IO NA

QF PC TA GK HF SL PC MF NP TH TL SL

`QFPCTAGKHFSLPCMFNPTHTLSL'

# Substitution: Checkerboard

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

Plaintext: THIS IS A BETTER CIPHER

Ciphertext: LH AE LI CE LI CE LE AW EW LH LH BW BT BI LI LW AE BW BT

# Drawbacks of Classical Cryptosystems

- Frequencies analysis

  Different letters have different probabilities to appear in a text

- Example

Ciphertext:
VXEVWLWXWLRQ
FLSKHUV FDQ
RIWHQ EH EURNHQ
EB IUHTXHQFLHV
DQDOBVLV

Frequencies (in %%):

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| A | 0 | 6.9 | J | 0 | 0.8 | S | 2 | 6.8 |
| B | 4 | 0.9 | K | 2 | 0.9 | T | 2 | 9 |
| C | 0 | 4 | L | 10 | 3.9 | U | 6 | 2.8 |
| D | 6 | 4.2 | M | 0 | 3 | V | 12 | 2.1 |
| E | 8 | 13.1 | N | 2 | 8 | W | 8 | 2.1 |
| F | 6 | 2.7 | O | 2 | 8 | X | 6 | 1 |
| G | 0 | 2 | P | 0 | 2.2 | Y | 0 | 2.5 |
| H | 14 | 3 | Q | 12 | 1 | Z | 0 | 0.8 |
| I | 4 | 7.9 | R | 6 | 8.2 | | | |

# Frequencies Analysis

V X E V W L W X W L R Q F L S K H U V F D Q

R I W H Q E H E U R N H Q E B

I U H T X H Q F L H V D Q D O B V L V

# Smoothing Frequencies: Grandpre

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | A | B | A | S | H | I | N | G |
| 2 | Y | O | K | O | H | A | M | A |
| 3 | C | O | E | X | I | S | T | S |
| 4 | D | E | A | T | H | F | U | L |
| 5 | J | A | C | K | P | O | T | S |
| 6 | Q | U | I | V | E | R | E | D |
| 7 | W | I | T | C | H | I | N | G |
| 8 | Z | O | D | I | A | C | A | L |

Plaintext: YOU CANNOT BREAK ME

Ciphertext: 21 22 47 31 11 17 77 24 37 12 66 33 13 23 27 42

# Smoothing Frequencies: Vegenere Cipher

Plaintext: SEND MORE MEN AND MUNITION

Key: KEY

Equivalent to shifts by 10 4 24 letters

S E N D M O R E M E N A N D M U N I T I O N

10 4 24

C I L N Q M B I K I L K R B W Y L S X G Y R

$$C_i \equiv P_i + K_{(i \bmod 3)} \pmod{26}$$

# Smoothing Frequencies: Vegenere Cipher (cntd)

- Idea: The longer key the better
- Codebooks
- Autokey
- Enigma
- One-time pad