CS458/CS558: Introduction to Computer Security

Basic Terminology

Some Basic Terminology

- Plaintext: original message
- Ciphertext: coded message
- Encryption: converting plaintext to ciphertext
- Decryption: restoring plaintext from ciphertext
- Cryptography: the area of study of encryption principles/methods
- Cipher: an algorithm for performing encryption
- Cryptanalysis: the area of study of principles/ methods of deciphering ciphertext without knowing key – breaking the cipher

Some Basic Terminology

- Cryptology: areas of cryptography and cryptanalysis together
- Secret key: the input of encryption algorithm. The key is independent of the plaintext and the alg..

Cryptography

- Characterize cryptographic system by:
  - Type of encryption operations used
    - Substitution: each element (a bit or a letter) in the plaintext is mapped into another element
    - Transposition: elements in the plaintext are rearranged.
    - product: multiple stages of substitutions and transpositions
  - Number of keys used
    - Symmetric, Single-key encryption
    - Asymmetric, Two-key or Public-key encryption
  - Way in which plaintext is processed
    - Block: process one block of elements at a time, producing an output block for each input block
    - Stream: process the input elements continuously, producing one element at a time.

Cryptanalysis

- Objective of attacking an encryption system: recover key rather than simply to recover the plaintext of a single ciphertext.
- General approaches:
  - Cryptanalytic attack:
    - Rely on the nature of the algorithm + some knowledge of the plaintext (e.g. English or French) or some sample plaintext-ciphertext pairs.
  - Brute-force attack
    - Try every possible key on a piece of ciphertext until an intelligible translation into plaintext is obtained.

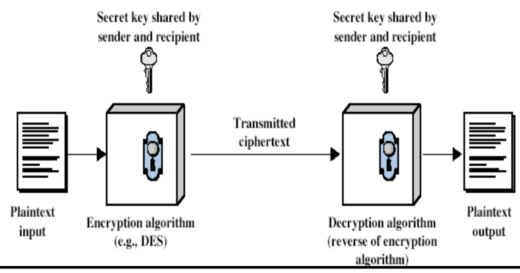
Chapter 2
Symmetric Encryption

Symmetric Encryption

- A form of cryptosystem in which encryption and decryption are performed using the same key – single-key encryption
- Was only type prior to invention of public-key in 1970's, and by far most widely used.

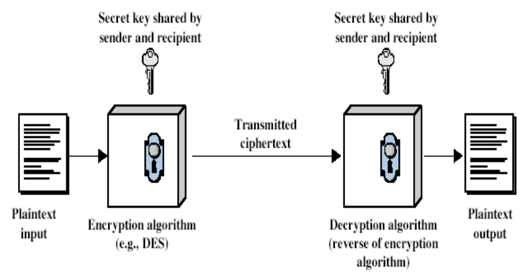
Symmetric Cipher Model

- Encryption algorithm: performs various substitutions a and transformation on the plaintext.
- Secret key: the input of encryption algorithm. The key is independent of the plaintext and the alg..



Symmetric Cipher Model

- Decryption algorithm: the ciphertext and the secret key and produces the original plaintext.



Requirements

- Two requirements for secure use of symmetric encryption:
  - A strong encryption algorithm: the opponent should be unable to decrypt ciphertext or discover the key even if he/she has a number of ciphertexts and the plaintext that produced each ciphertext.
  - Assume encryption algorithm is known
  - Mathematically have:

X: message, K: encryption key, Y: ciphertext

$$Y = E(K,X)$$

$$X = D(K,Y)$$

An opponent can observe Y, but do not have access to K or X.

Requirements

- Two requirements for secure use of symmetric encryption:
  - A secret key known only to sender/receiver
    - Sender and receiver must have obtained copies of secret key in a secure fashion and must keep the key secure.
    - A third party could generate the key and securely deliver it to both source and destination.
    - If someone can discover the key and knows the algorithm, all communication using this key is readable.

Unconditional Security

- Unconditional security
  - No matter how much computer power or time is available, the cipher cannot be broken since the ciphertext provides insufficient information to determine the corresponding plaintext.

Computational Security

- Computational security
  - Given limited computing resources (eg time needed for calculations is greater than age of universe), the cipher cannot be broken
    - The cost of breaking the cipher exceeds the value of the encrypted information
    - The time required to break the cipher exceeds the useful lifetime of the information

Brute Force Search

- Simply try every key until an intelligible translation of the ciphertext into plaintext is obtained.
- On average, half of all possible keys must be tried to achieve success - proportional to key size
- DES: 56-bit, triple DES: 168-bit, AES: > 128 bits
- Time required for various key spaces:

Key Size (bits)	Number of Alternative Keys	Time required at 1 decryption/µs	Time required at 10^6 decryptions/µs
32	$2^{32} = 4.3 \cdot 10^9$	2^{31} µs= 35.8 minutes	2.15 milliseconds
56	$2^{56} = 7.2 \cdot 10^{16}$	2^{55} µs= 1142 years	10.01 hours
128	$2^{128} = 3.4 \cdot 10^{38}$	2^{127} µs= $5.4 \cdot 10^{24}$ years	$5.4 \cdot 10^{18}$ years
168	$2^{168} = 3.7 \cdot 10^{50}$	2^{167} µs= $5.9 \cdot 10^{36}$ years	$5.9 \cdot 10^{30}$ years

Substitution Cipher

Classical Substitution Ciphers

- Letters of plaintext are replaced by other letters or by numbers or symbols

Caesar Cipher

- The earliest known substitution cipher (by Julius Caesar)
- First attested use in military affairs
- Replaces each letter with the letter standing K places further down the alphabet.
- When K = 3, can define transformation as:

```
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
```

- Example:

```
Plaintext:  meet me after the toga party
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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
```

- Example:

```
Plaintext:  meet me after the toga party
Ciphertext: PHHW PH DIWHU WKH WRJD SDUWB
```

Cryptanalysis of Caesar Cipher

Cryptanalysis of Caesar Cipher

- A brute force search can be easily performed: simply try all the 25 possible keys - far from security.
  - The language of the plaintext is known and easily recognizable.
- The input may be compressed, make recognition difficult, e.g., E.g. .zip file.

C:

KEY	PHHW	PH	DIWHU	WKH	WRJD	SDUWB
1	oggv	og	chvgt	vjg	vqic	rctva
2	nffu	nf	bgufs	uif	uphb	qbsuz
3	meet	me	after	the	toga	party
4	ldds	ld	zesdq	sgd	snfz	ozqsx
5	kccr	kc	ydrcp	rfc	rmey	nyprw
6	jbbq	jb	xcqbo	qeb	qldx	mxoqv
7	iaap	ia	wbpan	pda	pkcw	lwnpu
8	hzzo	hz	vaozm	ocz	ojbv	kvmot
9	gyyn	gy	uznyl	nby	niau	julns
10	fxxm	fx	tymxk	max	mhzt	itkmr
11	ewwl	ew	sxlwj	lzw	lgys	hsjlq
12	dvvk	dv	rwkvi	kyv	kfxr	grikp
13	cuuj	cu	qvjuh	jxu	jewq	fqhjo
14	btti	bt	puitg	iwt	idvp	epgin
15	assh	as	othsf	hvs	hcuo	dofhm
16	zrrg	zr	nsgre	gur	gbtn	cnegl
17	yqqf	yq	mrfqd	ftq	fasm	bmdfk
18	xppe	xp	lqepc	esp	ezrl	alcej
19	wood	wo	kpdob	dro	dyqk	zkbdi
20	vnnc	vn	jocna	cqn	cxpj	yjach
21	ummb	um	inbmz	bpm	bwoi	xizbg
22	tlla	tl	hmaly	aol	avnh	whyaf
23	skkz	sk	glzkx	znk	zumg	vgxze
24	rjjy	rj	fkyjw	ymj	ytlf	ufwyd
25	qiix	qi	ejxiv	xli	xske	tevxc

Monoalphabetic Cipher

- Allow an arbitrary substitution rather than just shifting the alphabet
- Each plaintext letter maps to a random ciphertext letter

```
Plain:  abcdefghIjklmnopqrstuvwxyz
Cipher: DKVQFIBJWPESCXHTMYAUOLRGZN
```

E.g.

```
If we wish to replace letters
```

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E.g.

```
If we wish to replace letters
WI RF RWAJ UH YFTSDVF SFUUFYA
```

Monoalphabetic Cipher Security

- Number of mappings

Monoalphabetic Cipher Security

- The number of mappings
  - 26! = 4*10^26 mappings
- With so many mappings, might think is secure

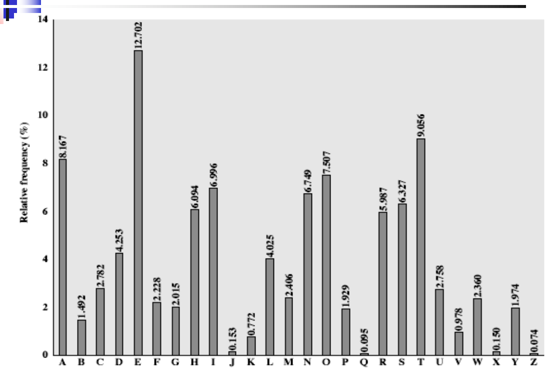
Monoalphabetic Cipher Security

- The cipher line can be any permutation of the 26 alphabetic characters
  - 26! = 4*10^26 mappings
- With so many mappings, might think is secure
- But would be WRONG – if the cryptanalyst knows the nature of the plaintext (e.g. noncompressed English text), then the analyst can exploit the regularities (frequency of letters) of the language

Language Redundancy and Cryptanalysis

- Human languages are redundant. Letters are not equally commonly used.
- In English E is by far the most common letter, followed by T,A,O,I,N,S,R, other letters like Z,J,K,Q,X are fairly rare.
  - If the mesg. is long enough, this technique alone may be sufficient.

English Letter Frequencies



Use in Cryptanalysis

- Key concept - monoalphabetic substitution ciphers do not change relative letter frequencies
- Calculate letter frequencies for ciphertext
- Compare counts/plots against known values

Example

- UZQSOVUOHXMOPVGPOZPEVAGZWSZOPFPESXUDBMETSXAIZVUEPH ZHMDZSHZOWSFPAPPDTSVPQUZWYMXUZUHSX

  EPYEPOPDZSUFPOMBZWPFUPZHMDJUDTMOGMQ

P 13.33	H 5.83	F 3.33	B 1.67	C 0.00
(16/120)	D 5.00	W 3.33	G 1.67	K 0.00
Z 11.67	E 5.00	Q 2.50	Y 1.67	L 0.00
S 8.33	V 4.17	Tt 2.50	J 0.83	N 0.00
U 8.33	X 4.17	A 1.67	I 0.83	R 0.00
O 7.50				
M 6.67				

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- UZQSOVUOHXMOPVGPOZPEVAGZWSZOPFPESXUDBMETSXAIZVUEPH ZHMDZSHZOWSFPAPPDTSVPQUZWYMXUZUHSX EPYEPOPDZSUFPOMBZWPFUPZHMDJUDTMOGMQ

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- P →e

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- P →e, Z → t

Example

- UZQSOVUOHXMOPVGPOZPEVAGZWSZOPFPESXUDBMETSXAIZVUEPH ZHMDZSHZOWSFPAPPDTSVPQUZWYMXUZUHSX EPYEPOPDZSUFPOMBZWPFUPZHMDJUDTMOGMQ

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- P →e, Z → t, {S,U,O,M,H} → {a,h,i,n,o,r,s}

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- P →e, Z → t, {S,U,O,M,H} → {a,h,i,n,o,r,s}
- Most common pair: ZW → and hence ZWP → , ZWSZ →

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- P → e, Z → t, {S,U,O,M,H} → {a,h,i,n,o,r,s}
- Most common pair: ZW → th and hence ZWP → the, ZWSZ → that
- Finally: it was disclosed yesterday that several informal but direct contacts have been made with political representatives of the viet cong in moscow

Playfair Cipher

- Not even the large number of mappings ($4*10^{26}$ mappings) in a monoalphabetic cipher provides security
- One approach to improving security is to encrypt multiple letters – e.g. Playfair Cipher.

Playfair Key Matrix

- A 5X5 matrix of letters based on a keyword
- Fill in letters of keyword (minus duplicates) from left to right and from top to bottom
- Fill rest of matrix with other letters
- Eg. using the keyword MONARCHY
- I and j count as one letter.

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

Playfair Cipher: Encryption

- Plaintext is encrypted two letters at a time
  - If a pair is a repeated letter, insert filler x, e.g. bolloon → bo lx lo on
  - If both letters fall in the same row, replace each with letter to right with the first element of the row circularly following the last, e.g. ar → rm
  - If both letters fall in the same column, replace each with the letter below it (again wrapping to top from bottom), e.g. mu → cm

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

Playfair Cipher: Encryption

- Plaintext is encrypted two letters at a time
  - Otherwise, each letter is replaced by the letter in the same row and in the column of the other letter of the pair, e.g. hs → bp, ea → im (or jm)

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

Playfair Cipher: Decryption

- To decrypt, use the inverse of the encryption rules and drop any extra x that does not make sense in the final message.
  - Decrypts two letters at a time
  - If both letters fall in the same row, replace each with letter to left, e.g. rm → ar
  - If both letters fall in the same column, replace each with the letter above it, e.g. cm → mu

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

Playfair Cipher: Decryption

- Plaintext is encrypted two letters at a time
  - Otherwise, each letter is replaced by the letter in the same row and in the column of the other letter of the pair
  - E.g. bp → hs, im → ea

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

Example

- Use the playfair cipher and key word commom to encrypt the message: gdddcgs

Security of Playfair Cipher

- Security much improved over monoalphabetic
- Would need a 676 (26*26) entry frequency table to analyse (verses 26 for a monoalphabetic)
- Was widely used for many years
  - eg. by US & British military in WW1
- It is relatively easy to break because it still leaves much of the structure of the plaintext language intact.

Polyalphabetic Ciphers

- Improve security using multiple monoalphabetic substitutions.
- Features
  - A set of related monoalphabetic substitution rules is used.
  - A key determines which particular rule is chosen for a given transformation
- Vigenère Cipher: Simplest polyalphabetic substitution cipher

Modern Vigenère Tableau

Plaintext

Key	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
a	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	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
c	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
d	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
e	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
f	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
g	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
h	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
i	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
j	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
k	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
l	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
m	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
n	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
o	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
p	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
q	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
r	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
s	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
t	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
u	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
v	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
w	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
x	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
y	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
z	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

The set of related monoalphabetic substitution rules consists of 26 Caesar ciphers

Plaintext

Key	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
a	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	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
c	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
d	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
e	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
f	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
g	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
h	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
i	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
j	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
k	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
l	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
m	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
n	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
o	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
p	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
q	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
r	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
s	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
t	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
u	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
v	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
w	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
x	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
y	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
z	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

- Each ceasar cipher is denoted by a key letter
- A normal alphabet for the plaintext runs across the top

Plaintext

Key	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
a	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	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
c	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
d	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
e	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
f	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
g	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
h	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
i	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
j	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
k	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
l	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
m	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
n	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
o	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
p	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
q	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
r	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
s	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
t	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
u	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
v	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
w	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
x	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
y	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
z	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

Given a key letter x and a plaintext letter y, the ciphertext letter is at the intersection of row labeled x and the column labeled y ➔ the ciphertext is v.

Plaintext

Key	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
a	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	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
c	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
d	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
e	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
f	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
g	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
h	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
i	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
j	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
k	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
l	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
m	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
n	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
o	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
p	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
q	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
r	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
s	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
t	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
u	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
v	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
w	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
x	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
y	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
z	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

- Write the plaintext out, write the keyword repeated above it
- Eg using keyword deceptive

```
key:       deceptivedeceptivedeceptive
plaintext: wearediscoveredsaveyourself
```

Plaintext

Key	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
a	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	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
c	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
d	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
e	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
f	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
g	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
h	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
i	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
j	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
k	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
l	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
m	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
n	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
o	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
p	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
q	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
r	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
s	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
t	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
u	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
v	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
w	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
x	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
y	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
z	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

- Write the plaintext out, write the keyword repeated above it
- Eg using keyword deceptive

```
key:       deceptivedeceptivedeceptive
plaintext: wearediscoveredsaveyourself
ciphertext:ZICVTWQNGRZGVTWAVZHCQYGLMGJ
```

Vigenère Cipher: Decryption

- Decryption:
  - The key letter identifies the row
  - The position of the ciphertext letter in that row determines the column
  - The plaintext letter is at the top of that column

Security of Vigenère Ciphers

- Have multiple ciphertext letters for each plaintext letter. Hence letter frequencies are obscured
- But not totally lost
- Suppose that the opponent believes that the ciphertext was encrypted using Vigenère Ciphers
  - If two identical sequences of plaintext occur at a distance that is an integer * length of keyword, they will generate identical ciphertext sequences.

```
key:       deceptivedeceptivedeceptive
plaintext: wearediscoveredsaveyourself
ciphertext:ZICVTWQNGRZGVTWAVZHCQYGLMGJ
```

Autokey Cipher: Encryption

- Ideally want a key as long as the message
- Vigenère proposed the autokey cipher
- A keyword is concatenated with the plaintext itself providing a running key.
- Eg. given key deceptive

```
key:       deceptivewearediscoveredsav
plaintext: wearediscoveredsaveyourself
ciphertext:ZICVTWQNGKZEIIGASXSTSLVVWLA
```

How to decrypt a ciphertext?

Autokey Cipher: Decryption

- Eg. given
  - key deceptive
  - Ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

```
key:        deceptive
ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA
plaintext:
```

Autokey Cipher: Decryption

- Eg. given
  - key deceptive
  - Ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

```
key:        deceptive
ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA
plaintext:  w
```

Autokey Cipher: Decryption

- Eg. given
  - key deceptive
  - Ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

```
key:        deceptivew
ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA
plaintext:  w
```

Autokey Cipher: Decryption

- Eg. given
  - key deceptive
  - Ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

```
key:        deceptivew
ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA
plaintext:  we
```

Autokey Cipher: Decryption

- Eg. given
  - key deceptive
  - Ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

```
key:        deceptivewe
ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA
plaintext:  we
```

Autokey Cipher: Decryption

- Eg. given
  - key deceptive
  - Ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA

```
key:        deceptivewearediscoveredsav
ciphertext: ZICVTWQNGKZEIIGASXSTSLVVWLA
plaintext:  wearediscoveredsaveyourself
```

One-Time Pad

- Use a random key that is as long as the message.
- The key is used to encrypt and decrypt a single message, and then is discarded: one-time pad

One-Time Pad

- Use a random key that is as long as the message.
- The key is used to encrypt and decrypt a single message, and then is discarded: one-time pad
- Problem: generation & safe distribution of key
  - Is of limited utility

Flu, Fever, etc

- Please do not attend the class if you have flu, fever, bad cough, or any infectious diseases
- If you are not be able to attend the class due to sickness, please email me before the class

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Assignment 1

Assignment 1

Due: 11:59pm, 02/18/2017 (Sunday)

This assignment is done by a group of 2 students

1. Learn how to write and use makefile

http://www.delorie.com/djgpp/doc/ug/larger/makefiles.html (C)
http://www.cs.swarthmore.edu/~newhall/unixhelp/javamakefiles.html (Java)

2. Implement a telnet client and an iterative telnet server using TCP sockets.

3. Implement the monoalphabetic cipher

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls //lists contents of the directory on the server side
telnet > mkdir <dir>

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls //lists contents of the directory on the server side
telnet > mkdir <dir> //create a directory <dir> on the server
telnet > rmdir <dir>

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls //lists contents of the directory on the server side
telnet > mkdir <dir> //create a directory <dir> on the server
telnet > rmdir <dir> //delete directory <dir>
telnet > cd <dir-relative-path>

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls //lists contents of the directory on the server side
telnet > mkdir <dir> //create a directory <dir> on the server
telnet > rmdir <dir> //delete directory <dir>
telnet > cd <dir-relative-path> //change the current working //directory to a path that is relative to //the current directory, e.g. cd path //<dir-relative-path> does not contain '/'
telnet > cd ..

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls //lists contents of the directory on the server side
telnet > mkdir <dir> //create a directory <dir> on the server
telnet > rmdir <dir> //delete directory <dir>
telnet > cd <dir-relative-path> //change the current working //directory to a path that is relative to //the current directory, e.g. cd path //<dir-relative-path> does not contain '/'
telnet > cd .. //move up one folder
telnet > pwd

PART I: Telnet Client/Server

Implement a telnet client and an iterative telnet server using TCP sockets.

- Support commands: ls, mkdir, rmdir, cd, pwd, and exit.

telnet > ls //lists contents of the directory on the server side
telnet > mkdir <dir> //create a directory <dir> on the server
telnet > rmdir <dir> //delete directory <dir>
telnet > cd <dir-relative-path> //change the current working //directory to a path that is relative to //the current directory, e.g. cd path //<dir-relative-path> does not contain '/'
telnet > cd .. //move up one folder
telnet > pwd //print the working directory of the server
telnet > exit // ends the telnet session with the server

Telnet Server

- The server is invoked as:

  telnetserv <server_port> (C/C++)
  java TelnetServ <server_port> (Java)

  - <server_port>: the port at which the server accepts connection requests.
    - Use a unique port number such as last 4 digits of your ID.

Telnet Client

- The client is invoked as:

  telnetcli <server_domain> <server_port> (C/C++)
  java TelnetCli <server_domain><server_port> (Java)

  - <server_domain>: the domain name of the machine hosting the server. If you use C/C++, you will need to convert the domain to the 32-bit IP address using gethostbyname(…) etc.
    http://retran.com/beej/gethostbynameman.html
  - <server_port>: the port number on which the server is listening.
- Upon connecting to the server, the client prints out telnet >, which allows the user to type commands.

Error Handling

- CS458: no error handling is required
- CS558: Error handling
  - Invalid commands, i.e., commands other than ls, cd, pwd, mkdir, rmdir, and exit specified above.

    You should not implement commands that are supported in Linux/Unix, but are not specified in the description.
  - telnet > mkdir <dir>: <dir> exists.
  - telnet > rmdir <dir>: <dir> does not exist
  - telnet > cd <dir>: <dir> does not exist.

  Your implementation should NOT support absolute path in cd command.

PART II: Monoalphabetic cipher

- Implement monoalphabetic cipher to encrypt/decrypt files
  - The file contains only a-z and does not contain space, tabs, and newlines.
  - Assume that the file contains less than 10000 characters.
- For each plaintext letter, your program should randomly generate the corresponding ciphertext letter based on a seed.
- Your code should result in an executable of the following form:
  ./mono <inputfile> <outputfile> <seed> 1/0

  - inputfile: input file name
  - outputfile: output file name
  - seed: the seed used to generate the mapping
  - 1/0: encryption/decryption

  Your program prints the mappings generated using the following format: a-b, b-d, c-h, ……

Grading Guideline (CS558)

- Readme, correct format of execution: 4'
- Makefile: 8'
- Part I: 50'
  - ls, exit: 12'
  - cd, mkdir, rmdir, pwd: 26'
  - Error handling: 12'
- Part II: 38'

Grading Guideline (CS458)

- Readme, correct format of execution: 4'
- Makefile: 8'
- Part I: 46'
  - ls, exit: 16'
  - cd, mkdir, rmdir, pwd: 30'
- Part II: 42'

Submission Guideline

- Only one of the group members should submit the program
- Hand in your source code, two makefiles (one for Part I and one for Part II) and a Readme electronically.
- Part I
  - If you use C/C++, the Makefile must give the executable server code the name telnetserv and the executable client code the name telnetcli.
  - If you use Java, generate TelnetServ.class and TelnetCli.class.
- Part II: The name of the executable must be mono.
- Your code should compile and run correctly on bingsuns.binghamton.edu.

Submission Guideline

- Write a README file (text file, do not submit a .doc file):
  - Names and email addresses of all group members.
  - Whether your code has been tested on bingsuns.
  - The language you are using (C/C++/Java)
  - How to execute your program.
  - (Optional) Anything special about your submission that the TA should take note of.

Submission Guideline (Cont.)

- Create two folders: part1 (source code of PART I and a Makefile) and part2 (source code of PART II and a Makefile).
- Place both folders and the README file under one directory with a unique name (e.g. p1-[userid] for assignment 1, e.g. p1-pyang).
- Tar the contents of this directory:

  tar –cvf p1-<userid>.tar p1-<userid>

  E.g. tar -cvf p1-pyang.tar p1-pyang/
- Use the mycourses to upload the tared file you created above.

Academy Integrity

- We will use moss to detect to plagiarism in this assignment.