Aalto University
School of Electrical
Engineering

Basic Principles in Networking

Principles of Cryptography

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Version 1.0

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Motivation (5 min)

Cyber Security – Top 10 threats

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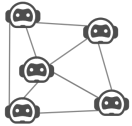
Part I (20 min)

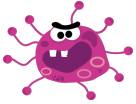
Introduction
Principles of Cryptography

Networks under attack

Networks under attack



Botnet:

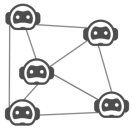


Virus:

Worm:

Trojan horse:

Networks under attack



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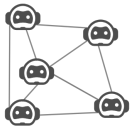

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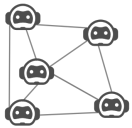

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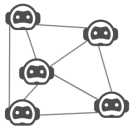
Networks under attack



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Trojan horse: Hidden part of some otherwise useful software. Executed in the background, without notice

Networks under attack






Malware is pervasive and costly to defend against

Task: While following this course, think about what computer network designers can do to defend connected devices from malware







Bad guys perspective

Denial of Service attacks

DoS attacks

Renders a network, host or other piece of infrastructure unusable by legitimate users. E.g. Web servers, email servers, DNS servers and institutional networks.

Bad guys perspective

Types of DoS attacks

Vulnerability attack Sending few well-crafted messages to a vulnerable application or operating system. With the right sequence of packets, the service can stop or the host can crash

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Connection flooding Establishing a large number of half-open or fully open TCP connections so that the host stops accepting legitimate connections due to the high load.

Bad guys perspective

Distributed Denial of Service attack

Denial of Service attack Attacker tries to send traffic at a rate that matches at least the Servers access rate R.

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Distributed denial of Service attack Attacker controls multiple sources and has each source generate traffic towards the target

- Much harder to detect and to defend against

Bad guys perspective

Packet sniffing

Security vulnerabilities through high number of wirelessly connected devices

Bad guys perspective

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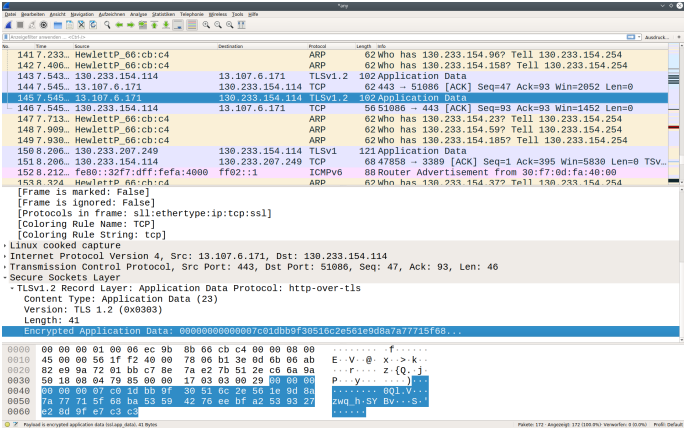
- packets sent
- packet content
- private/sensitive information
- connection habits, social ties, patterns, ...



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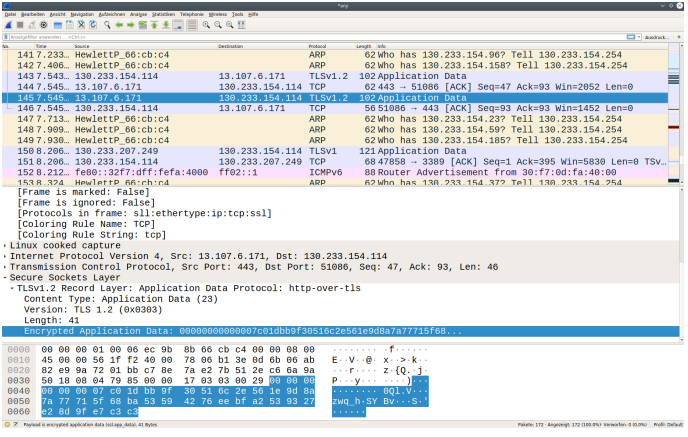
Solution: Encryption



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Masquerading

Creating a packet with **arbitrary source address, packet content and destination address**, a receiver might be disguised of the true sender.

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Injecting packets with false source address into the internet

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Solution: End-point authentication

Bad guys perspective

Man-in-the-middle attacks

An attacker might reside in one node within the communication path

- a compromised router,
- a software module on one of the end-hosts at a lower layer in the protocol stack

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MitM capabilities

Sniffing packets; inject, modify or delete packets

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MitM capabilities

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Solution: Establish data integrity

Why is the internet such an insecure place?

Bruce Schneider

Why is the internet such an insecure place?

Historical perspectives

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1961-1972: Development of packet switching Telephone network being the dominant communication network, first computer connections were cirquit switched; packet-switching over multiple hops just evolving

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2000-today New applications, content distribution, internet telephony, wireless access, security, P2P networking

Desirable properties of secure communication

Principles of Cryptography

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Confidentiality

Message integrity

End-point Authentication

Operational security

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Confidentiality	Only the sender and receiver should be able to understand the contents of a message
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Operational security	Firewalls and Intrusion Detection Systems	firewalls, packet inspection

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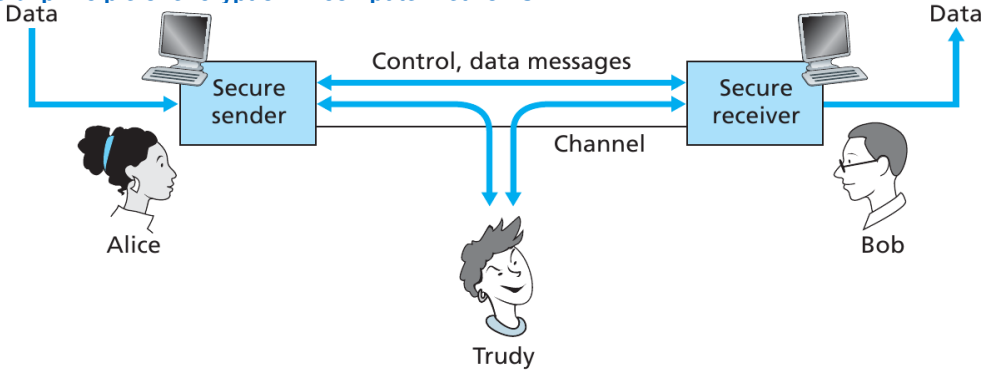
Part II (20 min)

Symmetric Key Cryptography
Block ciphers

Symmetric key cryptography

General principle of encryption in computer networks

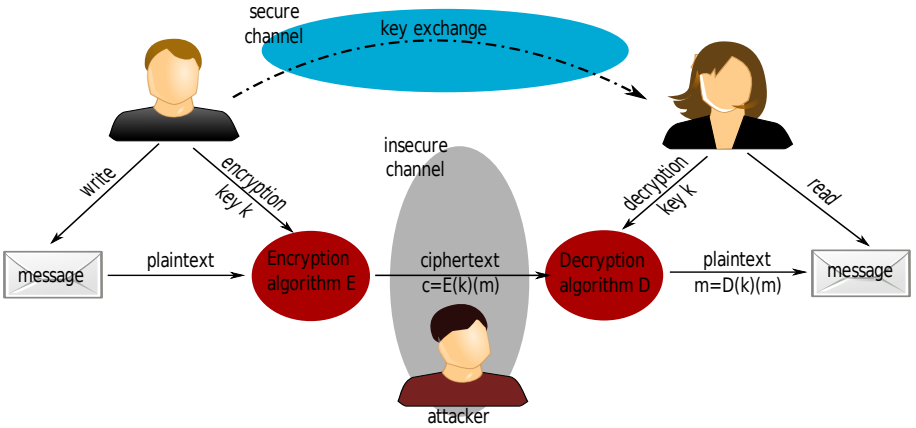


- Encryption technique known, published and standardized

Source: Computer Networking - A top-down approach; Kurose, Ross. Adisson Wesley 2012.

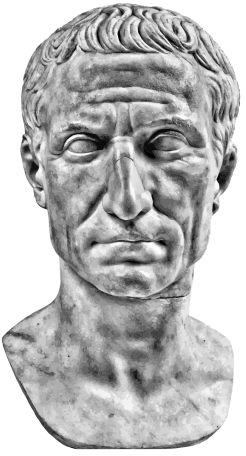
Symmetric key cryptography

Symmetric Encryption



Symmetric key cryptography

Historical encryption algorithms: Caesar Cipher



Symmetric key cryptography

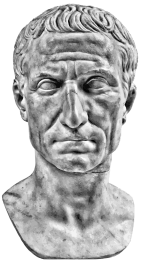
Historical encryption algorithms: Caesar Cipher

Algorithm: Cyclic shift of letters in the alphabet by k letters

Key: k

Caesar cipher with $k = 3$

Plaintext	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
Ciphertext	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



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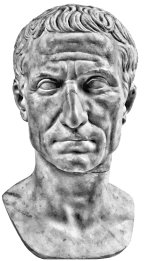

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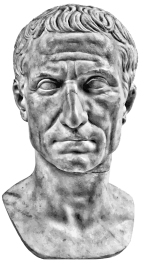

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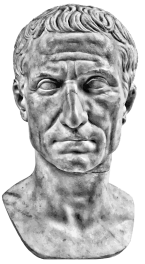
Possible Key values



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Possible Key values: 25 *(easy to brute-force if algorithm known)*

Symmetric key cryptography

Historical encryption algorithms: Monoalphabetic Cipher

Algorithm: Permutation π of the alphabet

Key: π

Monoalphabetic Cipher

Plaintext	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
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Example nkn, s gktc wky. mgsbc

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Possible Key values 26! (approx. 10^{26}) *(still vulnerable to statistical analysis)*

Symmetric key cryptography

Historical encryption algorithms: Polyalphabetic encryption

Algorithm: Concatenation of simple encryption schemes $C_1, \ldots, C_n$

Key: $\{C_j | j \in \{1, \ldots, n\}\}^m$

Polyalphabetic (here: Concatenation of Caesar-) ciphers: C_1, C_2, C_2, C_1, C_2

Plaintext	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
$C_1(k=5)$	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
$C_2(k=19)$	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

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$C_2(k=19)$	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

Example bob, i love you. alice

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Example

bob, i love you. alice

ghu, n etox dhz. tenvj

Symmetric key cryptography

Historical encryption algorithms: Polyalphabetic encryption

Algorithm: Concatenation of simple encryption schemes $C_1, \ldots, C_n$

Key: $\{C_j | j \in \{1, \ldots, n\}\}^m$

Polyalphabetic (here: Concatenation of Caesar-) ciphers: C_1, C_2, C_2, C_1, C_2

Plaintext	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
$C_1(k=5)$	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
$C_2(k=19)$	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

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Possible Key values

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Example bob, i love you. alice

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Possible Key values 25^m

Symmetric key cryptography

Cryptographic attacks

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Chosen-plaintext Intruder is able to choose the plaintext message and obtain its corresponding ciphertext (The quick brown fox jumps over the lazy dog)

Block Ciphers

Block ciphers are employed, for instance, in PGP (secure e-mail), SSl (securing TCP connections), IPsec (securing network-layer transport)

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input	0	1	0	1	1	0	0	0	1	1	1	1
output	1	0	1	0	0	0	1	1	1	0	0	1

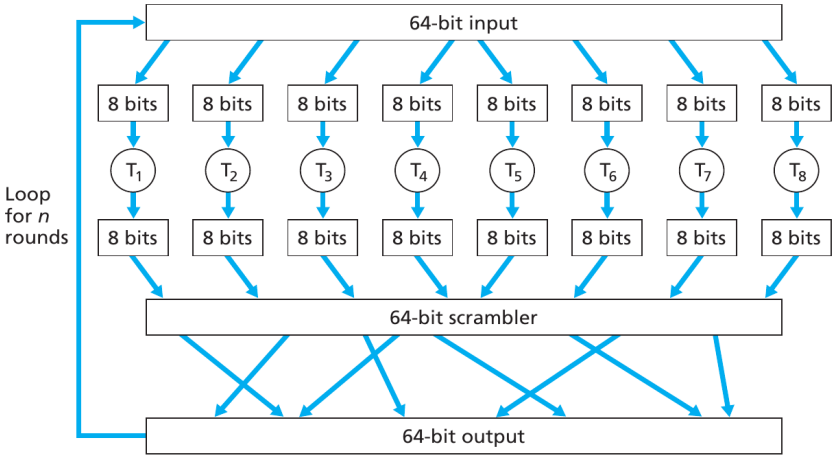
Block Ciphers

Example for a full block cipher

Using 64 bit input *(2^{64} different mappings)*

Encryption includes *n* cycles

Popular block ciphers today: e.g. DES, 3DES, AES



Source: Computer Networking - A top-down approach; Kurose, Ross. Adisson Wesley 2012.

Cipher block chaining

Problem with plain block ciphers: Repetition of text fragments might disclose information on the cipher. For instance: “HTTP/1.1”

How to resolve this problem?

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3. Ciphertext for the i-th block: $c(i) = K_S(m(i) \oplus c(i-1))$

Cipher block chaining – example

Example:

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output	110	111	101	100	011	010	000	001

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$c(0)$	0	0	1						
output									

Cipher block chaining – example

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$c(1)$				1	0	0			
$m(2) \oplus c(1)$				1	1	0			
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Aalto University
School of Electrical
Engineering

Video (5 min)

They are working for us

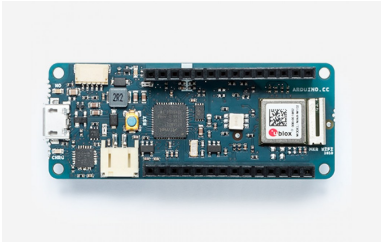
Aalto University
School of Electrical
Engineering

Exercise briefing (15 min)

Cryptography

Exercise briefing

- Additional pracical guidance
- Setting you up for the exercises
- Q&A



Questions?

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Literature

- J.F. Kurose,K.W. Ross: Computer Networking: A Top-Down approach (7th edition), Pearson, 2016.
- J.F. Kurose,K.W. Ross: Computer Networking: A Top-Down approach (6th edition), Addison-Wesley, 2012.