

Cryptography

ENEE/CMSC/MATH 456

Instructor: Dana Dachman-Soled

Lecture 1

1/25/2023

Syllabus Highlights

- Best way to contact me is via email:
 - danadach@umd.edu
- My office hours: Wed, Fri 9:30-10:30am in Iribe 5238
- Our TA:
 - Rui Tang (email: rui tang@umd.edu)
- TA Office hours: Tues, Thurs 4-5pm in Iribe 5161
- Class url:
 - www.ece.umd.edu/~danadach/Cryptography_23

Syllabus Highlights cont'd

- Small Quizzes/Class Exercises
 - More on next slide
- Weekly homeworks (about 9-10 overall)
 - See syllabus for late homeworks policy
 - Lowest grade will be dropped
- Grading Policy:
 - Small Quizzes/Class Exercises—5%
 - Homework—25%
 - Midterm—35%
 - Final—35% (not cumulative)
 - **Extra credit opportunity relating to current events
 - **Extra credit opportunity after the midterm
- Tentative midterm date: In class on Wednesday, March 15.

Reading Assignment/Quizzes

- Upcoming: Review of basic math, discrete math (combinatorics, probability).
- Read Chapters 1,2,3,6,7 of Prof. Jonathan Gross's lecture notes (link on course webpage):

COMS W3203 - DISCRETE MATHEMATICS

Fall 2012	HOME	COURSE MATERIAL	ADMINISTRATIVE
		<ul style="list-style-type: none">Chapter 1 - Logic and ProofsChapter 2 - Sets, Fcns, Seqs, SumsChapter 3 - Algorithms and IntegersChapter 4 - Number TheoryChapter 5 - Induction and RecursionChapter 6 - CountingChapter 7 - Discrete ProbabilityChapter 8 - Advanced CountingChapter 9 - RelationsChapter 10 - Graph Theory	<ul style="list-style-type: none">Administrative InfoLecture PlanHomework AssignmentsHomework 1 Cover SheetHomework 2 Cover SheetHomework 3 Cover SheetHomework 4 Cover SheetHomework 5 Cover SheetHomework 6 Cover Sheet

- 5 short 5-question quizzes on Canvas, one for each chapter.
- ***Due on Feb. 10, 11:59pm.
- Additional resources: Rosen, K. H. (2012) Discrete Mathematics and Its Applications. (7th ed.).

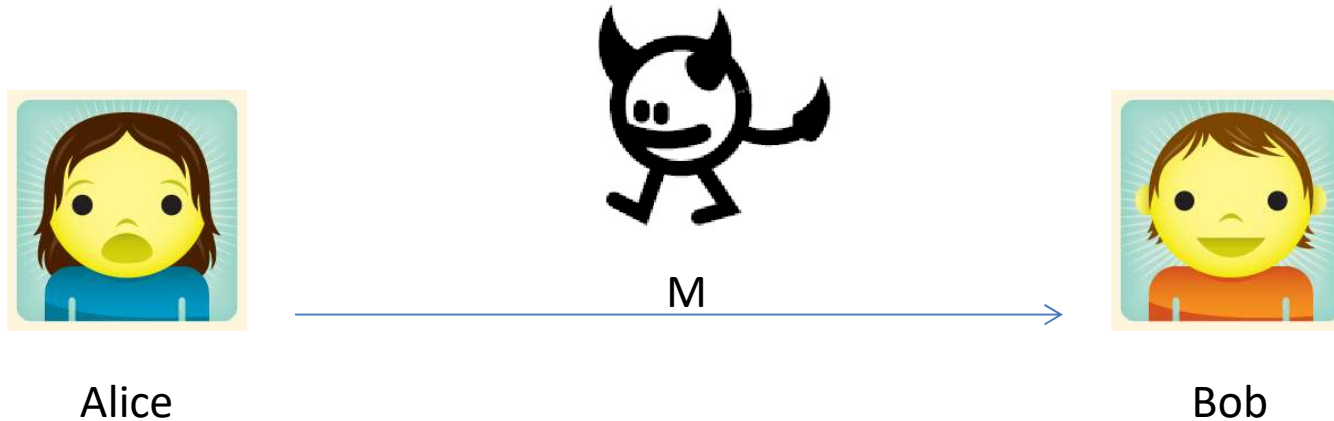
Additional Announcements

- Homework 1 is up on the course webpage. Due on 2/8 ****by beginning of class.****
- Homework due dates beyond Homework 1 on Canvas are ****tentative**** and will be updated once the homework is assigned.
- Encourage students to collaborate on homework
- Final submitted solutions must be *your own*.

Goals of Modern Cryptography

- Providing information security:
 - Data Privacy
 - Data Integrity and Authenticityin various computational settings.

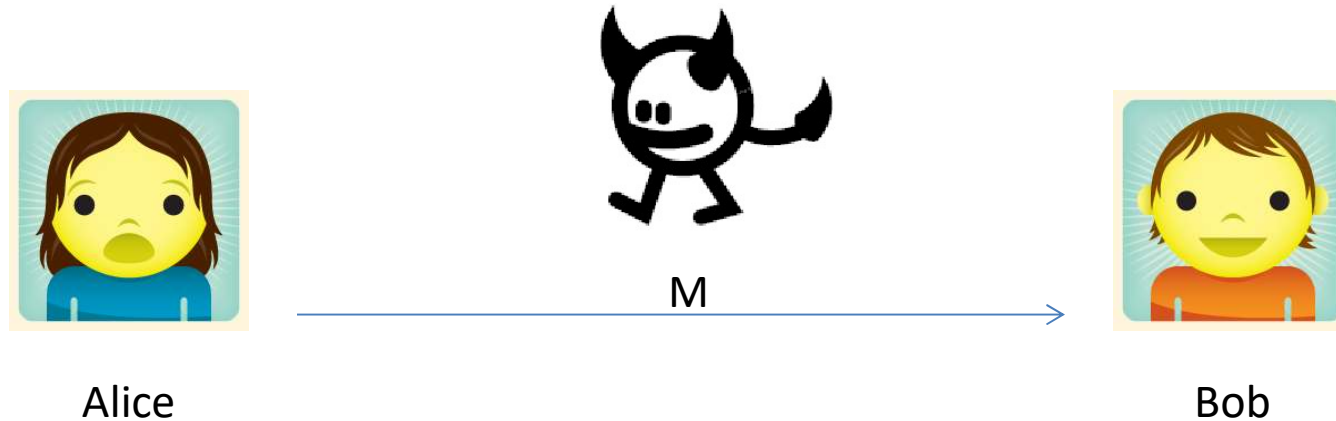
Data Privacy



The goal is to ensure that the adversary does not see or obtain the data (message) M .

- Example: M could be a credit card number being sent by shopper Alice to server Bob and we want to ensure attackers don't learn it.

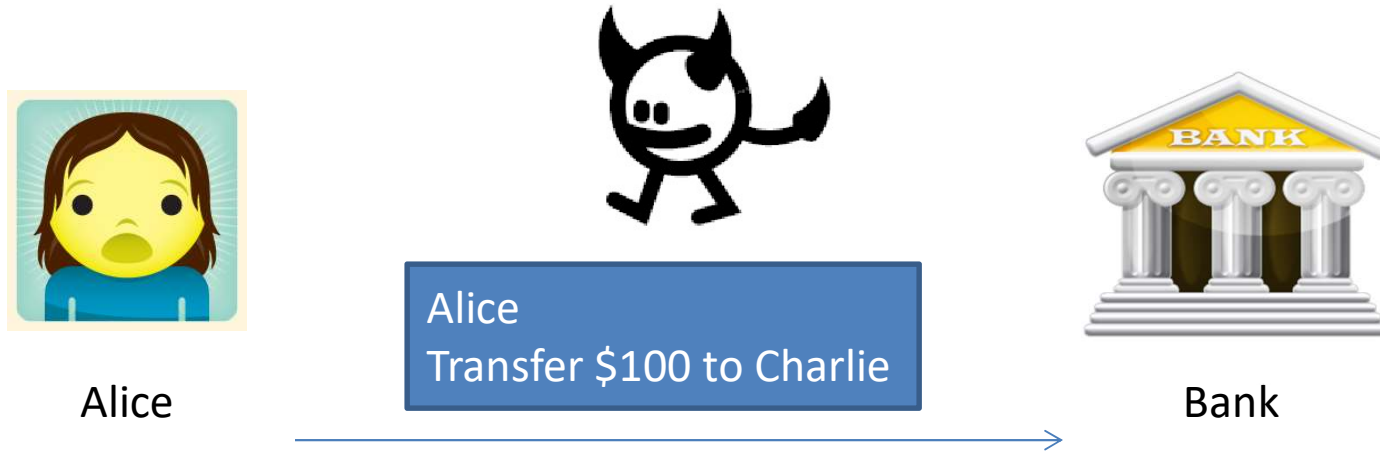
Data Integrity and Authenticity



The goal is to ensure that

- M really originates with Alice and not someone else.
- M has not been modified in transit.

Data Integrity and Authenticity



Adversary Eve might

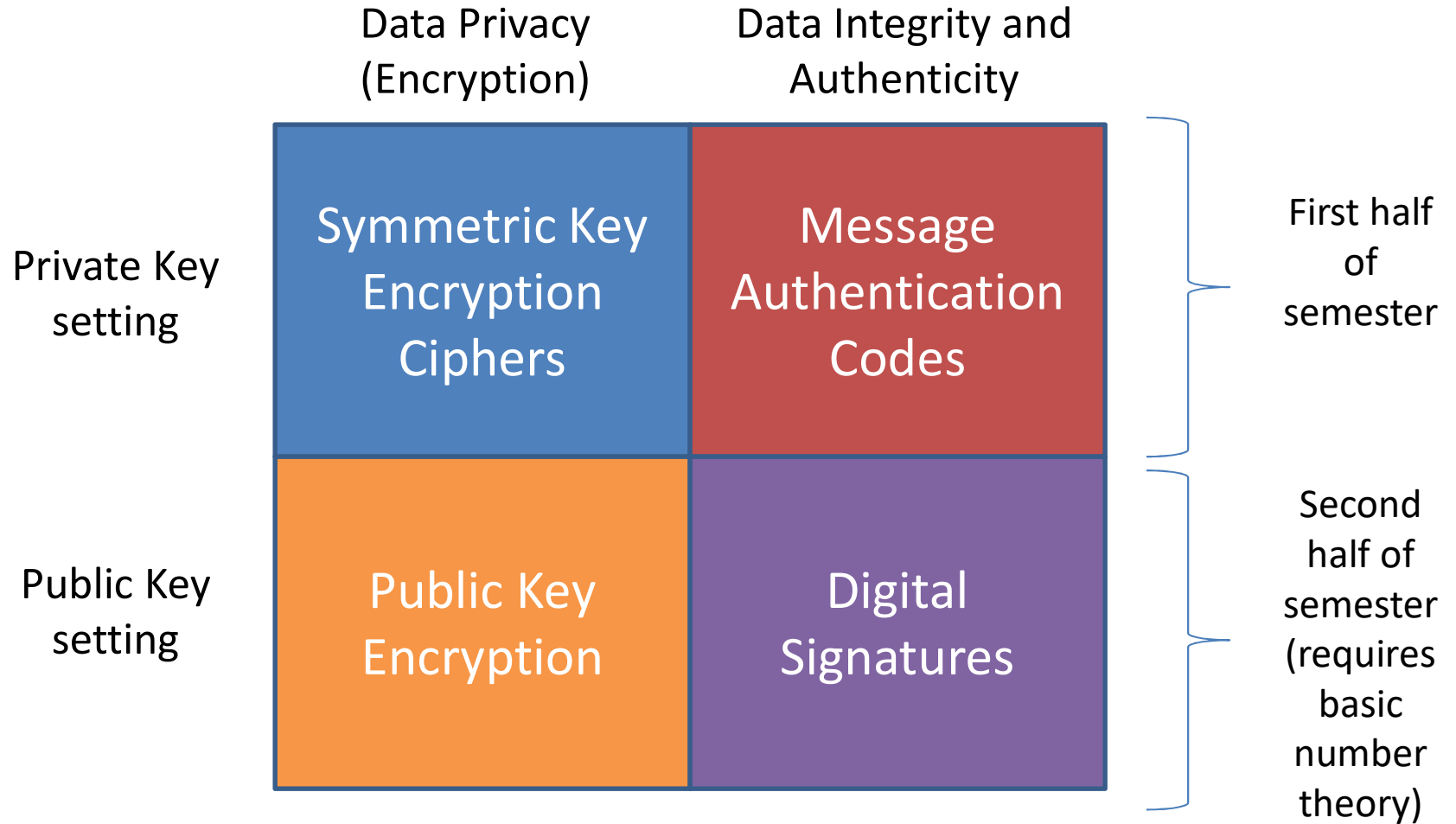
- Modify “Charlie” to “Eve”
- Modify “\$100” to “\$1000”

Integrity prevents such attacks.

General Topics

- Explore how to **define** security
 - What does it mean for something to be “secure”
 - Defining a threat model, placing computational restrictions
- Explore how to **prove** security
 - Mathematical proofs, proofs by reduction
 - Computational assumptions
- Learn about **tools** for building secure schemes
 - Tools for practical symmetric key constructions
 - Tools from number theory for public key constructions
- See lots of **constructions** of cryptographic schemes:
 - Symmetric key encryption (block ciphers, stream ciphers), Message Authentication codes (MAC), Collision-resistant hash functions, Key exchange, Public key encryption, Digital signatures.

What we will be doing this semester



Today:

- We will start on **symmetric key encryption** (also called **ciphers**).

Symmetric Key Encryption (Historically called “ciphers”)

Kerckhoffs' Principle (1800s)

“The cipher method must not be required to be secret, and it must be able to fall into the hands of the enemy without inconvenience.”

Today: Parties share a secret key which allows them to encrypt and decrypt, the scheme itself is public.



Advantages of open crypto design:

1. More suitable for large-scale usage.
 - All pairs of communicating parties can use the same scheme with different key.
2. Published designs undergo public scrutiny and are therefore likely to be stronger.
3. Public design enables the establishment of standards.

Historical Ciphers and their Cryptanalysis

For each cipher we discuss:

- What is the Encrypt algorithm?
- What is the Decrypt algorithm?
- What is the key space, key space size and secret key?
- How can it be broken?

Atbash Cipher (600 B.C.)

From Wikipedia: **Atbash** is a simple [substitution cipher](#) for the [Hebrew alphabet](#). It consists in substituting [aleph](#) (the first letter) for [tav](#) (the last), [beth](#) (the second) for [shin](#) (one before last), and so on, reversing the [alphabet](#). In the [Book of Jeremiah](#).



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

helloworld → SVOOLDLIOW

They didn't know Kerckhoff

Key Space = \emptyset

Security = no sec. ~ Kerckhoff's model

Shift/Caesar Cipher (100 B.C.)

From textbook: One of the oldest recorded ciphers, known as Caesar's cipher is described in "De Vita Caesarum, Divus Iulius" ("The Lives of the Caesars, The Deified Julius"), written in approximately 110 C.E.



Example: Caesar cipher with shift 19.

Outer wheel is plaintext letter.

Inner wheel is ciphertext letter.

secret key = shift

key space is \mathbb{Z}_{26}

size is 26.

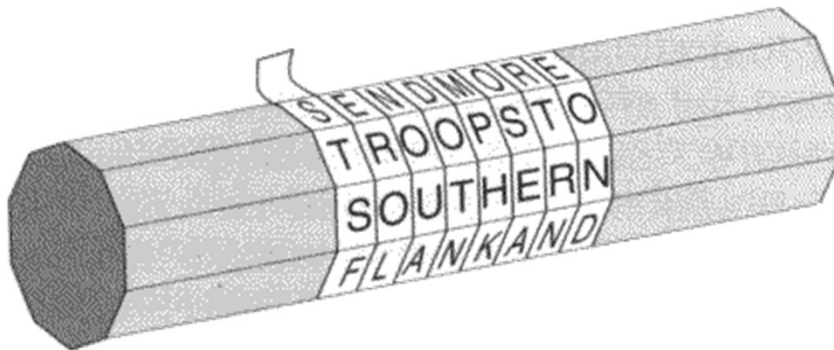
Security? Brute force search is feasible

Discussion

- Previous schemes: Either scheme is fixed (no secret key) or key space is small.
- If cipher method is public (as prescribed by Kerckhoffs) then these are completely broken by “brute force” search.
- Conclusion: key space must be large for cipher to be secure against “brute force” search.
- Is large key space **sufficient** for security?

Scytale Cipher (600 B.C.)

From Wikipedia: From indirect evidence, the scytale was first mentioned by the Greek poet [Archilochus](#), who lived in the 7th century BC. Other Greek and Roman writers during the following centuries also mentioned it, but it was not until [Apollonius of Rhodes](#) (middle of the 3rd century BC) that a clear indication of its use as a cryptographic device appeared. A description of how it operated is not known from before [Plutarch](#) (50-120 AD):



Thin sheet of papyrus wrapped around staff. Messages are written down the length of the staff.

secret key?
diameter of staff.

In order to recover the message, a staff of **equal diameter** must be used.

Key Space/Size very large (infinite)
Security - say every k -th letter for $k \in [1, \text{message length}]$

Monoalphabetic Substitution (800 A.D.)

- Each plaintext character is mapped to a different ciphertext character in an arbitrary manner.

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

secret key:
mapping from
plaintext letters
to ciphertext
permutation

tellhimaboutme



GDOOKVCXEFLGCD

- Size of key space?
 - $26! \approx 2^{88}$
- Brute force search is intractable, but is there a better way to break this cipher?

Frequency Analysis

If plaintext is known to be grammatically correct English, can use frequency analysis to break monoalphabetic substitution ciphers:

